ESA 2020

XVI European Society for Agronomy Congress

1 to 3 September, 2020 - **Sevilla - Spain**

SMART AGRICULTURE FOR GREAT HUMAN CHALLENGES

BOOK OF ABSTRACTS

Organizes:

Universidad de Sevilla

www.esa-congress-sevilla2020.es

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WELCOME

Dear participant in the ESA congress,

First, on behalf of the Organizing Committee, I would like to apologize for the alteration of the expected organization of the ESA congress due to the COVID pandemic situation. Our first idea was to maintain a face-to-face event. Even we though in a 1-year delay, which was not possible due to the overlap with other scientific events. These circumstances and uncertainty led to a low number of abstracts received after the submission deadline.The change to a virtual congress encourages people to participate, and the final number of communications is finally similar to previous congresses. This is not the type of congress we thought and planned, however we considered that this was the best format to keep the event. The change, the extended deadline, and the preparation of the virtual platform for the congress explain the delay in reviewing and accepting abstracts and in the preparation of the final program. Again, I would like to apologize for this.

Around 280 abstracts were finally received, which will be organized as oral and poster presentations. You will access oral sessions organized in three virtual rooms through the webpage of the congress where you can also download the definitive program and the abstract book. You will access using your e-mail and password. An advantage of the virtual format is that you will not miss any oral presentation: this will be available for you for 30 days. In any case, we have tried to avoid the overlap between keynotes. After the presentation, queries to authors will be possible by chat under the supervision of the chairman of the session.

For posters, all will be available along the 3 days of congress and you can use the platform for sending questions to the corresponding author that will receive this by e-mail. As for oral presentations, we would try to maintain available for you during a time.

In all the ESA congress it is always very relevant the Field trips. In this edition, we expected to show you relevant and innovative Mediterranean agrosystems. We have not renounced to this, and you will have available three virtual field trips as videos. With these videos, you will get an idea of the use of the reclaimed marshland area of the Guadalquivir Valley (intensive irrigated land, with around 40000 ha of rice), the new intensive tree orchards systems, and new tools for precision agriculture.

Finally, we would like to express our gratitude for your confidence in the celebration of the conference in these difficult times.

Antonio Delgado

On behalf of the Organizing Committee

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- Massimo Tagliavini, *Free University of Bolzano, Italy*
- Francesco Tei, *University of Perugia, Italy*
- Christine Watson, *Scothland's Rural College, UK*

KEYNOTE SPEAKERS

- Elías Fereres. *University of Córdoba, IAS CSIC.*
- Gustavo Slafer, *ICREA (Catalonian Institution for Research and Advanced Studies) at AGROTECNIO Center and the University of Lleida, Spain.*
- Nathalie Colbach, *Agroécologie, AgroSup Dijon, INRA, Univ. Bourgogne, Franche-Comté, Dijon, France.*
- Pytrik Riedsma, *Wageningen University, The Netherlands.*
- Marco Moriondo, *CNR, Italy.*
- Bruno Basso, *Michigan State University, USA.*
- Miguel Quemada, *Universidad Politécnica de Madrid, Spain.*
- Roberto Confalonieri, *University of Milan, Italy.*
- Urs Schmidhalter, *Technical University of Munich, Germany.*
- David Connor, *University of Melbourne.*
- Abdul M. Mouazen, *University of Ghent.*

PROGRAM

HOUR	AUTHOR	TITLE
TUESDAY, SEPTEMBER 1		**ROOM 1**
09:00 -09:15	JULIÁN MARTÍNEZ, VICE-CHANCELLOR OF RESEARCH OF THE UNIVERSITY OF SEVILLA	WELCOME
09:20 -09:50	ELÍAS FERERES	**KEYNOTE:** FACING THE WATER LIMITATION IN EUROPEAN AGRICULTURE
10:15 -10:30	COFFEE BREAK	
10:30 -13:30	**SESSION 1.1 CHAIRMAN: ROXANA SAVÍN**	**KEYNOTE:** CROP PHYSIOLOGY
10:30 -11:15	GUSTAVO SLAFER	**KEYNOTE** PHYSIOLOGICAL BASES FOR IMPROVING RESILIENCE TO ENVIRONMENTAL STRESSES AND RESOURCE USE EFFICIENCY IN WHEAT
11:30 -11:45	KOCH HEINZ-JOSEF	ROW DISTANCE EFFECTS ON SUGAR BEET YIELD FORMATION
11:45 -12:00	IAN DODD	LOW TEMPERATURE PERTURBS HYDRAULIC AND HORMONAL REGULATION OF LEAF EXPANSION AND PHOTOSYNTHESIS OF SOYBEAN SEEDLINGS
12:00 -12:15	JINWOOK KIM	PLASTICITY OF GRAIN NUMBER AND AVERAGE GRAIN WEIGHT IN RESPONSE TO HEAT WAVES AND SOURCE-SINK RATIO IN FIELD GROWN WHEAT.
12:30 -12:45	IVÁN FRANCISCO GARCÍA-TEJERO	HYDROSOS ALMONDS: IMPROVING THE FRUIT QUALITY BY MEANS OF DEFICIT IRRIGATION STRATEGIES
12:45 -13:00	NICOLA HOLDEN	MANAGING FOOD SAFETY HAZARDS IN HORTICULTURAL PRODUCTION
13:00 -14:00		LUNCH
14:00 -18:30	**SESSION 1.2 CHAIRMAN: FRANCESCO TEI**	CROP INTERACTION WITH BIOTIC AND ABIOTIC FACTORS
14:00 -14:45	NATHALIE COLBACH	**KEYNOTE:** INVESTIGATING CROP-WEED INTERACTIONS AS A DRIVER FOR AGROECOLOGICAL CROP PRODUCTION
14:45 -15:00	CHARITY AMARA	EFFECT OF LOCATION AND GENOTYPE ON DEGENERATION OF ORANGE-FLESHED SWEETPOTATO IN NIGERIA
15:00 -15:15	TAUBE FRIEDHELM	ARE YIELD INCREASES IN MAIZE IN NW-EUROPE DUE TO BREEDING PROGRESS OR THE SELECTION OF MORE SUITABLE HYBRIDS DUE TO CLIMATE CHANGE?
15:30 -15:45	RAPETTI MANON	USING TRAIT-BASED APPROACH TO SELECT BANANA VARIETIES ADAPTED TO AGROECOLOGICAL CROP SYSTEM
15:45 -16:00		COFFEE BREAK
16:00 -18:30	**SESSION 1.2 CHAIRMAN: NATHALIE COLBACH**	CROP INTERACTION WITH BIOTIC AND ABIOTIC FACTORS
16:00 -16:15	FEIKE TIL	MULTIPLE DISEASE SUSCEPTIBILITY, BREEDING PROGRESS AND YIELD LOSS OF WINTER WHEAT IN GERMAN VARIETY TRIALS DURING 1983-2019
16:15 -16:30	DIMA SABBOURA	A REVIEW OF HEAT STRESS IN CANOLA (BRASSICA NAPUS L.)
16:30 -16:45	KEYVAN ESMAEILZADEH SALESTANI	EXPRESSION OF AMMONIUM TRANSPORTER GENES IN BARLEY UNDER DIFFERENT FARMING SYSTEMS
16:45 -17:00	MARÍA LUISA GANDÍA TOLEDANO	UNRAVELLING THE RELATIONS BETWEEN THE SOIL WEED SEED BANK AND WEED EMERGENCE IN THE FIELD.
17:30 -17:45	JOHN BADDELEY	SOIL PH EFFECTS ON ROOT GROWTH AND ROOT:SHOOT RATIO IN SPRING BARLEY
17:45 -18:00	MOHAMED HUSSEIN	SALYSILIC ACID FOLIAR SPRAY EFFECTS ON MINERAL STATUS OF CANOLA SEEDS GROWN UNDER SALINITY
18:00 -19:00		VIRTUAL FIELD TRIP

HOUR	AUTHOR	TITLE
TUESDAY, SEPTEMBER 1		**ROOM 2**
11:15 -13:30	**SESSION 2.1** **CHAIRMAN: MARIANA RUFINO**	FARMING SYSTEMS
11:15 -12:00	PYTRIK REIDSMA	**KEYNOTE:** SUSTAINABILITY AND RESILIENCE OF FARMING SYSTEMS
12:00 -12:15	MARTIN HARRIES	CONTROLLING HERBICIDE RESISTANT WEEDS REDUCES DIVERSITY IN WESTERN AUSTRALIAN CROP AND PASTURE SYSTEMS
12:15 -12:30	CRYSTELE LEAUTHAUD	WHY DO FARMERS ASSOCIATE CROPS? LOGICS AND STRUCTURE OF OLIVE GROVE-VEGETABLE ASSOCIATIONS IN A MEDITERRANEAN REGION
12:30 -12:45	DIANE RAKOTOMANGA - CIRAD	EFFECTS OF COVER CROPS AND SOIL TILLAGE ON THE SPONTANEOUS COMMUNITY IN FALLOW PRECEEDING BANANA CROP
12:45 -13:00	NATHALIE COLBACH	COMBINING EXPERT KNOWLEDGE AND MODELS IN PARTICIPATORY WORKSHOPS WITH FARMERS TO DESIGN SUSTAINABLE WEED MANAGEMENT STRATEGIES
13:00 -14:00		LUNCH
14:00 -16:30	**SESSION 2.1** **CHAIRMAN: PYTRIK REIDSMA**	FARMING SYSTEMS
14:00 -14:15	ASHRAF TUBEILEH	PLANT COMPOSTS REDUCE SOIL VERTICILLIUM DAHLIAE LOAD AND SUPPRESS WEEDS
14:15 -14:30	WIM PAAS	PARTICIPATORY ASSESSMENT OF FUTURE SUSTAINABILITY AND RESILIENCE OF EUROPEAN FARMING SYSTEMS
14:30 -14:45	GODINOT OLIVIER	CONCEPTION AND TEST OF AN INTERDISCIPLINARY SERIOUS GAME TO LEARN AGROECOLOGY
14:45 -15:00	LEONARDO VERDI	ENVIRONMENTAL ASSESSMENT OF ORGANIC AND CONVENTIONAL ANCIENT WHEAT CULTIVATION: ACIDIFICATION AND EUTROPHICATION PERFORMANCES THROUGH A LCA APPROACH
15:00 -15:15	CHRISTINE WATSON	REDESIGNING A LONG-TERM ORGANIC FARMING EXPERIMENT TO ADDRESS CONTEMPORARY ISSUES
15:15 -15:30	ROBIN WALKER	LONG TERM YIELD TRENDS IN FOUR PARALLEL ORGANICALLY MANAGED CROP ROTATIONS
15:45 -16:00		COFFEE BREAK
16:00 -18:30	**SESSION 2.2.** **CHAIRMAN:** **CHRISTOS DORDAS**	CROP DIVERSIFICATION
16:00 -16:15	MUHAMMAD ALI RAZA	EFFECT OF PLANTING PATTERNS ON YIELD, NUTRIENT ACCUMULATION, AND DISTRIBUTION IN MAIZE AND SOYBEAN RELAY INTERCROPPING SYSTEMS
16:15 -16:30	FEDERICO MARTINELLI	LEGUMES IN BIODIVERSITY-BASED FARMING SYSTEMS IN MEDITERRANEAN BASIN
16:30 -16:45	WERY JACQUES	THE ROLE OF IMPROVED AGRONOMIC PRACTICES IN DE-RISKING AND ENHANCING THE SUSTAINABILITY OF CEREAL-BASED SYSTEMS IN THE DRYLANDS
16:45 -17:00	RAUL ZORNOZA	GREENHOUSE GAS EMISSIONS FROM SOIL IN AN ALMOND ORCHARD DIVERSIFIED WITH CAPER AND THYME
17:00 -17:15	RAUL ZORNOZA	EFFECT OF FAVA BEAN AND VETCH/BARLEY CROPS INTERCROPPED WITH MANDARIN TREES ON SOIL GREENHOUSE GAS EMISSIONS
17:15 -17:30	STILMANT DIDIER	DOES COMPLEX MIXTURES INCREASE PERFORMANCES OF ORGANIC TEMPORARY GRASSLAND?
17:30 -17:45	ALI ELHAKEEM	DO COVER CROP SPECIES MIXTURES ENHANCE RESILIENCE AND RESOURCE CAPTURE?
17:45 -18:00	MARIANO MARCOS PEREZ	INTERCROPPING OF MELON AND COWPEA CAN IMPROVE MELON PRODUCTION IN ORGANIC SYSTEMS

TUESDAY, SEPTEMBER 1		ROOM 3
11:11 -13:30	**SESSION 3.1** **CHAIRMAN: THOMAS DÖRING**	SUSTAINABLE INTENSIFICATION
11:11 -11:30	WERY JACQUES	EXCELLENCE IN AGRONOMY 2030: A CGIAR-WIDE INITIATIVE TO TAKE DATA-DRIVEN AGRONOMY TO SCALE IN THE GLOBAL SOUTH

HOUR	AUTHOR	TITLE
11:30 -11:45	FEIKE TIL	CONTRIBUTION OF IMPROVED IRRIGATION TO NARROWING FARMERS' WHEAT YIELD GAPS IN NORTH-EAST IRAN
11:45 -12:00	YAKUBU BALMA ISSAKA	TYPOLOGY OF LOWLAND RAINFED RICE PRODUCTION AND ITS IMPLICATION FOR SMALLHOLDER AGRICULTURAL INTENSIFICATION IN NORTHERN GHANA
12:15 -12:30	NA WANG	SYNERGIES AND TRADE-OFFS BETWEEN YIELD, QUALITY, RESOURCE USE EFFICIENCY AND ENVIRONMENTAL IMPACT OF POTATO PRODUCTION IN CHINA
12:30 -12:45	SARA BOSI	DEVELOPMENT OF AN ECONOMIC THRESHOLD FOR HERBICIDE APPLICATION IN COMMON WHEAT
13:00 -14:00		LUNCH
14:00 -16:30	**SESSION 3.1 CHAIRMAN: GORAN BERGKVIST**	SUSTAINABLE INTENSIFICATION
14:00 -14:15	DANIEL KINDRED	ACHIEVING PRECISION IN ON-FARM EXPERIMENTS
14:15 -14:30	FABIO MASCHER	STABILITY OF QUALITY AND YIELD IN WHEAT COMPOSITE CROSS POPULATIONS
14:30 -14:45	SARAH KENDALL	USING FARM INNOVATION GROUPS TO ACCELERATE PROGRESS IN AGRICULTURE.
14:45 -15:00	DOMENICO RONGA	STRUVITE AS A SUSTAINABLE BIO-FERTILIZER FOR THE REDUCTION OF PHOSPHATE ROCK DEPENDENCY AND BETTER DELOCALIZATION OF LIQUID DIGESTATE
15:00 -15:15	ANA AGUILAR	ECOSYSTEM FUNCTIONS OF MICROBIAL CONSORTIA IN SUSTAINABLE AGRICULTURE
15:15 -15:30	MARGARITA RUIZ-RAMOS	SUST-FARM: A MODEL TO ASSESS SUSTAINABLE INTENSIFICATION AND CLIMATE CHANGE ADAPTATION AT FARM SCALE
15:45 -16:00		COFFEE BREAK
16:00 -18:30	**SESSION 3.2 CHAIRMAN: HELENA GÓMEZ-MACPHERSON**	EFFICIENT RESOURCE MANAGEMENT: SOILS, WATER, NUTRIENTS, AND ENERGY
16:15 -16:30	VICTOR MAIGNAN	EVALUATION OF INNOVATIVE FERTILIZER ADDITIVES ON THE PHYSIOLOGICAL IMPACTS, AGRONOMIC PERFORMANCES AND PROTEIN QUALITY IN WINTER WHEAT
16:30 -16:45	ANTONIO RAFAEL SÁNCHEZ-RODRÍGUEZ	BIOFORTIFICATION OF CEREALS WITH SOIL AND FOLIAR APPLICATIONS OF ZINC IN THE SOUTH OF SPAIN
16:45 -17:00	SILVIA BACHMANN-PFABE	ENHANCING DROUGHT TOLERANCE IN PERENNIAL RYEGRASS
17:00 -17:15	MELPOMENI SIAKOU	KORONEIKI OLIVE TREE PHYSIOLOGY RESPONSES UNDER TWO DEFICIT IRRIGATION TREATMENTS IN CYPRUS
17:15 -17:30	ELENA NAVARRO SORIANO	ANALYSIS OF THE FREQUENCY OF DISTRIBUTION OF THE RELATIVE IRRIGATION SUPPLY INDEX IN THE WATER USERS ASSOCIATION OF SECTOR BXII OF THE LOWER GUADALQUIVIR RIVER
17:45 -18:00	SAMUEL FRANCO-LUESMA	MAIZE MONOCULTURE UNDER MEDITERRANEAN CONDITIONS: ASSESSING THE EFFECT OF DIFFERENT IRRIGATION AND TILLAGE SYSTEMS

WEDNESDAY, SEPTEMBER 2		ROOM 1
09:00 -11:30	**SESSION 2.4 CHAIRMAN: ANTONIO DELGADO**	MITIGATING CLIMATE CHANGE: MODELLING, PREDICTION, AND STRATE
09:00 -09:45	MARCO MORIONDO	**KEYNOTE:** EXPECTED IMPACT OF CLIMATE CHANGE ON FOOD PRODUCING SYSTEM IN THE MEDITERRANEAN REGION: HOW SMART AGRICULTURE CAN IMPROVE THE RESILIENCE
09:45 -10:00	QAISAR SADDIQUE	MULTIPLE CROP MODELS PROJECTION OF WHEAT PRODUCTION UNDER FUTURE CLIMATE CHANGE SCENARIOS IN THE GUANZHONG PLAIN, CHINA
10:00 -10:15	JAY RAM LAMICHHANE	HARNESSING CROP MODELS TO PINPOINT THE ESTABLISHMENT QUALITY OF FIELD CROPS UNDER THE 21ST CENTURY CLIMATE CHANGE: CASE STUDIES OF SOYBEAN AND SUGAR BEET IN NORTHERN FRANCE
10:15 -10:30	DANIEL MIRALLES	ADAPTATION STRATEGIES TO HIGH NIGHT TEMPERATURE IN WINTER CEREALES AND INTERACTION WITH MANAGEMENT PRACTICES

HOUR	AUTHOR	TITLE
10:30 -10:45	LUIS PARRAS-ALCÁNTARA	LAND MANAGEMENT CHANGE EFFECTS ON SOIL ORGANIC CARBON STOCK IN OLIVE GROVE HILLSIDES. IMPLICATIONS IN THE 40/00 NOTION
10:45 -11:00		COFFEE BREAK
11:00 -13:30	**SESSION 2.4 CHAIRMAN: MARCO MORIONDO**	MITIGATING CLIMATE CHANGE: MODELLING, PREDICTION, AND STRATE
11:00 -11:15	LUIS PARRAS-ALCÁNTARA	EFFECT OF TILLAGE AND TOPOGRAPHIC POSITION ON SOIL QUALITY IN MEDITERRANEAN OLIVE GROVE HILLSDIES
11:15 -11:30	ROESCH ANDREAS	APPROXIMATION OF GREENHOUSE GAS EMISSIONS FOR A FARM NETWORK USING READILY AVAILABLE DATA
11:30 -11:45	SEYEDREZA AMIRI	MODELLING DORMANT SEEDING OF RAINFED CHICKPEA AS AN ADAPTATION STRATEGY TO SUSTAIN PRODUCTIVITY UNDER CLIMATE CHANGE
11:45 -12:00	NAULLEAU AUDREY	STRATEGIES FOR ADAPTING VITICULTURE TO CLIMATE CHANGE: A PARTICIPATORY MODELING APPROACH WITHIN A MEDITERRANEAN CATCHMENT
12:00 -12:15	ROBIN MARIE HELENE	IDENTIFICATION AND EVALUATION OF CROP ADAPTATION STRATEGIES TO CLIMATE CHANGE FOR WHEAT, POTATO, AND SUNFLOWER IN FRANCE.
12:15 -12:30	TOMMASO TADIELLO	SOIL ORGANIC CARBON SEQUESTRATION IN MEDITERRANEAN AND HUMID SUBTROPICAL CLIMATES UNDER CONSERVATION AGRICULTURE: FIRST STEPS OF A META-ANALYSIS
12:30 -12:45	ELISA M. SUÁREZ-REY	CARBON AND NITROGEN FOOTPRINT OF DRIP-FERTIGATED GREENHOUSE TOMATO CROPS
12:45 -13:00	FOLTZER LOUIS	GRASSLAND RESILIENCE TO CLIMATE VARIABILITY ON NITRATE LEACHING
13:00 -14:00		LUNCH
14:00 -16:30	**SESSION 2.5/CHAIRMAN: ENGRACIA MADEJÓN**	**PROTECTING NATURAL RESOURCES AND THE HUMAN ENVIRONMENT**
14:00 -14:15	DONGMO ZANGUE YANNICK	PRESERVING ENVIRONMENT THROUGH FARMLAND MANAGEMENT PRACTICES (FMP)? A GENERIC REVIEW
14:15 -14:30	NENDEL CLAAS	SIMULATING NITRATE LEACHING FROM AGRICULTURAL LAND USE IN GERMANY
14:30 -14:45	STEFAAN DE NEVE	SOIL PHOSPHORUS (P) MINING IN AGRICULTURE - IMPACTS ON P AVAILABILITY, CROP YIELDS AND SOIL ORGANIC CARBON STOCKS
15:00 -15:15	NICOLAS BEAUDOIN	LONG TERM RESPONSES OF CROP YIELD, SOILS AND NITRATE LOSSES TO BEST AGRICULTURAL PRACTICES AT THE CATCHMENT SCALE
15:15 -15:30	ANDREA AGUILAR	PARTICIPATORY CONSTRUCTION OF FERTILITY AND HEALTH INDICATORS IN AGRICULTURAL SYSTEMS WITH A MEDITERRANEAN CLIMATE IN CHILE
15:30 -15:45	AWAIS SHAKOOR	MODELLING OF SOIL NITROGEN DYNAMICS IN CROPPING SYSTEM WITH LEACHM IN RAINFED SEMIARID MEDITERRANEAN REGION
15:45 -16:00		COFFEE BREAK
16:00 -17:00		VIRTUAL FIELD TRIP

WEDNESDAY, SEPTEMBER 2	ROOM 2

09:00 -11:30	**SESSION 2.2/CHAIRMAN: CHRISTINE WATSON**	CROP DIVERSIFICATION
09:00 -09:15	MARIANO MARCOS PEREZ	INTERCROPPED BROCCOLI-FAVA BEAN SYSTEM CAN IMPROVE OVERALL PRODUCTION AND ECOSYSTEM SERVICES
09:15 -09:30	NADINE ENGBERSEN	THE CONTEXT DEPENDENCE OF RESOURCE PARTITIONING IN CROP MIXTURES
09:30 -09:45	MARÍA ALONSO-AYUSO	CHARACTERIZATION OF PERFORMANCE OF NINE SPECIES AS COVER CROPS INTERSEEDED INTO MAIZE
09:45 -10:00	GENÍS SIMON-MIQUEL	SOYBEAN INTRODUCTION IN MEDITERRANEAN CROPPING SYSTEMS CAN REDUCE THEIR CARBON FOOTPRINT
10:00 -10:15	DUCHENE OLIVIER	PERENNIAL GRAIN ROOTS DIFFER FROM ANNUAL ONES, AFFECTING SOIL FUNCTIONING AND MICROBIOLOGY
10:15 -10:30	FEDERICO LEONI	SELECTION OF SUITABLE LEGUMES FOR RELAY INTERCROPPING WITH DURUM WHEAT IN MEDITERRANEAN CEREAL-BASED CROPPING SYSTEMS

HOUR	AUTHOR	TITLE
10:30 -10:45	ROBERTA FARINA	A SET OF INDICATORS TO ASSESS THE AGRO-ENVIRONMENTAL PERFORMANCE OF TWO MEDITERRANEAN DIVERSIFIED CROPPING SYSTEMS
10:45 -11:00		COFFEE BREAK
11:00 -13:30	**SESSION 2.2 CHAIRMAN: MARIE-HELENE JEUFFROY**	**CROP DIVERSIFICATION**
11:00 -11:15	XAVIER BOUSSELIN	CHOOSING SERVICE PLANT FOR INTERCROPPING WITH RAPESEED BASED ON PLANT-PLANT AND PLANT-SOIL INTERACTIONS
11:15 -11:30	SAMUEL FRANCO-LUESMA	CROP YIELD AND WATER USE EFFICIENCY IN THREE IRRIGATED MAIZE CROPPING SYSTEMS UNDER DIFFERENT NITROGEN FERTILIZATION RATES
11:30 -11:45	ANJA SCHMUTZ	WATER USE AND WATER SOURCE OF SIX DIFFERENT CROP SPECIES IN MIXED CULTURES
11:45 -12:00	CHRISTIAN SCHÖB	INCREASING PLANT DIVERSITY REDUCES REPRODUCTIVE EFFORT IN ANNUAL CROPS
12:00 -12:15	BARKAOUI KARIM	DO CROPS GROW BETTER IN OLIVE AGROFORESTRY UNDER DROUGHT ? A TEST FROM NORTHERN MOROCCO
12:30 -12:45	FRANCISCO ALCON	FINANCIAL ANALYSIS OF INTERCROPPING PRACTICES. THE CASE OF MANDARIN ORCHARD IN THE SE OF SPAIN
12:45 -13:00	CHRISTOS DORDAS	USE OF APPROPRIATE CULTIVARS IN INTERCROPPING CAN IMPROVE RESOURCE USE EFFICIENCY UNDER MEDITERRANEAN CONDITIONS
13:00 -14:00		LUNCH
14:00 -16:00	**SESSION 2.2 CHAIRMAN: ERIC JUSTES**	**CROP DIVERSIFICATION**
14:00 -14:15	NATHALIE COLBACH	CONTRIBUTION OF CEREAL-LEGUME INTERCROPPING TO AGROECOLOGICAL WEED MANAGEMENT
14:15 -14:30	RECKLING MORITZ	IMPACT OF CLIMATE ON GRAIN LEGUME YIELD STABILITY IN LONG-TERM EXPERIMENTS
14:30 -14:45	TIMOTHÉE CHERIERE	INTERCROPPING: A TOOL FOR CROPPING SYSTEM DIVERSIFICATION
14:45 -15:00	MATTHIEU CAROF	A CONCEPTUAL MODEL TO LINK CROP DIVERSIFICATION WITH ECOSYSTEM SERVICES
15:00 -15:15	ROBIN WALKER	PROSPECTS FOR GROWING ORGANIC OILSEED RAPE IN SCOTLAND: THE SCOTTISH ORGANIC CANOLA (SCOCAN) PROJECT
15:15 -15:30	KAIRSTY TOPP	NOVEL AND MINOR PROTEIN CROPS IN SCOTLAND
15:30 -15:45	ALICE BAUX	WHY SWISS FARMERS CHOOSE TO SOW WINTER OISLEED RAPE WITH COMPANION PLANTS?
15:45 -16:00		COFFEE BREAK
16:00 -17:00	**SESSION 2.3 CHAIRMAN: ERIC JUSTES**	**CROP LIVESTOCK INTEGRATION**
16:00 -16:15	ANNA WENDA-PIESIK	SOYBEAN NON-GM INNOVATIVE SOLUTIONS IN CULTIVATION AND FEEDING OF ANIMALS IN FARMS IN NORTH POLAND – EPI GROUP 'MY SOYBEAN' CONSORTIUM

WEDNESDAY, SEPTEMBER 2	ROOM 3

09:00 -11:30	**SESSION 1.3 CHAIRMAN: MARCELO DONATELLI**	**MODELLING CROP-ENVIRONMENT INTERACTIONS**
09:00 -09:15	IRIS VOGELER	EFFECT OF WINTER CEREAL SOWING TIME ON YIELD AND NITRATE LEACHING BASED ON EXPERIMENTS AND MODELLING
09:15 -09:30	TOMÁS ROQUETTE TENREIRO	FROM POINT TO FIELD SCALE - UNCERTAINTIES ASSOCIATED TO THE USPCALING OF MODELING FOR SPATIAL HETEROGENEITY ASSESSMENT
09:30 -09:45	EDMAR TEIXEIRA	EFFECTIVENESS OF LATE SOWN COVER CROPS TO REDUCE NITROGEN LEACHING UNDER CLIMATE CHANGE
09:45 -10:00	MOREAU DELPHINE	INTEGRATING PLANT-PLANT COMPETITION FOR NITROGEN IN A 3D INDIVIDUAL-BASED MODEL SIMULATING THE EFFECTS OF CROPPING SYSTEMS ON WEED DYNAMICS
10:00 -10:15	ASHIFUR RAHMAN SHAWON	A CROP MODEL FOR SIMULATING RYE GROWTH, DEVELOPMENT AND YIELD
10:45 -11:00		COFFEE BREAK

HOUR	AUTHOR	TITLE
11:00 -13:30	**SESSION 3.2 CHAIRMAN: JOSE ENRIQUE FERNÁNDEZ**	**EFFICIENT RESOURCE MANAGEMENT: SOILS, WATER, NUTRIENTS, AND ENERGY**
11:00 -11:30	MIGUEL QUEMADA	**KEYNOTE:** INTEGRATED MANAGEMENT TO ENHANCECOVER CROPS BENEFITS AND RESOURCE EFFICIENCY
11:45 -12:00	MINA DEVKOTA	OPTIONS TO ENHANCE WHEAT YIELD AND WATER PRODUCTIVITY IN A MEDITERRANEAN RAINFED ENVIRONMENT BY AGRONOMIC INNOVATIONS
12:15 -12:30	MARLOES VAN LOON	AGRONOMIC NUTRIENT USE EFFICIENCY AND GREENHOUSE GAS EMISSIONS FOR CEREAL SELF-SUFFICIENCY IN SUB-SAHARAN AFRICA TOWARDS 2050
12:30 -12:45	MARCO MANCINI	EFFECT OF SOIL AVAILABLE PHOSPHORUS AND NITROGEN ON WINTER WHEAT PRODUCTION
12:45 -13:00	BJÖRN REDDERSEN	DRONE BASED PHENOTYPING OF NUE RELATED PARAMETERS OF VAROIUS WINTER RAPSEED GENOTYPES
13:00 -14:00		LUNCH
14:00 -16:30	**SESSION 3.2 CHAIRMAN: MIGUEL QUEMADA**	EFFICIENT RESOURCE MANAGEMENT: SOILS, WATER, NUTRIENTS, AND ENERGY
14:00 -14:15	ERIC BÖNECKE	PRECISION LIME MANAGEMENT: A SENSOR-BASED SOIL MAPPING APPROACH
14:15 -14:30	BETTINA EICHLER-LÖBERMANN	(LITTLE) SHORT-TERM IMPACTS OF P FERTILIZER MANAGEMENT IN A LONG-TERM FIELD EXPERIMENT
14:30 -14:45	EVA HERRERO	FERTIGATION WITH SLURRY LIQUID FRACTION IS AGRONOMIC AND ENVIROMENTALLY SUSTAINABLE
15:00 -15:15	JOSE LUIS PANCORBO DE OÑATE	HYPERSPECTRAL AND THERMAL IMAGERY TO ASSES NITROGEN AND WATER STATUS IN WINTER WHEAT
15:15 -15:30	HELENA GOMEZ-MACPHERSON	POTENTIAL OF CONSERVATION TILLAGE COMBINED WITH REGULATED DEFICIT IRRIGATION FOR SAVING WATER
15:30 -15:45	MARÍA DOLORES RAYA-SERENO	GROUND LEVEL AND AERIAL SENSORS TO ASSESS WHEAT N STATUS AND TO ADJUST N FERTILIZATION
15:45 -16:00		COFFEE BREAK
16:00 -17:45	**SESSION 3.3 CHAIRMAN: DAVIDE CAMARANO**	INSTRUMENTS FOR RESOURCE MANAGEMENT: MODELS, MONITORING, AND DECISION-MAKING TOOLS
16:00 -16:30	BRUNO BASSO	**KEYNOTE:** DIGITAL AGRONOMY TO DESIGN AND SCALE SUSTAINABLE AGRICULTURAL SYSTEMS
16:45 -17:00	DAVID DE LA FUENTE	SMART INTEGRATED DATA ANALYSIS FOR AGRICULTURE SUPPORT DECISION - MAKING AND MANAGEMENT – SENSING4FARMING
17:00 -17:15	MARTINA CORTI	A SOLUTION TO OVERCOME SATURATION OF VEGETATION INDICES FOR CROP BIOMASS ESTIMATION
17:15 -17:30	SÉBASTIEN DANDRIFOSSE	ASSESSMENT OF THE IMPACT ON WHEAT YIELD OF THE INTERACTION BETWEEN FERTILIZATION AND YELLOW RUST THROUGH MULTI-SENSOR MACHINE VISION

THURSDAY, SEPTEMBER 3		ROOM 1
11:00 -13:30	**SESSION 1.3: CHAIRMAN: CLAS NENDEL**	MODELLING CROP-ENVIRONMENT INTERACTIONS
11:00 -11:15	DUCHENE OLIVIER	MODELLING PHENOLOGICAL DEVELOPEMENT OF THINOPYRUM INTERMEDIUM REVEALS A PHOTOPERIODIC EFFECT, AFFECTING FLOWERING EARLINESS
11:15 -11:30	SÉBASTIAN MIRA	A SIMULATION STUDY FOR STRUCTURAL EQUATION MODELS SELECTION IN AGROECOLOGY
11:30 -11:45	DIMA SABBOURA	IMPACT OF PLANT PROTECTION STRATEGY AND SOIL TILLAGE ON THE CARBON FOOTPRINT OF WHEAT
11:45 -12:00	KERSEBAUM KURT CHRISTIAN	MODELLING IRRIGATION EFFECTS IN CROP ROTATIONS ACROSS BRANDENBURG UNDER CLIMATE CHANGE
12:00 -12:15	MARÍA LUISA GANDÍA TOLEDANO	WEED DENSITY AND WEED DIVERSITY INFLUENCED BY RAINFALL, DIFFERENT SOIL MANAGEMENT AND ROTATION SYSTEMS.
12:15 -12:30	CHRISTIAN JOFRE CEKALOVIC	ESTIMATING TRANSPIRATION IN GRAPEVINES UNDER TWO WATER REGIMES USING THE TWO-SOURCE ENERGY BALANCE MODEL
12:30 -12:45	DANIEL KINDRED	THE AGRONOME: ATTEMPTING TO UNDERSTAND GENETIC X ENVIRONMENT X MANAGEMENT EFFECTS ON CROP PERFORMANCE

HOUR	AUTHOR	TITLE
13:00 -14:00		LUNCH
14:00 -15:00		VIRTUAL FIELD TRIP
15:00 -15:45	ANTONIO DELGADO, ESA PRESIDENT 2018-2020. CLAAS NENDEL, ESA PRESIDENT 2020-2022.	CLOSING SESSION

THURSDAY, SEPTEMBER 3		ROOM 2
09:00 -11:00	**WORKSHOP CHAIRMAN: SANTIAGO BONACHELA**	**SUSTAINABLE, INTENSIVE HORTICULTURE PRODUCTION SYSTEMS**
09:00 -09:45	DAVID CONNOR	**KEYNOTE:** CANOPY DESIGN AND MANAGEMENT IN INTENSIVE FRUIT ORCHARDS
09:45 -10:00	MARISA GALLARDO PINO	MODELLING MACRONUTRIENT UPTAKE OF GREENHOUSE TOMATO WITH THE VEGSYST MODEL
10:00 -10:15	ORLY ENRIQUE APOLO APOLO	A DEEP LEARNING APPROACH TO THE AUTOMATED DETECTION IN-FIELD TOMATOES RIPENING USING A MOBILE PLATFORM
10:15 -10:30	MARÍA ROSA GRANADOS	USE OF A COOLING EVAPORATIVE SCREEN IN A SOIL-GROWN SWEET PEPPER CROP IN A MEDITERRANEAN GREENHOUSE
10:30 -10:45	MARÍA ROSA GRANADOS	INTEGRATION OF PASSIVE COOLING AND HEATING SYSTEMS FOR VEGETABLE PRODUCTION IN MEDITERRAEAN GREENHOUSE
10:45 -11:00		COFFEE BREAK
11:00 -13:00	**WORKSHOP CHAIRMAN: MANUEL PÉREZ**	**TOWARDS EFFICIENT RESOURCE USE: SITE-SPECIFIC MANAGEMENT**
11:00 -11:45	URS SCHMIDHALTER	**KEYNOTE:** PRECISION FARMING - CHALLENGES, ACHIEVEMENTS, AND NEEDS
11:45 -12:30	ABDUL M. MOUAZEN	**KEYNOTE:** POTENTIAL OF MULTI-SENSOR DATA-FUSION FOR SITE SPECIFIC SOIL AND CROP MANAGEMENT

HOUR	AUTHOR	TITLE
12:30 -12:45	MANUEL PÉREZ-RUIZ	AN AFFORDABLE SYSTEM FOR HIGH-THROUGHPUT PLANT PHENOTYPING FOR MAIZE
12:45 -13:00	MARTA RODRÍGUEZ FERNÁNDEZ	EVALUATION OF SPECTRAL VEGETATION INDEX OBTAINED THROUGH SATELLITE AND UAVS IMAGES FOR VINEYARD MANAGEMENT
13:00 -14:00		LUNCH
14:00 -14:45	**WORKSHOP CHAIRMAN: MANUEL PÉREZ**	**TOWARDS EFFICIENT RESOURCE USE: SITE-SPECIFIC MANAGEMENT**
14:00 -14:15	DIONISIO ANDUJAR	NEURAL-NETWORK-BASED CLASSIFIER FOR WEED IDENTIFICATION IN MAIZE FIELDS
14:15 -14:30	DOMENICO RONGA	PREDICTION OF THE BIOCHEMICAL METHANE POTENTIAL OF TRITICALE USING NEAR-INFRARED SPECTROSCOPY FOR DIGITAL AGRICULTURE PURPOSE
14:30 -14:45	JAIME NOLASCO RODRÍGUEZ	3D CROP MODELING FOR DETERMINATION OF WHEAT RUST SEVERITY AND ITS IMPACT ON CROP YIELD

THURSDAY, SEPTEMBER 3		ROOM 3
09:00 -10:30	**SESSION 3.3/CHAIRMAN: URS SCHMIDHALTER**	INSTRUMENTS FOR RESOURCE MANAGEMENT: MODELS, MONITORING, AND DECISION-MAKING TOOLS
09:00 -09:15	NEBOJŠA NIKOLIĆ	EX-ANTE ASSESSMENT OF HERBICIDE REDUCTION BY IMPLEMENTING EARLY PRECISION WEED CONTROL IN SPRING CROPS
09:15 -09:30	ALEXIS CARLIER	WHEAT NITROGEN AND SENESCENCE DYNAMICS IN FIELD ASSESSMENT THROUGH TWO PHENOTYPING APPROACHES LATE IN SEASON
09:30 -09:45	CHANDRASHEKHAR BIRADAR	DIGITAL AUGMENTATION FOR SUSTAINABLE INTENSIFICATION OF DRYLAND FARMING SYSTEMS
09:45 -10:00	ALVARO LOPEZ-BERNAL	CROPEBAL: A WINDOWS PROGRAM FOR CALCULATING THE INPUTS AND OUTPUTS OF ENERGY FROM CROP ROTATIONS
10:00 -10:15	FRANCISCO VILLALOBOS	A SIMPLE DECISION SUPPORT SYSTEM FOR FERTILIZER MANAGEMENT: FERTILICALC
10:15 -10:30	LUCIANO LUGLI	TOWARDS STATISTICAL PATTERN RECOGNITION GRAPH MORPHOMETRY APPLIED IN AGRICULTURAL ROBOTIC VINEYARD PRUNING

HOUR	AUTHOR	TITLE
10:30 -11:00	**SESSION 3.4 CHAIRMAN: URS SCHMIDHALTER**	NEW AVENUES FOR MANAGING BIOTIC AND ABIOTIC STRESSES
10:30 -10:45	MOREAU DELPHINE	WHICH NITROGEN FERTILIZATION TECHNIQUES AND CROP TRAITS PROMOTE WEED BIOLOGICAL REGULATION BY COMPETITION?
10:45 -11:00		COFFEE BREAK
11:00 -13:00	**SESSION 3.2 CHAIRMAN: VINAY NANGIA**	EFFICIENT RESOURCE MANAGEMENT: SOILS, WATER, NUTRIENTS, AND ENERGY
11:15 -11:30	LAURE HOSSARD	EFFECT OF PRECEDING CROP ON NITROGEN EFFICIENCY FOR SOFT WINTER WHEAT IN SAIS REGION, MOROCCO
11:30 -11:45	ALFONSO MORIANA	WHY AND WHY NOT MIDDAY STEM WATER POTENTIAL COULD BE A USEFULNESS DEFICIT IRRIGATION TOOL IN OLIVE TREES
11:45 -12:00	JAKOB SANTNER	A BORON RECYCLING FERTILIZER MADE FROM CELLULOSE INSULATION WASTE
12:00 -12:15	ROSE BOYKO	RESOURCE MANAGEMENT FOR NUTRITIONAL QUALITY AND SOIL ACIDITY IN GRAZED GRASSLAND
12:15 -12:30	ROGER SYLVESTER-BRADLEY	GRAIN ANALYSIS CAN PROVIDE A COMPREHENSIVE POST-MORTEM ON THE ADEQUACY OF A CROP'S NUTRITION
12:30 -12:45	MOHAMMED YAHBI	EFFECT OF NITROGEN RATE AND VARIETY ON YIELD, AND YIELD COMPONENTS IN MOROCCAN VARIETIES OF RAPESEED (BRASSICA NAPUS L)
12:45 -13:00	KELLY ULCUANGO	THE LEGACY OF DIFFERENT COVER CROPS ON MYCORRHIZATION AND PLANT NUTRITION

ABSTRACTS OF ORAL COMMUNICATIONS

Plenary Session

0294

FACING THE WATER LIMITATION IN EUROPEAN AGRICULTURE

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Outside Southern Europe, the bulk of European agriculture takes place in favorable environments where water seldom limits productivity. The situation may change, however, as there is evidence of increasing duration of drought periods in the summer of Central Europe. Furthermore, while there is considerable more uncertainty in future hydrologic than in future temperature scenarios, increased evaporative demand and the quest for the sustainable intensification of production will increase the importance of water as a future limiting factor in Europe agricultural production. Removing such limitation will require crop manipulations at various scales, and environmental modification, moving towards a wider adoption of irrigated systems. The talk will cover selected aspects of the expected shifts in production systems, both from the crop and environment standpoints, to delineation of the main limitations for further irrigation expansion in Europe. The tight association between carbon and water exchange of crop plants has been uncovered since long ago, and genetic manipulation attempts to modify its ratio, the transpiration efficiency (TE), have had very limited success. Nevertheless, a positive outcome of the increase in atmospheric CO2 has been the continuous increase in TE which will play an important role in future water use scenarios. Agronomic manipulations to cope with drought spells will require improvements in sub-seasonal weather forecasts. Fortunately, the European Centre for Medium-Range Weather Forecasts has been particularly active and hopefully, will contribute to improved tactical decision making. Droughts will impact differently on winter cereals which would be near the end of their growing cycle, than in summer crops such as potato or maize, where water deficits will vary in impact depending on timing and severity of occurrence. Strategic decisions for new irrigation developments will be region-specific and will emphasize the use of supplemental irrigation. Supplemental irrigation management is much more complex than irrigation management in the arid zones and will need decision support tools such as crop simulation models and remote sensing. Yield response functions to water of the major European crops suggest that farmers should aim at meeting the full water requirements with irrigation systems that apply water with high uniformity. However, there will be tradeoffs between the high system costs to provide uniform irrigation and the increased pumping costs of cheaper systems. Given the current impact of European agriculture on water quality, an important consideration will be the control of water pollution with the expanded use of irrigation to prevent further water quality deterioration.

Keywords: water, drought, irrigation, agricultural systems

Session 1: Crop functioning and crop quality

Session 1.1: Crop physiology

0158 KEYNOTE

PHYSIOLOGICAL BASES FOR IMPROVING RESILIENCE TO ENVIRONMENTAL STRESSES AND RESOURCE USE EFFICIENCY IN WHEAT

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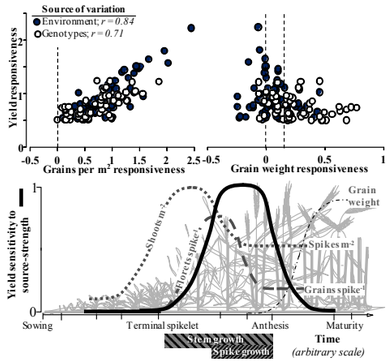
Wheat is essential for global food security. Large increases in wheat yield (and cereals in general) will be necessary to underpin food security in the near future. This is extremely challenging as yield gains in the last decades has been declining and we need to regain larger rates of yield increases in a context of climate change (that would impose more stressful conditions than in the past) and not increasing substantially the use of inputs (crop management should be environmentally more sustainable). We therefore need management and breeding alternatives to have crops more resilient to expected prevalent environmental stress and more efficient in using limiting resources. In this context, understanding how different physiological traits determining yield responses to environmental and genotypic factors would be relevant.

A comprehensive view of all physiological bases of yield determination identifying promising traits for designing alternative management practices or breeding strategies to increase resilience to climate change and resource use efficiency would be impossible in the framework of this presentation. In this context, it can be stated at least that yield, particularly large gains in yield, depends more on the number than on the average weight of the grains (former exhibiting far higher plasticity than the latter). The reason is that average grain weight seems mainly limited by its own capacity to grow (the availability of assimilates to fill the grains would be in excess in most conditions) while grain number per m^2 is strongly dependent on the availability of resources allowing more floret primordia initiated to become fertile florets at anthesis and most of them filled grains at harvest.

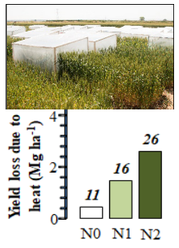


Thus for crop management and breeding to have a significant impact on further increasing yield they should affect the availability of resources or the efficiency in their use at the time the number of grains per m^2 is being determined. This is the main period in which wheat yield is unquestionably limited by source strength (most sensitive to changes in growth/partitioning). But the fact that grain growth is in general limited by the capacity of the grains to grow does not mean that final grain weight is independent of the environmental conditions during grain filling, as some factors may directly affect the capacity of the grains to grow (although less than grain number, grain weight also varies).

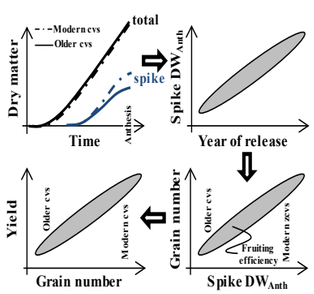
To illustrate how yield physiology knowledge may be used in designing management practices or defining breeding strategies, in this presentation we will focused on two examples: (i) N fertilization management to improve resilience to heat stress, and (ii) improving fruiting efficiency through breeding.

Among consequences of climate change on cereals, the most accurately predicted is that crops will be exposed to both higher CO_2 concentration and higher temperatures, mainly in the form of heat waves. Yield penalties produced by heat are well known, consistently affecting negatively the reproductive output of the crop. To gain in resilience to heat most research has focused on identifying genetic variation and genes/QTLs responsible for differences in sensitivity, as a first step to breed for that resilience. Much less has been done for identifying alternatives of crop management. N fertilization is one of the most common management practices that farmers have taken advantage to increase wheat yields (even in relatively dry environments). We wondered whether there could be interactions of heat x N that could be used to design fertilization strategies reducing the yield penalties due to heat, based on the fact that it had been speculated that high N would mitigate the effects of heat, assuming a likely synergy of damaging capacity between two different stresses. However, circumstantial evidences (mainly from

re-analyzing results form few controlled conditions experiments) showed that this assumption might not hold for this particular combination of two stresses (perhaps due to the fact that both did not take place at the same time).

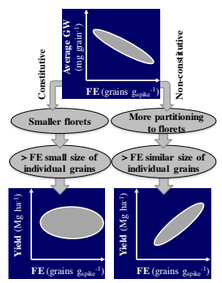


We conducted field experiments to quantify the magnitude of the yield penalty imposed by heat stress (during grain filling, when the likelihood of heat stress is largest) under contrasting soil N availabilities. As expected, yield was increased by higher N availability and penalized by heat. But the effects were far from independent: the higher the N availability the greater the sensitivity to heat. And this larger effect on high-N conditions was not simply the consequence of the higher yield in the unheated treatments in this condition, the penalty in relative terms was also higher (26%) in the high- than in the low-N condition (11%). This may imply that N-stressed plants might experience a sort of 'general acclimation' to stresses becoming less sensitive to another abiotic stress such as heat. In this context, fertilization recommendations may need to balance the yielding benefits of high N with the detrimental effect such fertilization scheme might have in the event of a heat stress.



Regarding breeding for crops being more efficient in the use of resources, this was achieved through breeding over the 20th century, clearly exemplified by the causes of yield increases produced by the green revolution, by breeding cultivars producing with similar overall growth of their predecessors (and using similar amounts of resources) but with a dramatically improved resource use efficiency, mainly through increasing the partitioning of pre-anthesis dry matter to the growth of the juvenile spikes whilst reducing proportionally plant height. Thus, breeding had increased the spike dry weight at anthesis, and that improved growth of the juvenile spikes immediately before anthesis brought about more or less proportional improvements in the number of grains per m2. As yield during grain filling is limited by the sink strength (chiefly, though not only, determined by the number of grains that will be filled after anthesis), improved cultivars with shorter stems allocating more resources to the grow of the spike at the time when grain number is being determined had consistently higher yields. The problem is that approach is rather exhausted in most breeding programs of the world, where modern cultivars have already optimum plant height and further shortening the stature would bring yield penalties (due to a reduction in radiation use efficiency associated to a deterioration of light distribution within the canopy) and alternatives must be found. These alternatives may include improving photosynthesis in pre-anthesis, identifying other sources of improved partitioning to the spike not implying further reductions in height, lengthening the duration of the spike growth period, and increasing fruiting efficiency (that is the efficiency with which resources allocated to the juvenile spikes immediately before anthesis are used to produce a certain number of grains). All of them have potential. Here we focused in the latter, the least studied so far.

Grains are the product of pollinated fertile florets, which in turn are the result of floret primordia development. Fruiting efficiency reflects the fates of floret development and grain abortion: more efficient genotypes would show a higher survival of floret primordia, and/or a reduced level of grain abortion. As abortion is low (most fertile florets set grains) and failure of floret primordia to become fertile florets is large, differences in fruiting efficiency in elite material maybe more related to survival of floret primordia. This may be achieved through (i) reduced demand of the florets for maintaining their normal development, or (ii) increased allocation of resources for the developing florets; though the former shall be avoided as it would bring about constitutive reductions in potential grain size (associated to the reduced size of the carpels) and consequently a compensation resulting in no yield gain. Fruiting efficiency can be used as criterion for selecting parents for strategic crosses, as it showed substantial transgressive segregation and trade-offs with spike growth can be avoided. Although it has been shown that the trait responds to selection, its real application would depend on counting with molecular markers.



Keywords: yield, yield physiology, heat, fruiting efficiency, cereals

Figures/schemes illustrating this abstract were adapted from:

Slafer, G.A., Elía, M., Savin, R., García, G.A., Terrile, I.I., Ferrante, A., Miralles, D.J. & González, F.G. 2015. Fruiting efficiency: an alternative trait to further rise wheat yield. Food and Energy Security, 4:92-109.

Slafer, G.A., Savin, R. 2007. Physiology of crop yield. In: "Encyclopedia of Plant and Crop Science" (R. Goodman, Ed.), Taylor & Francis, New York.

Slafer, G.A., Savin, R. 2018. Can N management affect the magnitude of yield loss due to heat waves in wheat and maize? Current Opinion in Plant Biology, 45:276-283.

Slafer, G.A., Savin, R., Sadras, V.O. 2014. Coarse and fine regulation of wheat yield components in response to genotype and environment. Field Crops Research, 157:71-83.

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LOW TEMPERATURE PERTURBS HYDRAULIC AND HORMONAL REGULATION OF LEAF EXPANSION AND PHOTOSYNTHESIS OF SOYBEAN SEEDLINGS

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Earlier soybean sowings in cooler soils are becoming more and more common in many temperate production systems. However, cold temperatures (T) during the early growing stages of soybean represent a main constraint for expansion of this crop towards higher latitudes. Chilling reduces root hydraulic conductivity thus limiting leaf expansion rate (LER) and photosynthesis (An), but whether endogenous hormone concentrations regulate genotypic variation in these traits under low T is uncertain. Following an initial low T screening of 18 European soybean cultivars, 6 genotypes of contrasting temperature sensitivity were grown in controlled environments at Lancaster University, UK. From sowing, plants were grown under low (L, 14 °C) or high (H, 24°C) temperatures until the tip of unifoliate leaf appeared, when half were either maintained at their original T or swapped, to result in 4 treatments (LL, LH, HL, and HH). Significant ($P<0.05$) genotypic variation in T responses (genotype x T interaction) occurred for physiological traits and the foliar hormones/precursors (ABA, JA, iP, *t*Z, ACC, SA, GA_3, GA_4, IAA) analysed. Genotypic variation in LER at low temperature was not explained by variation in LER at high temperature (LL *vs.* HH, $r^2=0.14$, NS). LER increased with foliar gibberellin concentrations in the HH treatment ($r^2=0.66^*$), and declined with leaf water content across the remaining T combinations ($r^2=0.42^{**}$), but also increased with increasing leaf ACC concentration ($r^2=0.87^{***}$) in the LL treatment. Genotypic variation in An at low temperature was correlated with variation at high temperature (LL *vs.* HH, $r^2=0.62^*$), and mostly explained by variation in stomatal conductance (g_s) across HH, HL and LH ($r^2=0.83^{**}$) plants. Genetic variation in g_s at low temperatures was highly correlated with variation at high temperature (LL *vs.* HH, $r^2=0.83^*$). Leaf ABA concentration was highly correlated with g_s in all treatments ($r^2=0.61^{***}$), except for LL plants. LL plants showed pronounced stomatal opening in spite of the highest ABA levels and lowest leaf water status, along with very low photosynthesis suggesting non-stomatal limitations. Massive foliar ACC (the ethylene precursor) accumulation in plants at low temperature likely antagonised ABA-induced stomatal closure, causing leaf water deficit that limited photosynthesis and leaf expansion. Genetic variation in hormone concentrations might provide a useful trait to select for genotypes with greater tolerance to low temperatures.

Keywords: chilling, soybean, leaf expansion, gas exchange, hormones

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PLASTICITY OF GRAIN NUMBER AND AVERAGE GRAIN WEIGHT IN RESPONSE TO HEAT WAVES AND SOURCE-SINK RATIO IN FIELD GROWN WHEAT

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Further increasing wheat productivity is more challenging due to consistently rising temperatures, but also the frequency of extreme events (such as "heat waves" characterized by few days of very high maximum temperatures). Heat waves negatively affects both main yield components of wheat; grain number per m^2 (GN) and average grain weight (AGW). The performances of wheat genotypes differ in the relevance of each of these components in determining yield as well as in the tolerance to heat stress. However, it is not clear (i) whether the compensation (cultivar with higher GN having lower AGW) would reflect competition between growing grains during grain filling, and (ii) if the sensitivity to heat stress would be related to the relevance

of the component in each cultivar and affected by an eventual source limitation (should growing grains compete for resources in cultivars with high GN and lower AGW). We selected two contrasting genotypes regarding GN and AGW and analyzed in detail (i) the causes for their differences in AGW and (ii) their GN and AGW responses to heat weaves imposed in the field at both pre- and post-anthesis using portable chambers with transparent polyethylene films in combination with different source-sink ratios. The reduced AGW of the cultivar with more GN was related to an increased proportion of grains with constitutively low weight potential (i.e. located in more distal positions), and it resulted in mainly decreasing the weight of the smallest grains, though there was also a smaller reduction in the size of the largest grains. Therefore, the difference of AGW between two contrasting genotypes, showing the negative relationship of yield components did not reflect resource competition. This was further confirmed by the fact that grain weight did not clearly respond to the increase in assimilate availability. Both GN and AGW were reduced by heat stress in both cultivars, evidencing the universal effect of heat on developmental and growth processes. However, the plasticity of GN and AGW was inversely related to the relative relevance of that component in determining grain yield of cultivars with different “strategy” for yield determination. The penalty in AGW produced by heat stress was not reduced by increasing the availability of resources per grain, though reducing that availability worsened the penalty. This means that the heat stress penalized AGW mainly through reducing the capacity of the grains to grow (i.e. reducing the individual grains sink strength).

Keywords: Wheat, Grain number, Grain weight, Heat stress, Source-sink limitation,

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ROW DISTANCE EFFECTS ON SUGAR BEET YIELD FORMATION

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In Europe, sugar beets are traditionally grown with a row spacing of 45 or 50 cm. Due to the crop´s slow canopy development in spring light interception during early growth is incomplete. It was hypothesized that lowering the row distance to 30 cm is likely to increase light interception during early growth and thus, increases yield. Field trials were conducted at two sites near Goettingen in 2018 and 2019 to quantify the effect of 30, 60 and 90 cm row distance compared to the 45 cm standard on canopy development, yield formation and light interception. Additionally, all row distances were tested in two varieties differing in leaf angle (upright, prostate).

Crops with 60 and 90 cm wide rows achieved the optimal leaf area index of 3 by about 10 to 14 days later compared to the 30 and 45 cm row distance treatments, and leaf area duration until mid-July was 37 % lower for 90 cm compared to 30 cm row spacing. Consistently, beet dry matter (dm) yield was 1.25 t ha^{-1} (17 %) lower in July. In absolute terms, this decrease in yield (dm, sugar) remained constant until October while in relative terms it decreased to about 7 % between 30/45 and 90 cm row spacing. The 60 cm rows produced an intermediate yield. There was no significant variety x row spacing interaction.

The diminished early growth of sugar beet grown in wide rows might be due to an increased shading of neighboring plants within rows and thus, decreased light interception. In all treatments, plant population was kept constant between 90.000 and 100.000 plants ha^{-1}, thereby decreasing the average in-row plant distance from 35 to 12 cm. It can be hypothesized, that decreasing the plant population by increasing in-row plant distance might diminish the yield loss due to wide rows.

In the second half of the growing season, the reduced light interception of ‘open’ canopies due to wide-row stands might have been compensated for by additional light interception at the edges of the canopies. Further, it can be speculated that light interception was not limiting for yield formation from July onward.

Keywords: sugar beet, row spacing, yield formation, light interception

Session 1.2: Crop interaction with biotic and abiotic factors

0060 KEYNOTE

INVESTIGATING CROP-WEED INTERACTIONS AS A DRIVER FOR AGROECOLOGICAL CROP PRODUCTION

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Weeds are a most interesting case study to investigate how to switch from intensive pesticide-based to agroecological pest management. Indeed, they are considered to be the most harmful pest for crop production because they compete with crops for light and soil resources, they are a key component of biodiversity in agricultural landscapes and their dynamics are subject to biological regulation. The present paper describes how (1) crops and weeds interact in arable crops, (2) cultural techniques influence these interactions, (3) combinations of cultural techniques allow to reconcile crop production, low herbicide use and biodiversity. (4) Mechanistic models play a key role in these investigations, to synthesize the many processes and cultural techniques interacting in the field, to identify knowledge gaps, and as virtual experimental fields to assess cropping-system prototypes designed by stakeholders ranging from scientists to farmers. We chose the FLORSYS model (Colbach et al, 2014, Weed Res) as a framework to illustrate these four points.

Emergence timing and establishment: the first out wins the race. There are three major emergence processes that are relevant for crop-weed interactions as well as for crop-crop interactions in intercropping, a key lever of agroecological production. Plant emergence timing and abundance is crucial as the earliest emerging species is usually the most successful species in a species mixture even if it is not the most competitive ones. Emergence is the result of (1) seed dormancy which determines the season when the seeds can potentially germinate, (2) seed germination which occurs when the soil is warm and moist enough for the species, (3) pre-emergent seedling mortality caused by soil compaction, drought or insufficient seed reserves. Emergence timing mostly depends on ecological requirements (represented by base temperature, base water potential, light sensitivity) whereas emergence abundance is more a matter of “strength” (seed reserves, shoot diameter...) and location (seeds on soil surface lack contact with soil to absorb water, deeply buried seeds have trouble germinating or reaching the soil surface). FLORSYS models all these processes at a daily time step and per 1-cm soil layer.

In terms of weed management, rotation is the key technique, sowing crops when the dominant weeds are dormant and, to a lesser degree, choosing species and varieties that germinate and emerge fast. Tillage is another indispensable technique, either to bury the seeds to avoid them emerging after crop sowing, or to trigger weed germination during summer fallow (by increasing soil-seed contact, exposing buried seeds to light) when the resulting weed plants can be destroyed before sowing the crop. Delaying sowing dates of winter crops can amplify this “false seed bed” technique whereas earlier sowing to precede weed emergence only works if there are no weeds emerging earlier (because they are dormant or their ecological requirements are not met) and the sown crop is able to outcompete the weeds.

Competition for resources: be large or be flexible. Once established, the major interaction between different plant species is competition for light and soil resources which, in heterogeneous canopies such as crop-weed canopies or crop mixtures, must be investigated at the plant rather the canopy scale. In high-input agroecosystems of temperate climates, light is generally the resource for which plants compete the most. The amount of light a plant intercepts depends on its own morphology and that of its neighbour plants. Shading by neighbours reduces light interception and thus biomass accumulation, depending on species light use efficiency, temperature requirements and air temperature. But morphology also changes as plants try to compensate shading with thinner larger leaves, taller and narrower plants etc. Generally, weeds are more responsive than crops, and non-legumes dicotyledenous crops more than cereals. Plants similarly compete for soil resources, i.e. the amount of resource they can take up depends on how their root systems overlap, how good they are at taking up and using the resources, and how they adapt their morphology to stresses.

Crops and varieties must therefore be chosen carefully, both to control weeds and in intercropping. Simulations with FLORSYS in non-limiting nitrogen and water conditions showed the crops with the highest competitive ability (identified via the lowest yield loss) to be wide, shading and flexible, i.e. their plants grew laterally in unshaded conditions (leaving less space for later emerging weeds), had thinner larger leaves, particularly from flowering onwards (intercepting more light and shading neighbours more) and etiolated when shaded by neighbour plants, with taller plants per biomass and even thinner larger leaves. Sowing density and pattern are also crucial: the more denser and the more regularly the crop plants are placed, the more they hinder weeds.

The biophysical field memory: vengeance is a dish best served cold. Plants do not only interact inside a multispecies canopy, they also interact over time by changing the biophysical environment for the next generation. The weed seed bank, is the main reason why weeds are so difficult to manage. Indeed, it is usually not the sole weed plant surviving in one year that damages crop production, but the hundreds or thousands of seeds it produces, which will infest later crops. Crops can also directly contribute to weed seed bank replenishment, via volunteers resulting from crop seeds lost before or during harvests. Seed loss in the soil over the years is the result of several processes, seed mortality due to predation, diseases and old age as well as well as seed germination. In terms of physical memory, soil structure and soil water left after harvest will affect germination and emergence of both subsequent crops and weed communities.

The field memory is one of the main reasons why models are essential to understand and manage weeds. Simulations with FLORSYS have allowed to assess unexpected long-term side effects of control measures with interesting short-term effects. For instance, cover crops during summer fallow can reduce weed pressure, even inside the following cash crop. However, weed infestation of future crops increases if cover crops prevent false seed bed techniques.

Tackle species diversity with comparative functional ecology. Weed communitiesconsist of dozens of contrasting species and ecological intensification calls for crop diversification, which means that more species must be investigated. Instead of investigating a small number of crop and weed species in detail, we need to predict the behaviour of a large number of species by comparing generic traits and processes. We applied this principle to the FLORSYS model (1) with a generic description of individuals, e.g., plants are described as an above-ground cylinder on top of below-ground spilled cone with leaf area and root biomass distributed inside these volumes, (2) the same processes apply to all species, e.g. plant dimensions are determined daily from plant biomass, plant stage, past stresses and species parameters, disregarding processes specific some species such as tillering, (3) parameters are linked to easily accessible species traits, e.g. seed mortality in the soil decreases with increasing seed coat thickness, or pre-emergent shoot and root lengths increase with seed mass. This makes it easier to predict the behaviour of many new species, and thus to simulate the interactions in multispecis canopies and sucessions.

Design and evaluate multiperformant weed management strategies. Virtual experiments were run with the FLORSYS model to evaluate and promote strategies for agroecological weed management, by (1) identifying crop ideotypes for weed control, (2) tracking innovative solutions in farm-field networks to reconcile crop production and biodiversity with reduced herbicide use, (3) evaluating prototypes proposed by experts and stakeholders, and (4) feeding participatory workshops with farmers. The case studies demonstrate that the best strategies for reconciling crop production, biodiversity and reduced herbicide use depend on the production situation, and thus the need for flexible weed-management rules and the usefulness of models such as FLORSYS to establish these rules.

Keywords: crop-weed interaction, functional ecology, cropping system design, mechanistic model, species trait

0018

EFFECT OF LOCATION AND GENOTYPE ON DEGENERATION OF ORANGE-FLESHED SWEETPOTATO IN NIGERIA

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The use of sweetpotato vine cuttings from previous crops or Volunteer Plants as planting materials by farmers in Nigeria, result in the accumulation of systemic pathogens, especially viruses. Information on the rate of degeneration due to this practice is very meagre. Studies were conducted during the 2015 and 2016 planting seasons at Iresi in southwest and Umudike in southeast Nigeria to evaluate the rate of degeneration of seventeen orange-fleshed sweetpotato genotypes (Amelia,Delvia,Gloria,Irene,Lourdes,Melinda,Namanga,Sumaia,Tiojoe,Umuspo1,Umuspo3,Bela,Cecelia,Erica,Esther andIninda) over three generations. The experiment was a split- plot in randomized complete block design with three replications. The two locations (Iresi and Umudike) constituted the main plot and the genotypes were assigned to the subplots. The trials started with virus-free planting material and succeeding trials retained planting material from previous crops. The observed virus symptoms were small twisted leaves with reduced leaf-size, vein chlorosis, purpling of mature leaves and stunted growth. There was higher virus incidence at Iresi in the first year of cropping while Umudike had higher disease incidence in the second year. At 8 WAP, Cecelia and Esther had higher virus incidence than other genotypes and along with Bela, Erica and Ininda , did not survive beyond the first season of cropping. Genotype Jane had the highest virus incidence and severity while Umuspo 1, Umuspo 3, Delvia, Tiojoe and Sumaia had the least in the second year of cropping. Vine length at 8 to 12 WAP, number of branches at 10 to 12 WAP, number of storage roots per plant and storage root yield were significantly higher at Iresi than at Umudike. In the first season of cropping, Umuspo 3, Ininda and Namanga produced significantly higher storage root yields than other genotypes, except Umuspo 1, Erica, Tiojoe and Gloria. In the second year of cropping, however, genotypes Umuspo 1 and Umuspo 3 produced the highest storage root yield, followed by Namanga, Jane and Delvia. Genotypes that contributed to the significantly higher storage root yield of the second year cropping were Umuspo 1, Umuspo 3, Sumaia, Namanga, Irene and Delvia. Storage root yields were negatively and significantly correlated with virus incidence and severity but positively and significantly correlated with number of branches at 12 WAP, number of storage roots and root weight.

Keywords: Sweetpotato, genotype, location, virus infection, yield.

0021

ARE YIELD INCREASES IN MAIZE IN NW-EUROPE DUE TO BREEDING PROGRESS OR THE SELECTION OF MORE SUITABLE HYBRIDS DUE TO CLIMATE CHANGE?

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Yield increases in forage maize (Zea mays L.) in NW-Europe over time are well documented. The driving causes for these, however, remain unclear as there is little information available regarding the role of plant traits triggering this yield progress. Ten different hybrids from the same maturity group, which have typically been cultivated in northern Germany from 1970 to recent and which are thus representing breeding progress over four decades were selected for a two-year field study in northern Germany. Traits that were investigated included leaf area index, leaf architecture, photosynthesis, root mass, root length density and turnover. Parameters related to leaf characteristics, in particular the number of leaves and the leaf orientation had the greatest impact on linear biomass yield progress (0.13 tons ha^{-1} $year^{-1}$). In contrast to our hypothesis root biomass and morphology did not increase in newer cultivars compared to older ones. The observed increase in yield over the last four decades is due to a combination of increased temperatures and the resulting earlier maturity, and an efficient use of these increased temperatures (~240 GDD within 40 years) through an increased leaf number, a lower leaf angle, and an increased leaf area index (r^2 0,7) of newer compared to older cultivars. Future selection of maize hybrids depending on changing environmental conditions are likely to be the key for high productivity and quality, as well as for the economic viability of maize growing and expansion in Northern Europe.

Keywords: maize, yield, plant functional traits, breeding progress, leaf area index, root length density, climate change

0048

USING TRAIT-BASED APPROACH TO SELECT BANANA VARIETIES ADAPTED TO AGROECOLOGICAL CROP SYSTEM

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The ecological intensification of dessert banana (Musa AAA Cavendish) crop includes alternative practices to chemical that can be restrictive for light interception and nutrients uptake. Indeed, leaf removal was used as a substitute for leaf fungicide application, but reduces the photosynthetic leaf area. In the same way, instead of using herbicide and mineral fertilizer, the use of cover plants and organic fertilizers may limits soil nitrogen availability. However, the currently cultivated Cavendish varieties have been selected for their high performance in intensive cropping systems and are not so productive with leaf removal and limited N resources. In this context, bananas varieties tolerant to sub-optimal conditions must be selected. We hypothesize that a trait-based approach enable to select banana varieties according to their tolerance to leaf-removal and to limited N resources. This approach is adapted from functional ecology and consists in studying plant-environment interactions through their functional traits. The aim of our study was to determine the banana functional traits that characterize the tolerance to leaf removal and to limited N resources. First, we reviewed the physiological mechanisms involved in stress tolerance and in yield elaboration. It reveals that source-sink balances are in the center of all those mechanisms. We assumed that studying sink-source balance thanks to functional traits must allow characterizing the tolerance to leaf removal and N limited resources. For the traits selection, our main research hypothesizes were: (i) sink-source balance can be studied by leaf area and sink organ volume measurements; (ii) roots N absorption can be

studied through roots distribution on a soil profile. We selected a set of functional traits that we measured on a range of 13 banana varieties to establish their functional profile. Then we studied these varieties under four conditions: with and without N limited resources; with and without leaf removal. We measured and compared yield components (cycle duration, fruits number, fruit size, fruit conservation) for each variety in the different conditions. We confronted the functional profiles of the varieties with their agronomic performances in order to validate the functional traits selected. Finally significant traits, such as leaf emergence rate or biomass ratios between the source/sink organs seems to be good indicators to select tolerant banana varieties to leaf removal and limited N resources.

Keywords: crop ecology, low input agriculture, crop-environment interaction: soil

0089

MULTIPLE DISEASE SUSCEPTIBILITY, BREEDING PROGRESS AND YIELD LOSS OF WINTER WHEAT IN GERMAN VARIETY TRIALS DURING 1983-2019

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This study aimed at quantifying breeding progress achieved in resistance breeding towards varieties with higher yield and lower susceptibility for six major diseases under natural infection during 1983-2019. Further aim was the prediction of disease related yield losses during 2005-2019 by mixed linear models using disease traits as covariates. For all traits, overall progress of the fully treated intensity (I2) was considerably higher than for intensity without fungicides and growth regulators (I1). The susceptibility level was considerably reduced during the study period for mildew (MLD), tan spot (DTR), and Septoria nodorum blotch (SNB), to a lesser extent for brown rust (BNR) and Septoria tritici blotch (STB), however, not for yellow/stripe rust (YLR). Considerable yield loss under severe disease infestation was predicted for STB (-6.6 %), BNR (-6.5%) and yellow rust (YLR, -5.8 %), but lower losses for the other diseases. The yield loss for low vs. high susceptible varieties under severe disease conditions was about halved for BNR and YLR providing evidence of resistance breeding progress. The empirical evidence on the functional relations between disease infestation, variety resistance and yield loss based on a large-scale multi-disease field trial data set in German winter wheat may give an important contribution to the ongoing discussion on the reasonableness of chemical plant protection in European crop production.

Keywords: biotic stress, yield security, fungicides, multi-environment trials

0094

A REVIEW OF HEAT STRESS IN CANOLA (BRASSICA NAPUS L.)

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Canola (*Brassica napus L.*), also known as oilseed rape, is an oil crop of worldwide importance. Due to global warming and production expansion to warmer regions, the risk for heat stress in canola is gradually increasing. Here we provide an overview of the current state of knowledge of high temperature stress in canola. With regard to the experimental approaches for the assessment of heat stress effects, most studies are conducted under controlled conditions, with most studies setting their maximum daytime temperatures above 30°C. In the different studies the duration of heat stress treatments vary between 5 and 14 days. Most studies excerpted heat stress during flowering and seed development stage, while fewer investigated early heat stress during germination and vegetative development. An alternative approach used to study the effect of heat stress is the use of natural field conditions by alternate sowing dates in warm climate regions. With regard to the physiological effects of heat stress net photosynthesis, chlorophyll content and carboxylation efficiency rate were reduced. Furthermore, morphological effects such as reduced plant height and stem diameter, as well as fresh and dry weight were reported. Additionally, heat stress caused degradation of flowers and pollen sterility. Depending on the timing and intensity of heat stress, yield effects worked via reduced number of siliques, seed number per silique and thousand seed weight. Further, seed oil content decreased, while protein content and fatty acid composition were enhanced. Finally, limitations of previous research are discussed, and knowledge gaps identified.

Keywords: Abiotic stress, physiological effects, high temperature, climate chamber experiments

0116

EXPRESSION OF AMMONIUM TRANSPORTER GENES IN BARLEY UNDER DIFFERENT FARMING SYSTEMS

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In plants, Nitrogen is taken up either as nitrate or ammonium by roots directly from the soil. Ammonium uptake is mainly governed by ammonium transporter (AMT). Two high-affinity AMT genes (AMT1 and AMT2) have been characterized as the most important ones in barley. Although nitrogen is a critical element for plant growth and development, the excess amount of nitrogen fertilizers cause problems such as higher costs of crop production, lower nitrogen use efficiency and environmental hazard. Therefore, organic farming is applied to promote sustainable agriculture. Nevertheless, understanding of the molecular mechanisms is crucial to figure out the optimum amount and type of nitrogen fertilizer to have highest productivity and sustainability. In the present study, five different growth stages of barley were used for gene expression analysis under conventional and organic farming fertilizing regimes. The plants were collected at tillering growth stage and 5, 10, 15 and 20 days after. The organic system consisted of three subtreatments: Org 0 as control, OrgI with cover crops, and OrgII with cover crops and composted cattle manure. Conventional system had four subtreatments: $N_0P_0K_0$ as control; $N_{40}P_{25}K_{95}$; $N_{80}P_{25}K_{95}$, and $N_{120}P_{25}K_{95}$. The results showed that mineral nitrogen fertilizer had a greater impact on expression of both AMT1 and AMT2 genes. The highest expression of AMT1 was seen in the last studied growth stage and conventional treatments, particularly with the highest amount of applied mineral fertilizer. Expression of AMT2 was higher in organic treatments compared to conventional plots. Taken together, Framing system had an impact on AMT1 and AMT2 expression.

Keywords: Ammonium transporter, Expression, Barley, Conventional and organic farming

0141

UNRAVELLING THE RELATIONS BETWEEN THE SOIL WEED SEED BANK AND WEED EMERGENCE IN THE FIELD.

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The weed populations of agro-ecosystems are dynamic and weed seeds emergence are influenced by multiple factors. It is clear that biotic and abiotic factors influence the soil seed bank acting as a source of successive infestations for crops. The influence of environmental factors on weed seed bank evolution can be known despite of their resilience to changes. Also, soil weed seed bank studies can be a means to gain historical information from fields.

The soil seed bank constitutes the potential weed infestation in the field and depends on environmental conditions and crop management. Their final germination give us the real weed density in the field.

This study compared the potential weed infestation with the real infestation occurred in two agro-ecosystems, located in Madrid and Seville, during two consecutive years (2018 and 2019). In both locations, a 4-leaf crop rotation (wheat, barley, pea and rape) was established. The potential weed infestation was analysed with data from the soil weed seed bank. We carried out 144 samples per year corresponding on 16 plots in Madrid and Seville respectively. Data from soil weed seed bank were collected by two techniques: the seed extraction method and seed germination method. A comparison of seed density/m², seed frequency, weed species diversity and relative importance value between common species were evaluated for both methodologies.

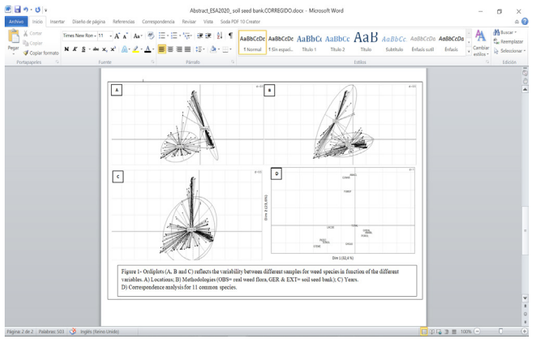
Furthermore, the real weed infestation was determined by counting 6 samples of 0.25x0.25m per plot and weed density was calculated, in both agro-ecosystems, at several times during the crop cycle.

Our results showed that extraction method had higher weed seeds density, weed frequency and weed species diversity compared to seed germination method. Correlations were then searched for between the common species obtained from soil seed bank (the potential weed infestation) and the weed density in field (the real weed infestation). Several correspondence analyses (ordiplots) were obtained and differences in weed species composition for both locations were found. The weed samples collected in Seville were more homogeneous in behaviour and composition than those obtained from Madrid.

Regarding the locations, the relationship between potential infestation and real infestation was significantly different. Although the years did not affect the sampling variability, there were a total of 11 weed species that showed a high correlation with the analysed variables.

Our work reveals that complementarity of methodologies to study the weed population dynamic can be considered as a strategy to study changing agro-ecosystems.

Keywords: agro-ecosystems, ordiplot, seed extraction, seed germination, weed density



0250

MANAGING FOOD SAFETY HAZARDS IN HORTICULTURAL PRODUCTION

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Horticultural crops that are sold as ready-to-eat or minimally processed can be associated with foodborne illness. Crops can become contaminated with foodborne pathogens such as Salmonella or pathogenic Escherichia coli from irrigation water or via manure, whereas other such as Listeria species may arise from environmental sources. Contamination events are rare and the incidence of transmission of pathogens into the food-chain is low, but the consequences are serious and so the issue has important implications. Therefore, management strategies need to be adopted in horticultural production to take into account the hazards and resulting likelihood of causing disease. Here, we consider the potential routes of contamination, plant-microbe interactions and in particular the potential role of the endemic microbiome. Plant microbiomes are dynamic and complex, and well known to be influenced by edaphic and plant factors. Increased knowledge and technological advances means that we can now raise key questions about their functions in crop production, including whether the microbiome is route to control of human pathogens on crops. This work has been done as part of an EU COST network, HuPlantControl.

0260

SOIL PH EFFECTS ON ROOT GROWTH AND ROOT:SHOOT RATIO IN SPRING BARLEY

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The influence of soil pH on crop performance is well documented and farmers can spend considerable time and money to ensure that their soil is at what is considered an optimum pH for their crops. The effect of soil pH on a crop is mediated through the root system and impacts on crop nutrition. However, the exact nature of the relationship between soil pH, root growth and crop yield are frequently derived from studies on crops grown in hydroponic systems, on different soil types or in soil that has recently had its pH manipulated. All of these have profound effects on nutrient availability and the soil microbial community, which makes comparisons with the true field situation difficult.

A long-term experiment was established on a sandy loam soil at Aberdeen, North-East Scotland in 1961. This had an eight-course crop rotation typical for the area superimposed on plots in which the soil pH was adjusted annually to between pH 4.5 and pH 7.5 in 0.5 increments. In this paper we present results from a three-year study using this unique experimental platform. We measured the rooting parameters and crop yield of spring barley, the main cereal crop grown in Scotland.

Root length density, root biomass and root surface area all showed a general trend to decrease at higher values of soil pH, despite large weather-related inter-annual variations. Grain yields were greatest in the range pH 5.5-6.5. The relationship between grain yields and root parameters was less clear, with apparently little effect of soil pH on the amount of grain produced per unit surface area of roots. These results are important in helping us to understand the relationship between rooting parameters and crop performance, and in developing recommendations for farmers about soil pH.

Keywords: soil pH, root growth, root:shoot ratio, crop production, long term experiments

0266

SALYSILIC ACID FOLIAR SPRAY EFFECTS ON MINERAL STATUS OF CANOLA SEEDS GROWN UNDER SALINITY

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A pot experiment was conducted in the greenhouse of the National research centre at Dokki, Cairo Egypt during winter season to evaluate the concentration and content of macro and micro-nutrients in shoots of different varieties of canola plants. The treatments were as follows: The salt concentration in water of irrigation: Tap water (250 ppm, 0.39 dS/m), 2500 (3.9 dS/m) and 5000 ppm (7.8 dS/m). Spraying salicylic acid at the rate of 100 and 200 than tape water as a control. The concentration of K, Mg and Na increased parallel to the increase in the percentage of seawater in irrigation solution. On the other hand, the concentration of Ca seemed to be without differences. The concentration of different macronutrients K, Mg, Na and Ca seemed to be without response by the salicylic acid application. Ca:Na ratio the only affected but negatively with the increase of salt in the diluted seawater.Ca:(Na+K), Mg:-Na and K:Na concentration ratios did not showed any clear response to the salinity treatments. while did not show any effect on Mg/Na ratio compare to the control treatment. The concentration of different macronutrients determined in this work i.e. K, Mg, Na and Ca seemed to be without response by the application of salicylic acid. No responses were observed in the all Na ratios with the other elements i.e. K/Na, Ca/Na, Mg/Na and Ca(Na+K) to the application of salicylic acid.

Keywords: Canola (Brassica napus L) ,Seeds-Salt stress, Salicylic acid, Macronutrients,micronutrients.

Session 1.3: Modelling crop-environment interactions

0020

EFFECT OF WINTER CEREAL SOWING TIME ON YIELD AND NITRATE LEACHING BASED ON EXPERIMENTS AND MODELLING

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The sustainable management of intensively managed agricultural land requires high productivity with low environmental impacts. There is a lack of understanding if early sowing of winter cereals is a potential mitigation measure for reducing nitrate leaching losses.

To test this, an experiment was conducted in Denmark over three years (2016-2019) with timely and ca. three weeks earlier sowing of winter rye and with different levels of nitrogen (N) fertilisation. Early sowing reduced nitrate leaching but did not affect grain yield or grain N concentration.

Deterministic models are increasingly being used to aid farm management and inform policy making and compliance. The Agricultural Production Systems sIMulator (APSIM) modelling framework has been widely used worldwide to simulate crop growth and N uptake, and estimate environmental impacts. The model has, however not been used under Danish conditions. The APSIM model was evaluated and calibrated for winter rye, and the climatic conditions prevailing in Denmark. After changing a few crop coefficients and variables, the model adequately simulated dry matter yield and grain N concentration across the different N fertilisation rates. Comparison between measured and predicted nitrate leaching showed poor performance for the timely sown winter rye, whereas the prediction was better for the early sown winter rye. Cumulative nitrate leaching over the three years studied also shows better performance of the model. Long term simulations suggest a slight reduction in nitrate leaching, on average of 5%, with the use of early sowing.

Keywords: Nitrate leaching, increasing N fertilisation rates, early and timely sowing, winter rye, APSIM

0028

FROM POINT TO FIELD SCALE - UNCERTAINTIES ASSOCIATED TO THE USPCALING OF MODELLING FOR SPATIAL HETEROGENEITY ASSESSMENT

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Significant advances have been made in the engineering aspects of precision agriculture such as increasing spatial resolution, delivery of variable rate technologies and automation, but much less effort has been devoted to understand the crop mechanisms underlying the responses to spatial variations. The success of precision agriculture and site-specific management would benefit from advances in the spatial modelling of crops, but insufficient attention has been devoted to the scaling up of the 'cause-effect' relations associated with spatial variations. We have conducted a spatial analysis of a 10 ha rainfed commercial plot by combining a (point-based) crop simulation model with remote sensing data, collected for five different growing seasons (2015-2019) in order to capture different crop x year interactions in a typical rainfed rotation scheme. A geospatial assessment of the simulated heterogeneity was conducted in order to capture spatial patterns of crop performance associated to multiple field measured geomorphological properties (i.e., elevation, slope orientation, soil apparent electrical conductivity - ECa, %Clay, %Sand, pH). We believe that the use of remote sensing for yield estimation in rainfed agriculture is problematic due to the spatial variations of the harvest index that are not captured by the time-series analyses of imagery (representative of biomass mapping only). Even the biomass assessment has significant uncertainty according to a meta-analysis that we conducted on more than 20 published studies (compiling more than 1400 data points associated to 26 different crops). We found ample variation when using standard vegetation indexes to derive canopy structure parameters with implications on crop transpiration and photosynthetic activity, such as LAI or canopy ground cover. In addition, by acknowledging the lack of 'cause-effect' relations in the upscaling of point-based models to field level, we hypothesize that an error gradient is transmitted in proportion to field elevation, or, in other words, to the degree of different forms of water inflow taking place at each simulated point. The current set of simulations revealed temporal asymmetry of spatial patterns, which indicates instability of management zones (MZ) in a typical annual-rotation scheme. This point emphasizes multiple uncertainties regarding the delineation and interpretation of MZ in precision agriculture, and it stresses out how much remote, digital and fully automated agriculture is still far from reality. The quantification of temporal asymmetry or unstable zones may be used for risk assessment, helping us to estimate margins for economic improvement. Besides the scientific advances on spatial modelling, attention dedicated to the quantification of such margins is highly appealed for critical thinking on precision agriculture opportunities and barriers.

Keywords: Crop ecology, Modelling, Remote sensing

0070

INTEGRATING PLANT-PLANT COMPETITION FOR NITROGEN IN A 3D INDIVIDUAL-BASED MODEL SIMULATING THE EFFECTS OF CROPPING SYSTEMS ON WEED DYNAMICS

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Promoting biological weed regulation by shifting resource availability and use from weed to crop may provide an option for a more sustainable weed management. Light is generally the main resource for which crops and weeds compete in conventional cropping systems. But, with the necessity to reduce mineral nitrogen fertilizer use, better managing crop-weed competition for nitrogen may become crucial. However, it requires better understanding the functioning of heterogeneous canopies in nitrogen-deficient situations. Simulation models are powerful tools to reach this goal. Our objective was to integrate plant-plant competition for nitrogen into the FlorSys model, already simulating competition for light. The final aim was to provide the first mechanistic and 3D individual-based model simulating the effects of cropping system and pedoclimate on weed dynamics, integrating competition for nitrogen.

The new formalisms were mostly inspired from pre-existing models and adapted to make them compatible with the individual-based representation of FlorSys. Soil-nitrogen concentration is predicted by the STICS soil submodel linked to FlorSys. Plant nitrogen uptake was simulated by confronting plant nitrogen demand (driven by shoot growth) to plant nitrogen supply (depending on root characteristics, soil-nitrogen availability and the presence of neighboring plants with roots in the same soil zone). Competition for nitrogen occurred when the amount of nitrogen available in a soil voxel (i.e. 3D soil pixel) was lower than the requirements of all the plants with roots in this voxel. A nitrogen stress index allowed to account for the impact of plant nitrogen nutrition on plant photosynthesis, biomass allocation and morphology. To reflect the plant adaptation to the spatial heterogeneity in soil-nitrogen availability, we introduced 'compensation'. For a given plant, if nitrogen uptake in one soil voxel is insufficient to fulfil plant nitrogen requirements in this voxel, this local nitrogen-deficiency could be compensated by increasing nitrogen uptake in other nitrogen-richer voxels. The new formalisms needed only seven plant parameters which we measured for several crop and weed species. Simulations showed that, despite simplifying hypotheses in formalisms, predictions were consistent with knowledge on canopy functioning and crop-weed interactions.

The nitrogen version of FlorSys will be useful to understand the role of nitrogen in crop-weed interactions and to identify sustainable management strategies promoting weed regulation by competition (see Perthame et al., this congress). Due to its process-based representation and genericity (it can simulate diverse crop species), it will also be useful to better understand crop-crop interactions in intercropping.

0074

A CROP MODEL FOR SIMULATING RYE GROWTH, DEVELOPMENT AND YIELD

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Rye (Secale cereale L.) is a promising crop towards attaining sustainable agriculture. Compared to other major cereals, rye offers comparatively high hardiness against abiotic stress like frost and drought, which make it suitable in marginal environments. Despite of remarkable progress in rye hybrid breeding and respective genetic improvement, lodging susceptibility and a low harvest index (HI) remain major challenges. To overcome these challenges the EU-project RYE-SUS (www.rye-sus.eu) pursues the introgression of the gibberellin (GA) sensitive dwarfing gene Ddw1 as a promising strategy. To be able to test the performance of different novel semi-dwarf genotypes developed in RYE-SUS a crop model-based approach is applied. Process-based crop models simulate crop growth, development, and yield under diverse soil, climate, and management condition. We report on the adaptation of the DSSAT-NWheat model for rye to predict the effects of Ddw1 introgression on the performance of different rye genotypes in various target environments and to distinguish effective strategies to genetically adapt rye to climate change. Further, the morpho-, physio-, and phenological effects of Ddw1 introgression are parameterized for a series of tall and near-isogenic semi-dwarf genotypes. Finally, these genotypes' performance will be analyzed in prominent rye growing regions under current (1991-2020) and future (2035-2065) climatic conditions.

Keywords: modeling, cereals, and climate change

0077

EFFECTIVENESS OF LATE SOWN COVER CROPS TO REDUCE NITROGEN LEACHING UNDER CLIMATE CHANGE

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The use of cover crops is a well-established adaptive option to reduce risks of nitrogen (N) leaching losses. However, it is unclear how effective cover crops are when sowing occurs late in the growing season, both

for current or future climate conditions. This is particularly important for agricultural systems in temperate regions in which main crops are harvested late in autumn/winter and residual N loads are high. This is the case in New Zealand for forage kale and fodder beet crops that are grazed by livestock from May to July. This creates four to five months of fallow conditions at a time when the risks of drainage are highest due to water saturated soils. We combined field experimentation and biophysical modelling to quantify the potential of winter sown oat cover crops to take up residual mineral N from the soil considering current and future climate change projections. Field results showed that the pattern of cover crop growth was characterized by a long lag-phase followed by a rapid onset of canopy expansion in early-spring. Uptake of N by winter-sown cover crops differed more than 2 depending on initial soil water and N conditions. A more comprehensive evaluation of temporal and spatial variability in cover crop response was then obtained by testing the oat crop APSIM Next Generation model against the field dataset and simulating the system for 30-year periods, across four key agricultural locations considering four Representative Concentration Pathways (RCPs) and six General Circulation Models (GCMs). There was a large variability in cover crop effectiveness to reduce N leaching across years, locations and climates. Climate change impacts on cover crop performance also differed spatially, with minor effects in warmer northern locations (Hawke's Bay and Waikato) but significant increases in cover crop N uptake and soil N mineralization rates for the cooler southern locations (Canterbury and Southland). Uncertainty from GCMs was scenario dependent, increasing at high RCPs particularly in more southern locations. These results highlight the importance of considering plant-soil interactions across space and time for a comprehensive evaluation of adaptive measures, such as the use of cover crops, to climate change conditions.

Keywords: Adaptation, catch crops, modelling, pollution

0082

MODELLING PHENOLOGICAL DEVELOPEMENT OF *THINOPYRUM INTERMEDIUM* REVEALS A PHOTOPERIODIC EFFECT, AFFECTING FLOWERING EARLINESS

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The wild wheat-relative intermediate wheatgrass (Thinopyrum intermedium (Host) Barkworth & D.R. Dewey) is a winter-hardy cool-season perennial grass, which has recently undergone development as a perennial grain by numerous breeding programs. Perennial grains may be an interesting option to support the transition to agroecological systems thanks to its perenniality which permits production a forage-grain dual income crop for several years at minimum soil and environmental costs. However, the introduction of IWG in grain systems is currently limited by its reduced grain yields. While breeding efforts have mostly been dedicated to improve performance and heritabilities of seed size, mass and number per head, little attention has been paid to IWG phenological milestones that unlock its reproductive growth cycle. Most perennial grasses have a dual induction requirement for reproductive development. It refers to the - primary induction - exposure to winter conditions, including low temperature and short daylength, followed by a - secondary induction - period of transition to longer days and higher temperatures initiating inflorescence development. Current worldwide endeavors for IWG production has called for deeper investigations of environmental requirements associated with flowering and yielding capacity. In our study, IWG growth stages were measured at the field level, representing the reproductive growth stage and utilizing the BBCH scale. Fields locations in four countries (France, Belgium, US and Canada), representing 127 field observations, obtained from 2012 to 2019.

The IWG phenology model was adapted from the STICS soil crop model. After optimization, IWG phenology model was compliant (RRMSE= ~0.03) with experimental results. Our results indicate that IWG vernalization requirements (primary induction) are fulfilled within a range of temperatures from -5 degree to +11 degrees, with an optimum at +3 degree. The total number of equivalent vernalization days required was about 50 days. Then, plant growth and flowering (secondary induction) are associated to both heat unit accumulation and photoperiodic response, leading to potentially significant differences in heat unit accumulation requirements for flowering depending on latitude. Reproductive growth was found to be possible from 10h to 17h daylengths.

Overall, modelling IWG phenology enables researchers to virtually explore suitable growth contexts, to optimize field management choices, and to advise further breeding strategies. IWG phenology provides critical information for dealing with sowing choices, weed issues, fertilization or risk of water stress during reproduction. However, phenologic and ontogenic plasticity of such perennial grasses may lead to divergent ecotypes under various agroecosystems with different resource availabilities and management options.

Keywords: perennial grains, Thinopyrum intermedium, phenology, modelling

0097

A SIMULATION STUDY FOR STRUCTURAL EQUATION MODELS SELECTION IN AGROECOLOGY

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In a context of agroecological transition, plant microbiome studies are promising for the description of the relation between soil properties and plant performances of the rhizosphere. Indeed, the rhizosphere is a vital interface for plants to acquire resources and to enhance plant health thanks to the plant microbiome, and is altered by the plant itself and many other biotic and abiotic factors. In addition to the difficulty of rhizosphere soil sampling, the rhizosphere involves complex root-soil interactions challenging our ability to study rhizosphere processes. Coupled to the impact of farming practices on these interactions, agroecological research should address new statistical tools able to model the complexity of the rhizosphere. Recent studies using Structural Equation Modelling (SEM) demonstrated the value of this statistical tool to explore complex ecological interactions in holistic approaches by the identification of causal links between latent variables of interest (Lamb et al., 2011; Cantarel et al., 2015; Schmidt et al., 2019). The use of SEM is based on the definition of a conceptual scheme usually build on scientific knowledge. Similar to a network, the conceptual scheme summarizes the relationships that are fitted by the model and the quality of the model therefore depends on the validity of the conceptual scheme. In our context, several candidate conceptual schemes can be tested that raised the question of model comparison to select the optimal conceptual scheme. In this work, we address the question of model selection by comparing the ability of information criteria (AIC, BIC and relatives) to select the optimal model. Therefore, we conducted an extensive simulation study by considering various realistic scenarii. For each scenario, we compare the performances of criteria under a wide range of conditions (sample size, value of misspecified parameters and composition of the set of models tested). In this study, we show that the ability of each criterion to select the optimal model varied according to the conditions tested and some criteria seemed more adapted than others to detect the optimal model. The value of SEM in agroecology goes along with difficulties to converge models using experimental datasets. Simulation studies like this improve the knowledge of SEM necessary to develop this tool in agroecology. Indeed, we provided useful suggestions on the choice of model selection criteria to conduct SEM analysis.

Keywords: Structural equation modelling; model selection; criteria; interactions; plant microbiome

0102

IMPACT OF PLANT PROTECTION STRATEGY AND SOIL TILLAGE ON THE CARBON FOOTPRINT OF WHEAT

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Climate protection is in the self-interest of agriculture due to the increasing negative effects of climate change on crop production. The effects of different crop protection strategies, the non-usage of fungicides, and reduced tillage were assessed regarding climate impact of wheat production based on a long-term field trial in Dahnsdorf, North-East Germany in 2008-2019. The assessment was carried out using a partial life cycle assessment (LCA). On average across all treatments and years, the greenhouse gas (GHG) emissions were 2963 kg CO_2eq ha^{-1} and the carbon footprint (CFP) was 0.54 kg CO_2eq kg^{-1}. Although the treatments with plow caused about 100 kg CO_2eq ha^{-1} higher emissions, their CFPs were usually lower than without plow.

The yield-securing effects of fungicides led to reduced CFPs. While GHG-emissions hardly fluctuated, CFPs varied by a factor of two to three over the years. This underscores the need for evaluation over longer time series and the value of long-term trials.

Keywords: Climate protection, GHG emissions, LCA, fungicide, integrated pest management

0134

MODELLING IRRIGATION EFFECTS IN CROP ROTATIONS ACROSS BRANDENBURG UNDER CLIMATE CHANGE

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Water supply to crops is a main issue in the Federal State of Brandenburg since it belongs to one of the driest areas in Germany dominantly covered by sandy soils with low water holding capacity. The dry years in 2018 and 2019 showed significant reduction in crop yields since irrigation is limited to less than 4% of the agricultural land. Climate change may exacerbate the water scarcity. However, the additional water demand strongly depends on the Representative Concentration Pathway (RCP) and the Global Climate Model (GCM) to project future scenarios. We present a regional study across the Brandenburg/Germany based on climate data for baseline and RCPs 2.6 and 8.5 of two GCMs at 25x25 km grid resolution, and a digital soil map using the HERMES agro-ecosystem model. The aim was to investigate the effect of irrigation for different crops embedded in different crop rotations under current and future climate conditions regarding productivity and environmental effects. Five types of crop production were addressed by defining site specific crop rotations over a 4-5 year sequence, which were simulated continuously over 30 years. Simulations with and without irrigation were repeated in shifted phases to ensure that each crop is simulated for each year. Automatic management algorithms for sowing, harvest, irrigation and nitrogen fertilization based on soil and climate information were applied. Additionally, cover crops were implemented in alternative rotations to prevent winter fallow. The soil map was intersected with the climate grid considering 276 soil types defined by their soil profiles including soil organic matter and texture down to 2 meters. Groundwater levels were estimated using the depth of reduction horizons to consider capillary rise. Beside crop yields we analyzed the outputs for trends in irrigation demand, groundwater recharge, and nitrogen leaching. Our results indicate that spring crops are more negatively affected by climate change than winter crop especially on soils with low water holding capacity. Crops on more loamy soils and potential contribution of capillary rise from a shallow groundwater may even benefit from climate change. However, the combination of clay soils a shallow groundwater may lead to oxygen deficiency reducing yields. Irrigation in most cases improved crop yield especially for spring crops. However, a first economic analysis indicates, that irrigation gains an economic benefit only for rotations containing high value crops, e.g., potatoes. Implementing winter cover crops may reduce nitrogen leaching if they can still be successfully established under future conditions.

Keywords: modeling, water management, environmental impact, climate change

0135

WEED DENSITY AND WEED DIVERSITY INFLUENCED BY RAINFALL, DIFFERENT SOIL MANAGEMENT AND ROTATION SYSTEMS

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Cereal crops in rainfed under semiarid Mediterranean climate depend on total and stational rainfall during growing season (GSR) and has a great influence on yield and weeds.

We studied weed density and weed diversity over three years (2014-2015; 2015-2016 and 2016-2017) under 3 different soil managements and two cropping systems. The soil managements were: conventional tillage (CT), minimum tillage (MT) and no tillage (NT); and the cropping systems compared were wheat monoculture vs. wheat rotation (with fallow, barley and vetch).

Each year of study, total rainfall was lower than the historical average. In 2016-2017 the decrease was 43,4% in relation to the average. The years 2014-2015 and 2016-2017 had a similar distribution pattern, more than 50% of GSR was concentrated in the autumn months (from September to December). In contrast, 2015-2016 had a very dry autumn (44 mm) and there was higher levels of precipitation in winter and spring (247 mm in 6 months). This year, total of GSR was similar to 2014-2015.

Our results showed that weed density (pl/m2) was significantly affected by the year, tillage and year x tillage. The year 2015-2016 was significantly different from the other two, weed density measured was low due to the lowest accumulate rainfall until March (time of weed sampling). Regarding the tillage we observed that the highest average of weed density was measured in NT. And cropping system did not influence in this variable.

Weed diversity was assessed using Shannon's diversity index and Pielou´s evenness index. Shannon´s index showed a large difference between 2015 -2016 with the other two years and between the tillage systems. Pielou´s index showed differences among the tillage systems. During these 3 years, 9 weed species were constantly present in this trial. It was found that the climatic year influenced significantly on the presence of 7 species from the total studied. The NT system affected 6 of the 9 species while the MT affected 1 of the 9 species. Also, the management under a rotation system influenced on 3 of 9 species.

Our results highlight that NT system reached higher values in weed density and weed diversity than CT and MT system despite of the irregular GSR occurred during this study. Then, data of total and GSR play a fundamental role in these variables. These findings should be considered when predictions about future shifts in weed population related to the selecting of agronomic practices are made.

Keywords: abundance, cereal, crops systems, Mediterranean climate, precipitation

0234

ESTIMATING TRANSPIRATION IN GRAPEVINES UNDER TWO WATER REGIMES USING THE TWO-SOURCE ENERGY BALANCE- MODEL

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Accurate estimations and monitoring of actual crop evapotranspiration are critical to determine crop water requirements. Nevertheless, separate estimations of soil evaporation and canopy transpiration are even more challenging and interesting, since only the transpiration is related to plant water status. Some energy balance models, such as the Two-Source Energy Balance (TSEB) allow to partition both components by setting a resistances scheme, which includes soil and canopy temperature separately. This study aims to estimate the transpiration of grapevines under different water status through the TSEB validating the model performance against sap-flow measurements. Besides, this study will address the aerodynamic factors that affect wind speed attenuation to evaluate the effects of wind modeling on canopy transpiration in heterogeneous crops. The TSEB inputs, such as the biophysical parameters of the vines, and the radiometric temperature will be obtained from very high-resolution imagery. Nine vines under two different irrigation treatments will be continuously monitored with sap-flow sensors and infrared radiometers during the 2020 growing season. Also, two apogee sonic anemometers were placed above and below the canopy for accounting for the wind speed attenuation. Very high-resolution UAV images will be collected throughout the growing season with thermal, multispectral, and RGB cameras. Concomitant to image acquisition, we will measure stem water potential, leaf transpiration, stomatal conductance, and photosynthesis using a pressure chamber and a portable IRGA. We expect that the result of this study will show the accuracy of TSEB to estimate actual transpiration and hence identify water stress in vines and additionally to identify heterogeneities in the crop that can lead to biased evapotranspiration estimations.

Keywords: Two-Source Energy Balance, Sap-flow, Evapotranspiration, remote sensing, plant stress

0258

THE AGRONOME: ATTEMPTING TO UNDERSTAND GENETIC X ENVIRONMENT X MANAGEMENT EFFECTS ON CROP PERFORMANCE

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Variation in yield and other metrics of crop performance is large, within fields, between fields and between farms. The Yield Enhancement Network (YEN) was initiated in 2012 to identify arable innovators who do things differently and consistently out-perform others. Operating as a competition and as a benchmarking platform, detailed crop, soil, agronomy and weather data is collected and integrated from around 200 farms per year, giving a dataset of over 1000 cereal entries

covering 7 years, mostly from UK but including crops from across Northern Europe. Yields range from below 6 t/ha to above 16 t/ha, with an average of 10.7 t/ha.

Analysis of this dataset using REML reveals that 24% of the variance is attributable to farm where 19% is due to season. Whilst there are significant associations with soil parameters (soil available water content), weather variables (dry winters, cool summers), rotational position and agronomic inputs (N & P fertiliser use, PGRs & fungicide applications), these explain relatively little of the variation. We find no significant association of variety with yield. We conclude that the 'Farm Factor' is most important in explaining yields but this does not relate simply to easily measurable soil characteristics or rates of inputs applied; it is much more about 'attention to detail' and putting together a whole farm system that works for the given soil-climate environment. It is our contention that a better understanding of what is driving yields at farm level is our fastest route to increasing productivity, through identifying, developing and sharing improved 'best practice'.

We propose that field-scale variation in the outcomes of farming can be considered through the concept of the 'agronome'. Fundamentally all variation must be due to differences in soils, weather, genetics, pests and multiple facets of management; Genetics x Environment x Management, including their multiple interactions and acknowledging the importance of Social factors on the behaviour and decisions of the farmer. The digitisation of agriculture and the power of connected big-data now offers the prospect of conducting analyses at scale to evaluate 'what works'. This is however contingent on integrating multiple datasets that are currently disconnected. Most importantly, farm data is required for crop management, yield & quality records. We believe that scaling networks like the YEN can provide the trust and the incentives for farmers to engage and share such data, with them instantly receiving benchmarking on how they compare to their peers across the full range of metrics.

[Wanted to include below but no space:

We calculate that arable farmers in the UK face an apparent quadrillion, quadrillion (~10^30) decision combinations when species, varieties, cultivation methods, dates, rates and products used in sowing and application of fertilisers, herbicides, fungicides and insecticides are considered across the range possible soil and weather conditions at key timings. Whilst most of the interactions here will not be important, many must be.]

Keywords: Yield; data analysis; metrics; big data.

0002

AN AFFORDABLE SYSTEM FOR HIGH-THROUGHPUT PLANT PHENOTYPING FOR MAIZE

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The Earth will have sufficient resources to feed the people on the planet if we use technology, develop an infrastructure to provide knowledge, and propose new intelligent solutions to manage these resources. Plant breeders all over the world are striving to develop cultivars that best suited to the changing environmental conditions. The development of plant phenotyping technologies can facilitate and accelerate the search for new cultivars. This study was conducted at the research facilities and maize breeding stations that the company Corteva Agrisciences has in Seville (Spain), partly dedicated to developing more drought-resistant maize cultivars. Three irrigation treatments (a flowering water stress treatment, a grain-filling water stress treatment, and a well-irrigated treatment) and twelve maize cultivars were used in this study. We made a first attempt to design and built a high-throughput plant phenotyping platform (HTPP) for maize. To demonstrate the potential of this system for plant breeding, different sensors, including 2D LiDAR and an odometry system, were used to take measurements of maize plots from overhead. These measurements were subsequently used to build an accurate 3D model of the maize plots for the purpose of calculating the canopy height. In addition, NDVI and PRI spectral indexes were obtained using both low-cost spectral reflectance sensors (SRSs) and a UniSpec-DC spectroradiometer. Furthermore, two prototypic artificial reference surfaces were mounted on the HTPP in order to calculate the Crop Water Stress Index (CWSI) on the go. Knowledge of the physical traits of new genotypes could provide us with a vast amount of valuable plant-growth-related information, such as photosynthetic carbon uptake and evapotranspiration related variables. These parameters, often determinants of the final crop production, will provide valuable information for decision making of breeders.

Keywords: Maize breeding, remote sensing, precision phenotyping, crop water stress index (CWSI), LiDAR

0215

EVALUATION OF SPECTRAL VEGETATION INDEX OBTAINED THROUGH SATELLITE AND UAVS IMAGES FOR VINEYARD MANAGEMENT

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Remote sensing based of multispectral images is currently a important tool in precisión viticulture, which helps vinegrowers with the handling and management of the vineyard. Vegetation index provide relevant information throughout the campaign, allowing differentiated management and zoning in the vineyard that facilitates vegetation management activities throughout the campaign.

The objective of this work is the comparison of different vegetation index from Sentinel 2 satellite images and images obtained from flights with an unmanned aerial vehicle (UAV). For this, two flights have been made at critical moments of the 2019 campaign (flowering and veraison), in a 9 hectare vineyard located in the D.O Rías Baixas (Galicia), planted in its entirety with 'Albariño' variety and intended for the production of sparkling wines, in which the management of the vegetation has an important role. Subsequently, vegetation index calculated from Sentinel 2 images were compared with spectral index calculated from images of UAV flights to assess the spatial variability of vegetation development throughout the vineyard.

With the evaluation of the maps generated from vegetation index of satellite images and UAVs, it can be seen how the images from Sentinel 2 allow the calculation of a big variety of spectral index periodically and free of charge, being able to analyze different related aspects with the state of the vegetation of the vineyard throughout the campaign. On the other hand, images from UAV flights give rise to high-resolution images with a smaller pixel size, which allow detailed zoning of the state of vegetation that behaves differently in subplots along the vineyard. Although, with the use of both platforms, the differential behaviors can be observed within the total vineyard.

Keywords: Remote sensing, Tree orchard management, Monitoring Tools.

226

NEURAL-NETWORK-BASED CLASSIFIER FOR WEED IDENTIFICATION IN MAIZE FIELDS

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The increasing public concern about food security and the stricter rules applied word wide concerning herbicide residues in the agri-food chain, reduce consumer acceptance of chemical plant protection. Site Specific Weed Management can be achieved by applying a treatment only on the weed patches. Crop plant and weeds identification is a necessary component for various aspects of precision farming in order to perform on the spot herbicide spraying or robotic weeding and precision mechanical weed control. The combination of computer vision systems with Decision Support Systems can create implements able to apply weeding treatments selectively. During the last years, a lot of different methods have been proposed, yet more improvements need to be made on this problem, concerning speed, robustness, and accuracy of the algorithms and the recognition systems. Digital cameras and Artificial Neural Networks have been rapidly developed the past few years, providing new methods and tools also in agriculture and weed management. In the current work images gathered by an RGB camera of Zea mays, Alopecurus myosuroides, Amaranthus retroflexum, Avena fatua, Chenopodium album, Echinochloa crus-galli, Lamium purpureum, Matricaria spp, Setaria spp, Sinapis arvensis, Solanum nigrum, Stellaria media were provided to train Convolutional Neural Networks (CNNs). 3 different CNNs, namely VGG16, ResNet50 and InceptionV3 were adapted and trained on a pool of 81K images. The training images consisted of images with plant material with only one species per image, yet the recognition capabilities of the trained networks were tested also in typical images deriving from a cultivated farm. A Top-1 accuracy between 77% and 98 % was obtained in plant detection and weed species discrimination, on the testing of the images. The classification algorithm was connected through an ISOBUS protocol to perform a site-specific treatment using a commercial sprayer.

Keywords: Artificial Intelligence, ISOBUS, DACWEED, Precision Agriculture, Maize

0269

PREDICTION OF THE BIOCHEMICAL METHANE POTENTIAL OF TRITICALE USING NEAR-INFRARED SPECTROSCOPY FOR DIGITAL AGRICULTURE PURPOSE

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Cereals are largely cultivated for food, feed and energy purposes. Among them, triticale (X Triticosecale Wittmack) shows several advantages: high biomass potential and grain yields due to high tolerance to biotic and abiotic stresses. Our objective was to obtain a rapid tool to measure the biochemical methane potential (BMP) of the cultivated triticale for digital agriculture purpose. The experiment was performed near Modena, Italy (Castelfranco Emilia, 44°34'40.9"N 11°02'11.7"E, altitude 40 m asl), in 2018. The annual mean temperature was 14.4 °C, and total rainfall 780 mm. The field trial was carried out on a silty clay loam soil. A split-plot experimental design with four replicates was used: 10 cultivars (as whole-plot treatment) and two harvest times (milk and dough grain stages, as subplot treatment). All cultivars were sown at 190 kg ha-1 and fertilized with 100 kg of N ha-1. At each harvest and for each cultivar, the yield potential and nutritional composition were estimated. Nutritional parameters were estimated using the instrument Foss NIRS system 5000. In addition, the BMP test (according to the UNI EN ISO 11734: 200) was used as an index of the anaerobic biodegradation. The recorded data were analyzed (analysis of variance, split-plot ANOVA) using SPSS 21.0, SPSS Inc. Means were statistically separated on the basis of the LSD test, when the 'F' test of ANOVA for treatment was significant at least at the 0.05 probability level. Backward-stepwise regression analysis was used to generate empirical models capable of predicting BMP based on NIRS analysis. Triticale yield dry weight harvested at the milk grain stage ranged from 7.21 to 9.67 t ha-1, and BMP from 281 to 329 Nm3 CH4 t of volatile solids (VS); at the dough stage yield ranged from 7.97 to 11.79 t ha-1, and BMP from 282 to 325 Nm3 CH4 t VS-1. Backward-stepwise regression analysis showed a good prediction model (r2 0.614 and p > 0.05) the regression model retained the following 4 NIRS parameters (Y = 1121.569 -6.178 * (a) -0.896 * (b) +28.922 * (c) -2.854 * (d); a = ashes (% of dry matter (DM)), b = total solids (g kg-1), c = fats (% DM) and d = sugars (% DM)). The backward-stepwise regression proposed in this study can represent a rapid and economic tool for predicting the BMP of the whole triticale plant using Near-Infrared Spectroscopy and might be implemented on harvester machine per digital agriculture practices.

Keywords: Biochemical methane potential, Triticale, Near-Infrared Spectroscopy, Digital agriculture

0287

3D CROP MODELING FOR DETERMINATION OF WHEAT RUST SEVERITY AND ITS IMPACT ON CROP YIELD

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Wheat rusts consisted in three species (yellow, leaf and stem rust) that are a global major threat to wheat production. Significant losses in yield and grain quality are caused by the indirect impact of rust on grain traits and wheat biomass, determining the productivity of wheat crop. The diagnosis and detection of rust has traditionally been carried out through visual recognition of symptoms and subjective classification of the degree of severity. By reconstructing a 3D model of wheat plants with photogrammetric techniques such as Structure-From-Motion (SfM), it is possible to measure crop characteristics (plant height, plant cover, plant biomass, number of spikes among others) in a non-destructive and accurate way. Thus, the objective of this work was to develop a methodology based on advanced 3D modeling to capture the traits of rust-infected wheat plants. In this context, a trial with three cultivars and six replicates per cultivar for both durum and soft wheat was carried out. Each cultivar was inoculated 78 days after sowing with leaf rust race 'Conil Don Jaime 13' and yellow rust race 'Ecija Jerezano 18' for durum and bread wheat, respectively, were the races assessed. High resolution RGB images of two randomly selected replicates per cultivar were taken to generate the 3D model. A total of 100 images for each one of them were obtained in three different time periods (one before and two after rust inoculation). The 3D reconstruction from the high-resolution point clouds obtained was used to estimate plant biomass, count the number of spikes and grains and evaluate the level of affection caused by rust disease. At the end of the growth cycle all replicates were manually harvested and some crop traits were determined, such as plant biomass, number of spikes and grains and total yield. Actual and estimated measurements in the three periods were compared. Preliminary results showed satisfactory correlations between all the studied traits. Ongoing research on high-throughput field phenotyping will benefit from the precise results shown by the photogrammetry technique employed in this work.

Keywords: wheat, rust, photogrammetry, high-throughput phenotyping, 3D model.

Session 2. Farming systems and ecosystem services

Session 2.1: Farming system design for conventional and organic production

0164 KEYNOTE

SUSTAINABILITY AND RESILIENCE OF FARMING SYSTEMS

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Agricultural systems face accumulating economic, ecological, societal and institutional challenges, raising concerns about their sustainability and resilience to shocks and stresses. Farms operate in a regional context, in interaction with other farms, farmers' organizations, service suppliers and supply chain actors, and therefore sustainability and resilience issues need to be addressed at farming systems level. Integrated assessment is required to address multiple challenges and impacts (Reidsma et al., 2015). In the SURE-Farm project, a framework to assess the resilience of farming systems was developed (Meuwissen et al., 2019) and operationalized (Reidsma et al., 2019)

Sustainability can be defined as an adequate performance of all system functions across the environmental, economic and social domain. Resilience of a farming system was defined as its ability to ensure the provision of the system functions in the face of increasingly complex and accumulating economic, social, environmental and institutional shocks and stresses, through capacities of robustness, adaptability and transformability. Both concepts are not different, but complementary. Farming system functions include: 1) deliver healthy and affordable food products, 2) deliver other bio-based resources for the processing sector, 3) ensure a reasonable livelihood for people involved in farming, 4) improve quality of life in farming areas by providing employment and decent working conditions, 5) maintain natural resources in good condition, 6) protect biodiversity of habitats, genes and species, 7) ensure that rural areas are attractive places for residence and tourism with a balanced social structure, and 8) ensure animal health and welfare.

The resilience framework followed five steps: 1) characterizing the farming system (resilience of what?), 2) identifying key challenges (resilience to what?), 3) iden-

tifying desired functions (resilience for what purpose?), 4) assessing resilience capacities, 5) assessing resilience attributes (what enhances resilience?). The framework was designed to assess resilience to specific challenges (specified resilience) as well as a farming system's capacity to deal with the unknown, uncertainty and surprise (general resilience). The framework was operationalized in 11 case studies across the EU.

The methodology deployed a mixed-methods approach: qualitative methods, such as interviews and stakeholder workshops, access experiential and contextual knowledge; quantitative methods, such as statistics and modelling, were used to make estimations based on data, and identify underlying patterns and causal explanations. In my talk, I will summarize results from methods in both categories, and conclude with observed mismatches and recommendations for farming systems design.

According to stakeholders that participated in workshops, main functions of farming systems were related to food production, economic viability and maintenance of natural resources (Paas et al., 2019). Performance of these and five other functions was perceived to be moderate. Past strategies were often geared towards making the system more profitable, and to a lesser extent towards coupling production with local and natural resources, social self-organization, enhancing functional diversity, and facilitating infrastructure for innovation (all considered to be resilience-enhancing attributes). Overall the resilience of the studied farming systems was perceived as low to moderate, with robustness and adaptability often dominant over transformability. To allow for transformability, being reasonably profitable and having access to infrastructure for innovation were viewed as essential.

Next to a participatory approach, a quantitative method was used to investigate the ability of the 11 case study farming systems to provide private and public goods (Reidsma et al., 2019). This assessment focused on ecosystem services, which can be considered as public and private goods provided by the biophysical system. The main ecosystem services provided by the administrative regions containing the case study farming systems were assessed, and whether the farming systems were increasing or decreasing multifunctionality to their region.

The 11 EU farming systems belonged to one of two groups: (i) farming systems bringing multifunctionality to the surrounding regions, or (ii) farming systems removing public goods to the region to focus on the delivery of private goods. In group (i), arable farming in the East of England improved the multifunctionality of the region via application of practices for improving carbon storage, erosion control and recreation potential; hazelnut farming in central Italy brought functions intrinsically connected to the presence of permanent crops (e.g., habitat quality, recreation potential); and extensive livestock farming in French and Spanish case studies brought functions complementary to the rest of the region. In group (ii), large-scale arable farming in Bulgaria was formed by monocultures poor in habitat quality and organic matter in soil; mixed farming in north-east Romania decreased almost all the public goods of the region (especially carbon storage, NOx deposition, and habitat quality); arable farming in the north-east of the Netherlands and horticulture in Poland removed public goods to regions already poorly multifunctional; large-scale corporate farming in East Germany lowered the level of multifunctionality in a region moderately multifunctional; and high-value egg and broiler systems in southern Sweden was clearly disconnected from the surrounding region which was mostly occupied by forests.

Integrating results from all methods, it was concluded that three mismatches likely contribute to the struggle of farming (Meuwissen et al., 2020). First, while the delivery of public goods such as biodiversity and attractive landscapes was seen as major concern, most future strategies focused on the delivery of private goods. Second, while farming systems comprised many non-farm actors, future strategies largely focused on farms and their robustness, neglecting other options and opportunities. Third, while the majority of farming systems was at the start of a period in which transformation is required, their capacity to transform was relatively low. Furthermore, policy instruments and forms of mutual dependence largely focused on maintaining the status quo. It is therefore recommend that researchers, business and policy more explicitly account for the delivery of public goods, e.g. through new business models, to address the role of actors beyond the farm, and to propose instruments and tools to enhance, not to constrain, system level capacity to adapt and transform. A shift is required from responses to short-term processes to strategies that deal with long-term processes, and, ecological (e.g., coupling to natural capital), technological (e.g., innovation) as well as social (self-organization) solutions are needed.

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Keywords: integrated assessment, sustainability, resilience, farming systems, framework

0023

CONTROLLING HERBICIDE RESISTANT WEEDS REDUCES DIVERSITY IN WESTERN AUSTRALIAN CROP AND PASTURE SYSTEMS

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Western Australia has a Mediterranean type climate, with rainfed crop and pasture production occurring over an area of 14 million hectares. Weeds with resistance to herbicides evolved in Western Australia in the mid 1990's and populations have spread across the entire production area. By monitoring 184 fields spanning 1500 km, over a 6 year period from 2010 to 2015 our study investigated relationships between changes in farming practices and weed populations. Records of land use, integrated weed management actions and herbicide inputs were compared to observations of weed populations across three distinct agroecological zones. Key findings were that weed density was low, with fewer than 10 grass weeds/m2 at anthesis, and the diversity of weed species observed had declined from earlier surveys. This was despite the most common grass weed species (annual ryegrass, Lolium rigidum) being confirmed as resistance to at least one herbicide in 92% of monitored fields.

Land use was dominated by cereal production with 68% of field.years sown to either wheat or barley. This differed across agroecological zones with cropping more frequent in the Northern Region, at 90% of field. years, compared to 78% in the Southern Region. Land use selection was based around the weed challenge: land uses in which weeds were controlled more effectively were selected when weed numbers were higher and in regions where herbicide resistant weeds were more frequent. In the Northern Region, where herbicide resistance was most frequent, long sequences of cropping were accompanied with integrated weed management to minimise the weed seed bank. An undesirable consequence of this was that the pasture seed bank was poor and self-regenerating pastures in the Northern Region were sparse with an unproductive botanical composition, containing very few legumes in comparison to other regions.

Industry statistics show the WA sheep flock declined from 26 million head to 14 million head over the period 2005 to 2019 and lupin production declined from a high of 1.1 million hectares to 350,000 hectares. These legumes have been replaced with canola (including glyphosate tolerant cultivars), increasing from 0.4 to 1.3 million hectares 2005 to 2019, and more frequent cereal production.

This supports our findings, that changes in land use in response to herbicide resistant weeds have reduced diversity within these agroecological systems. While herbicide resistant weeds are effectively controlled there are concerns about the long-term sustainability of this strategy, particularly in regard to crop nutrition and pathogens.

Keywords: Land use, rotation, herbicide resistant weeds.

0045

WHY DO FARMERS ASSOCIATE CROPS? LOGICS AND STRUCTURE OF OLIVE GROVE-VEGETABLE ASSOCIATIONS IN A MEDITERRANEAN REGION

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Agroforestry systems are diverse in the Mediterranean region. Despite the numerous economic and environmental benefits they provide, there is a gap in scientific literature concerning irrigated olive grove agroforestry with vegetable crops in the Mediterranean region. This study questions why and how farmers design these associations within their farming system. The objectives were to describe farmers' logics behind olive-vegetable associations, characterize the physical structure of the agroforestry grove and analyze their linkages. Qualitative and quantitative data from 132 olive groves and 31 semi-directive interviews from the Merguellil plain in Central Tunisia were collected. A typology of four types of logics was established, using differentiating factors comprising awareness of agroforestry benefits or disadvantages, knowledge on processes, skills, economic orientation, quality and security of land, local income opportunities, social networks, land, water, capital assets and farmer's age. Logics were diverse, ranging from strategies of intensive cultivation to reduced input consumption. Limited and fragmented access to production factors induced contractual arrangements between farmers with different land, water and workforce assets to realize associations. The structure of the olive grove was equally diverse, differing in number of species, tree canopy cover and age, crop densities and field size. Farmer's strategies were partially visible in the structural characteristics of the groves. This study highlights the multiple farmers' logics behind the practice of agroforestry, and on the importance of taking into account farmer's rationalities when analyzing farming system designs.

Keywords: Mediterranean region, agroforestry, market gardening, typology

0052

EFFECTS OF COVER CROPS AND SOIL TILLAGE ON THE SPONTANEOUS COMMUNITY IN FALLOW PRECEEDING BANANA CROP

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Cover crop are frequently used to control the spontaneous species (Lu et al. 2000; Snapp et al. 2005). Soil tillage is another mean to control the spontaneous species by destroying seedlings and decreasing the seedbank (false seedbed technique) (Cordeau et al. 2017; Kanatas et al. 2020), while improving cover crop rate of germination. However, the effects of the combination of these practices on the spontaneous community are poorly documented. Our aim was to understand how different modalities of soil tillage and species of cover crops affect the density and richness of the spontaneous community in a fallow of banana cropping system after five months.

The experiment was carried out in Guadeloupe Island, in a banana cropping system during the fallow period preceding banana replantation. Two factors were crossed in a split-plot design composed of five blocks and eight treatments repeated in each block. The main factor was the modality of soil tillage before sowing of the cover crop (M1: coarse tillage, M2: coarse tillage followed by false seedbed technique). The nested factor was the species of cover crop (B: a mixt of Brachiaria decumbens+Brachiaria ruziziensis, C: Crotalaria spectabilis, P: Pueraria phaseoloïdes, T: a reference of spontaneous vegetation). Five months after sowing, in three quadrats per elementary plot, all spontaneous species were identified, the number of individuals of each species was counted and the specific richness calculated. The effects of the treatments on these variables were assessed with nested anovas.

Five months after the sowing of the cover crops, we observed that the eight treatments provided communities with different species composition and densities. Densities and specific richness of communities associated with C and T were significantly higher than the ones associated with B and P. This suggests that Brachiaria decumbens+Brachiaria ruziziensis and Pueraria phaseoloïdes are more competitive than Crotalaria spectabilis. In C and T treatments, specific richness and densities were significantly higher in M2 than in M1. This suggests i) that the soil tillage modalities impacts the spontaneous community only when poor competitive cover crops are used, ii) and that the false seedbed technique has promoted the germination of the spontaneous species seeds without efficiently reduce the seedbank, contrary to what had been expected. We concluded that Brachiarias and Pueraria phaseoloïdes were highly efficient to control spontaneous species after five months of growth and that the effects of the modalities of soil tillage depended on the species of cover crop sown.

Keywords: banana cropping system, cover crops, spontaneous vegetation, tillage, false seedbed technique.

0092

COMBINING EXPERT KNOWLEDGE AND MODELS IN PARTICIPATORY WORKSHOPS WITH FARMERS TO DESIGN SUSTAINABLE WEED MANAGEMENT STRATEGIES

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In order to design cropping systems reconciling crop production, biodiversity and reduced herbicide use, we organized participatory workshops with farmers in the Champagne region (North-Eastern France). Methods combined cropping-system prototyping by farmers, expert opinion and models. In a first meeting, farmers determined their objectives and constraints, and chose a reference system existing in one of their farms (oilseed rape/winter wheat/winter wheat/spring barley heavily infested by autumnal grass weeds). In a second meeting, two sets of prototypes were designed by two separate groups, using the Mission Ecophyt'eau® tool (https://ecophytopic.fr/pour-aller-plus-loin/outil-mission-ecophyteaur) as support.

The reference and the prototypes were evaluated in terms of (1) technical feasability from farmers' and scientists' expertise, (2) weed harmfulness for crop production and weed contribution to biodiversity with FlorSys which simulates crop and weed growth and reproduction in cropping systems at a daily time step over several years (Colbach et al., Weed Res 2014), and (3) economic, social and environmental sustainability with the DEXiPM (Pelzer et al, Ecol Indicators 2012) model. Steps 2 and 3 were carried out after the meeting. At a third meeting, these results were presented to the farmers who continued improving the prototypes, using the DeciFlorSys model which includes decision trees to guide farmers during cropping-system design and a fast calculator estimating weed harmfulness and biodiversity of cropping system prototyes (Colas et al., Eur J Agron 2020). Both prototypes presented increased crop diversification, introducing legumes and other broad-leaved crops, crop mixtures and cover crops. Prototype A was based on reduced tillage and annual crops only. Prototype B also included multi-annual lucerne and optimised both tillage and mechanical weeding. Both prototypes reduced weed harmfulness for crop production (yield loss, harvest contamination, field infestation) and herbicide use intensity (approx. -60%) compared to the reference system. Prototype B also improved weed-based trophic resources for carabids and pollinators. The best solution was a suboption of prototype B replacing most of the herbicides by mechanical weeding, dividing yield loss by nearly two compared to the reference and improving biodiversity by 5-10%. The workshop participants appreciated the knowledge on agroecosystem functioning and the complementarity of models: DeciFlorSys allowed a direct evaluation during workshops, FlorSys produced a detailed diagnosis of the technical and meteorological causes of the cropping systems' performance and DEXiPM assessed working times and economic viability of the prototypes. Following the workshops, some participants invested in new implements for mechanical weeding and introduced more spring crops into their rotations.

Keywords: design, participatory approach, model, prototyping, cropping system

0165

PLANT COMPOSTS REDUCE SOIL VERTICILLIUM DAHLIAE LOAD AND SUPPRESS WEEDS

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Compost amendments are usually a top priority for regenerative farmers. However, composts and their effects can be very different depending on the source of the feedstock used and preparation methods. This paper reports on several research experiments done to evaluate the effects of four different composts on

soil load of Verticillium dahliae and weed pressure. The four composts used in the different experiments were prepared using the following materials: dairy and horse manure mix (manure compost), olive pomace/dairy manure mix (olive compost), grape pomace (grape compost), and mixed crop residue compost (crop residue compost). In the first study, the four composts and an untreated control were applied on 12 June 2018 at 25 t ha-1 to two neighboring fields; certified organic (biological) or conventionally managed. Abundance of the fungal pathogen V. dahliae was assessed from composite soil samples collected at several time points throughout the growing season. Pre-application levels of V. dahliae were not statistically different between field or among treatments. For each of the treatments, there was no difference between the organic and conventional fields so data from both were pooled together. Compared to the control, all composts significantly reduced the pathogen load on 30 June, less than two weeks after the application. The reduction was more pronounced with the plant-based composts, which decreased the pathogen load by 40% (olive compost) to 46% compared to the untreated control. The three plant-based composts still had values lower by 28% (grape compost) to 41% (olive compost) than the control treatment on 11 August, eight weeks after the application of treatments.

To confirm these results, aqueous compost extracts were prepared and tested on V. dahliae in Petri dish lab experiments. Plant composts reduced V. dahliae growth by 40-60%, especially during the first week after application, while the manure compost extract was not statistically different from the untreated control.

In a pot experiment, two rates of the aforementioned composts were mixed into a clay-loam soil at 0.10 or 0.20 L L–1, to assess their effects on weed pressure. Composts reduced weed dry matter (composed mostly of purslane (Portulaca oleracea L.)), with the crop residue compost being the most effective, reducing total weed biomass by 67% compared to the untreated control.

Keywords: Composts, compost extracts, soil amendments, pathogen suppression, soil-borne diseases

0166

PARTICIPATORY ASSESSMENT OF FUTURE SUSTAINABILITY AND RESILIENCE OF EUROPEAN FARMING SYSTEMS

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Sustainable and resilient farming systems in European are important for food production, economic prosperity, maintenance of natural resources and the quality of life as well as the attractiveness of rural areas. However, current sustainability and resilience levels of European farming systems require improvements.

In participatory workshops across nine EU farming systems we elicited information from stakeholders from the farmer community, government, NGOs, and the processing industry to discuss farming system performance and resilience in possible futures. The case studies included arable, livestock, mixed and perennial farming systems. Stakeholders reflected in plenary and small group sessions on: 1) the requirements for maintaining the status quo, 2) critical thresholds and the consequences if these would be exceeded (system decline), 3) possible alternative systems with improved sustainability and resilience, and 4) strategies to realize those alternative systems. Alternative systems were then compared with five scenarios for European agriculture (Eur-Agri-SSPs).

Most studied systems seem close to at least one critical threshold for system challenges and for functions related to food production and economic viability. Exceeding the thresholds was expected to result in moderate negative developments for system functioning, compared to the status quo. An overall analysis of thresholds mentioned suggests that low economic performance can hasten the decline of farming systems, especially through farmers exiting the farming system, lack of successors and low availability of labor.

Proposed alternative systems are mainly adaptations of the status quo, which could indicate path-dependent thinking of participating stakeholders. Alternative systems were expected to primarily improve economic performance, either in combination with increased food production, or in combination with improving biodiversity and quality of life. Also presence of resilience attributes is expected to improve, specifically in the social domain. To realize alternative systems in the future, boundary conditions and strategies are generally expected to shift from farm level in the agronomic and economic domain to farming system level in the social and institutional domain, e.g. more focus on collaboration and an enabling policy environment. This shift may be explained by the erosion of social functions observed in many of the studied farming systems, leading to a situation in which those functions only can be rehabilitated by improved collaboration between actors in and outside the farming system.

Alternative systems seem strongly incompatible with one Eur-Agri-SSP and at most moderately compatible with four other Eur-Agri-SSP scenarios. A re-design of European farming systems might hence have to encompass more than participating stakeholders have suggested.

Keywords: farming systems, adaptability, transformability, social functions

0173

CONCEPTION AND TEST OF AN INTERDISCIPLINARY SERIOUS GAME TO LEARN AGROECOLOGY

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European agriculture is facing many challenges and agroecology is considered as a pertinent option to reconcile the various pillars of agricultural sustainability. To promote its application, agroecological concepts should be taught to students and professionals in the agricultural sector. However, most agricultural courses are not adapted to teach agroecology due to little interdisciplinarity and a lack of a systems approach to farm management. Serious games help to fill these gaps by simulating complex models in which players can learn by doing. The aim of this project was to develop a serious computer game, called SEGAE (SErious Game for AgroEcology learning), and to assess its pedagogical interest.

SEGAE represents a mixed crop-livestock farm oriented in dairy production. It includes a variety of agroecological practices and give players the ability to assess impacts of these practices on the three pillars of sustainability: environmental, economic, and social. To do it, SEGAE is based on an innovative model created for the game that has three components: a matrix, a calculation engine, and a graphical interface that represents the farm. The matrix (not available for players) represents impacts of 124 practices on 591 indicators. Practices are related to management of crop and livestock, management of landscapes and biodiversity and strategic decisions. The indicators reflect technical, economic, environmental, and social aspects of the farm. The impacts of practices are represented by factors in the matrix. These factors were determined from a literature review that included meta-analysis, targeted and case-study analysis, and expert assessment. Each practice influences one or more indicators which helps players understand the many relations among the three pillars of sustainability.

The pedagogical interest of SEGAE was evaluated during a one-week workshop where two types of surveys were given to university students who played the game: a knowledge survey on agroecology and a feedback survey based on flow theory. Results showed that students increased their knowledge of agroecology significantly, particularly those who had little knowledge of crop production. More than 86% of the students enjoyed the game, appreciating its interaction and feedback. Overall, it can be concluded that SEGAE is a relevant tool for learning agroecology in a fun way. Since this serious game is available online at no cost, it can be used in addition to other trainings on agroecology, whether digital or not, and thus contribute greatly to the agroecological transition of European agriculture.

Keywords: Farming systems, Sustainability, Environmental impact, Modeling

0189

ENVIRONMENTAL ASSESSMENT OF ORGANIC AND CONVENTIONAL ANCIENT WHEAT CULTIVATION: ACIDIFICATION AND EUTROPHICATION PERFORMANCES THROUGH A LCA APPROACH

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The adoption of synthetic chemicals and other environmental contaminants in agriculture are resulting in detrimental consequences on environment such as soil acidification and eutrophication of waters. This study aims to assess the impacts of the production chain of an ancient wheat variety (var. Verna) in Tuscany, Italy, in terms of acidification and eutrophication. LCA was performed applying the SimaPro V8.5 software on Ecoinvent v.3.4 database. Functional Unit (FU) was defined as 1 kg of wheat grain. The system boundaries included all the wheat cultivation activities, from seeds production to the harvest of the product (wheat grains) and the transport to the storage center. Data on wheat cultivation were obtained from five organic and five conventional farms homogenously distributed in Tuscany region for four growing cycles (2014/2015 to 2018/2019). Results about acidification and eutrophication were expressed as kg SO2eq FU-1 and kg PO43-eq FU-1, respectively. Acidification impacts were 3.12*10-3 and 3.93*10-3 kg SO2eq FU-1 for organic and conventional farming, respectively. The main sources from organic farming were tillage operations (80%), copper production for seed tanning and seeds (14%). Main impacts of conventional farming derived from tillage operations (39%), fertilizers production (31%) and use (23%), pesticides and seeds production (7%). Eutrophication impacts were 1.63*10-3 and 5.42*10-3 kg PO43-eq FU-1 for organic and conventional farming, respectively. Tillage operations (35%), fertilizers use (49%), copper production for seed tanning and seeds production (14%) were the main sources of impact from organic farming. Differently, fertilizers use was the main source of impact from conventional farming (79%), while fertilizers production, tillage operations and pesticides production accounted to 8%, 6% and 6%, respectively. Based on the reference scales at EU25 level, results were standardized for the evaluation of the magnitude of the two categories. Normalized results show that in the organic farming system similar impacts occurred between acidification and eutrophication. In the conventional farming system, eutrophication impacts were 271% higher than acidification.

Further, conventional farming was also the main driver of eutrophication, due to N and P fertilizers use. Based on the results, the improvement of nutrient use efficiency and a reduction of losses due to excessive soil tillage may represent an effective mitigation strategy.

Keywords: Sustainable agriculture, Nitrogen, Phosphorus, Resources consumption, Tillage

0248

REDESIGNING A LONG-TERM ORGANIC FARMING EXPERIMENT TO ADDRESS CONTEMPORARY ISSUES

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A long-term experiment designed to understand the impact of crop rotation design on crop productivity and environmental impact was established in Aberdeen, Scotland in 1991. The original experiment compared 2 ley/arable systems with different proportions of grass/clover ley in a 6-course rotation. Leys in both rotations were grazed by sheep. In a participatory approach with farmers, advisors and policy makers the experiment was redesigned in 2007. One of the original rotations (3 years grass/clover ley and 3 years arable) has been maintained throughout the entire period and has now completed 5 full rotations. The 2nd rotation was changed in 2007 to a stockless system without any additions of external inputs. This redesign supported the principles of the Scottish Organic Action Plan and the demand for organically produced arable crops. In the current climate the experiment allows a comparison between a livestock-based system and an essentially “vegan” organic system which does not rely on any animal-based inputs. This paper will compare the impacts of changes in the experimental design on crop yield and productivity as well as soil organic matter and extractable nutrients. It also addresses the challenges of modifying long-term experiments.

Keywords: ley/arable; grain legumes; white clover; rotations

0275

LONG TERM YIELD TRENDS IN FOUR PARALLEL ORGANICALLY MANAGED CROP ROTATIONS

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A long-term experiment (LTE) based on a 6-year rotation was established in Aberdeen, Scotland in 1991 and has been managed to organic certification standards since then. This experiment originally compared two ley-arable rotations with contrasting lengths of ley (one being 4 years grass-white clover and 2 years cropping; the other a 3-year grass-white clover ley and 3 years cropping - the 50% ley rotation). In both cases, grass-clover plots were either cut for silage, or grazed with sheep. Farm yard manure (FYM) return to key points in the rotation were based on estimated manure production by the livestock that were supported by the crops and grass-clover grown each year. After the end of the 2006 season, data indicated that there had been little divergence between the two rotations in terms of productivity, or soil parameters such as P and K availability or soil organic matter (SOM). A decision was made to retain the 50% ley rotation, but split the plots so that instead of just spring oats being grown after the grassland phase, which had been the case up until that point, one half of the plot continued to grow oats at this point in the rotation, while the other half of the plot was used to grow spring barley, thus ensuring there were two subtly different stocked rotations running in parallel from 2007 onwards. The rotation that had consisted of 4 years grass-clover and 2 years cropping (ley spring oats and undersown spring oats) was converted to a stockless system in 2007. This consisted of a cut and mulch grass-red clover fertility building phase followed by 5 years of cropping, which included undersown spring cereals and field beans as well as potatoes. In order to push the stockless system, no external manure or composts were applied, and no livestock grazing took place. Straw was chopped and incorporated on cereal and bean plots. Again, as with the 50% rotation, plots were split so that two parallel rotations could take place, one with undersown spring wheat followed by potatoes after the cut and mulch phase, the other with potatoes followed by undersown wheat at the same point in the rotation. In both cases, these were followed by undersown spring beans, undersown spring barley and undersown spring oats. This paper will highlight some of the long term crop trends from each rotation and indicate some of the underlying reasons driving the results.

Keywords: organic, rotation, stocked, stockless, yield

Session 2.2: Crop diversification

0009

EFFECT OF PLANTING PATTERNS ON YIELD, NUTRIENT ACCUMULATION, AND DISTRIBUTION IN MAIZE AND SOYBEAN RELAY INTERCROPPING SYSTEMS

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Planting patterns affect nitrogen (N), phosphorus (P), and potassium (K) acquisition and distribution among different plant organs in intercrop-species under intercropping conditions. This experiment aimed to elucidate the N, P, and K accumulation and distribution at organ level of intercrop-species under different planting patterns, and thus to fully clarify the needs and balance of major nutrients of intercrop-species in response to changing planting conditions. The effects of different planting patterns (SI, 50:50 cm and SII, 40:160 cm) on dry matter, N, P, and K concentration in organ (root, straw, and seed) level, seed yield, competition ratios (CR) and land equivalent ratio (LER) of maize and soybean were investigated through field experiments for two-years under maize-soybean relay-intercropping system (MSR), all the treatments were compared with sole cropping of maize (SM) and soybean (SS). The results showed that, as compared to SI (single row relay-intercropping), the strip relay-intercropping (SII) increased the accumulation of N, P, and K in each organ of soybean by 20, 32, and 18 (root) %, 71, 61, and 76 (straw) %, and 68, 65, and 62 (seed) %, respectively, and decreased the N, P, and K in each organ of maize by 1, 4, and 8 (root) %, 1, 10, and 3 (straw) %, and 5, 10, and 8 (seed) %, respectively. Moreover, the increased nutrient uptake in SII considerably enhanced the mean dry matter accumulation (DMA) and allocation to root, straw, and seed of soybean by 61, and 29, 64, and 62%, respectively, and decreased the mean DMA and distribution to root, straw, and seed of maize by 4, and 5, 3, and 5%, respectively than SI. Compared to SI, SII also increased the CR values of soybean (by 81%) but decreased the CR values of maize (by 80%), which in turn significantly increased the soybean DMA and seed yield by maintaining the maize DMA and yield. Overall, under SII, relay-cropped soybean produced 83% of the sole cropping yield, and relay-cropped maize produced 95% of the sole cropping yield, and the SII achieved

LER of 1.8. Our findings implied that selection of optimum planting pattern (SII) may increase the N, P, and K uptake and influence the balance nutrients distribution among different organs of maize and soybean under MSR which will significantly increase the intercrops productivity, and should be paid more attention to major nutrients when considering the sustainability of MSR via appropriate planting pattern selection.

Keywords: Intercropping, nutrient uptake, maize, soybean, land equivalent ratio

0022

LEGUMES IN BIODIVERSITY-BASED FARMING SYSTEMS IN MEDITERRANEAN BASIN

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In this talk, we will present LEGU-MED, a three-year project that has been selected for funding by PRIMA foundation 2019 and it is going to start in June 2020. The aim of the project is to characterize, use and manage legumes for a biodiversity-based agriculture will enhance sustainability of farming systems the Mediterranean basin. This purpose with be obtained through: 1) the development of traditional and innovative farming systems based on diversification, multi-crop rotations, biological regulation of productions, enhancement of plant-microbe symbiosis and soil fertility conservation, 2) the agronomic, phenotypic and molecular evaluation of wild relatives, land races, neglected genotypes, elite cultivars coming from the all the countries involved in the proposal. We wish to redesign cropping systems for pulses to support sustainable land use and render farming systems more productive under current and future climate change causing increasing desertification of the Mediterranean, i.e. increasing ecosystem services, maintaining soil fertility, optimizing the use of scarce natural resources, minimizing the use of pesticides and mineral fertilizers, producing sufficient and steady income to farmers. The proposal is structured in three work packages. In the first work package, we will perform an agronomic screening and molecular characterization of more than 100 genotypes for lentil and chickpea (two main legumes in Mediterranean basin) in different geographic areas. The best 10 genotypes for each area will be phenotyped using a high-throughput system. In the second work package, we will deliver develop and test new models, tools and approaches for biodiversity-based agriculture. A field evaluation of the 10 best genotypes with improved rhizobial strains specific for them will be performed. New farming systems including different legumes that enhance ecosystem functions and services will be tested in different Mediterranean regions. As for the third objective, we will involve stakeholders such as grower's associations (ATAE), an international research center (ICARDA) and private companies (Promovert, Agricultura y Ensayo, Sacco SRL) to perform larger field tests and a socio-economic analysis of the proposed approaches, tools and models (e.g. social acceptability, cost/benefit analyses, ecosystem functions and services, short- and long-term consequences on the economic structure and on the health and wealth of the farming communities). Finally, we will perform an intense activity of technology demonstrations, outcome dissemination and exploitation, through the organization of yearly workshops and of a scientific congress.

Keywords: biodiversity, diversification, farming systems, ecosystem services, sustainability.

0037

THE ROLE OF IMPROVED AGRONOMIC PRACTICES IN DE-RISKING AND ENHANCING THE SUSTAINABILITY OF CEREAL-BASED SYSTEMS IN THE DRYLANDS

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The expansion of cereal monocropping has been a growing challenge in the dry areas. This trend is mostly a consequence of policies and incentives for the intensification of wheat and perceived economic disadvantages of legumes. Despite the intensification efforts, wheat yields in the drylands are far below their potential and carry high economic risk for the producers because rainfall uncertainty disincentivizes farmers to invest in chemical inputs. Consequently, efforts for intensification in the drylands of Africa and Asia may succeed to increase long-term average cereal yields but may be unsustainable bearing higher risk to producers unless accompanied with appropriate agronomic practices.

In this paper, we present results of several analyses carried in the West Asian and North African region demonstrating that the individual and combined adoption of improved technologies and agronomic practices help farmers in drylands to achieve crop diversification, higher yields and farm income and manage production risk. For example, using to a two-year data from a large sample of 2643 fields cultivated with different varieties of wheat and faba beans, a Moroccan study published in 2019 found that availability of improved faba-bean varieties increased the adoption of rotation and the joint adoption of rotations and improved faba bean varieties is the best available cropping option leading to 48% higher two-year average income than wheat monocropping. Another study published in 2018 also demonstrated that rotation in Tunisia enhances nutrient uptake and reduces yield gap in the following wheat crop. Adoption of zero tillage (ZT) among Moroccan wheat farmers is also found to lead to 33% higher yields, 40.3% higher wheat income and 65.6% less risk of obtaining below1000 kg/ha yield than those who practice tillage. Two other studies among Syrian wheat farmers obtained not only similar yield and income gains and risk reduction with those from Morocco but also higher technical efficiency with ZT. Retention of 30% or more crop residue on Moroccan wheat fields is found to lead to 17% higher yields, 22% higher income and 27% lower risk of obtaining yield levels below 1000 kg/ha in the subsequent crop. The results of these and other studies reviewed consistently show the importance of improved agronomic practices in enhancing and stabilizing yield and income in drylands. By de-risking the use of chemical inputs in the face of variable weather, improved cropping systems may support national policies towards food security and nutritional diversity in the drylands of Africa.

Keywords: Sustainability; production risk; drylands; agronomy; technology; adoption.

0038

GREENHOUSE GAS EMISSIONS FROM SOIL IN AN ALMOND ORCHARD DIVERSIFIED WITH CAPER AND THYME

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Increasing world population dictates a challenge to increase agricultural population without increasing greenhouse gas (GHG) emissions, since agriculture provides both sources and sinks of GHG. Some of the management controls that interact with GHG are the crop type, tillage or crop diversification. Thus, the aim of this study was to evaluate the influence of the rainfed almond cropping system (monoculture with intense tillage against diversifications with *Capparis spinosa* and *Thymus hyemalis* with reduced tillage*)* on CO_2 and N_2O emissions for one year. This study was carried out in an almond orchard in SE Spain, with semiarid Mediterranean climate. Almond trees were separated 8 m each. Plots had a size of 220 m^2, with 3 replications per cropping system. Secondary crops were planted in the alleys. In the monoculture, 3 tillage episodes per year (30 cm depth) were carried out, while in the diversified plots tillage was reduced to once a year, and only in the 2 m next to the almond tree. GHG emissions were measured using the dynamic chamber method. The chamber was made of stainless steel, with an inlet and outlet to connect to an ultrasensitive cantilever photoacoustic infrared spectroscopy analyzer. The cameras were inserted into the bare soil at a depth of 10 cm. Gas measurements were made once a week between 9:00 and 13:00. Cumulative CO_2 and N_2O emissions for each treatment were estimated by numerical integration. CO_2 emission rates were significantly influenced by the sampling date and the cropping system.

Regarding cropping system, CO_2 emission rate was lower in the almonds intercropped with *C. spinosa* y *T. hyemalis* compared to the almond monoculture. Cumulative CO_2 emission was reduced by 29.8 % (corresponding to 504 g m^{-2}) and 20.7 % (corresponding to 569 g m^{-2}) in diversifications with *C. spinosa* and *T. hyemalis* compared to monoculture, respectively. N_2O emissions were not significantly affected by the sampling date or cropping system. In addition, crop diversification led to a better land use, with a land equivalent ratio of 1.51 for the diversification with *T. hyemalis* (no data on caper yield yet). The lowest CO_2 emissions in the diversified crops were related to a reduction in the frequency of tillage. Thus, crop diversification resulted in a sustainable solution to reduce CO_2 emissions in almond orchards.

Keywords: CO_2 emissions; N_2O emissions; Capparis spinosa; Thymus hyemalis; almond.

0039

EFFECT OF FAVA BEAN AND VETCH/BARLEY CROPS INTERCROPPED WITH MANDARIN TREES ON SOIL GREENHOUSE GAS EMISSIONS

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Human activity through agriculture is causing significant changes to the global climate due to the increasing emissions of greenhouse gases (GHG). Inorganic fertilizers, plant residues and even biological and soil processes are the largest contributors in GHG. However, shifts in agriculture practices are thought to have a mitigating role. In this context, the aim of our work was to assess the influence of agroforestry (mandarin intercropped with fava bean/vetch/barley) on soil CO_2 and N_2O emissions compared to a mandarin monoculture. This study was carried out in a mandarin farm under drip irrigation located in SE Spain, with semiarid Mediterranean climate. Mandarin trees follow a 6 m x 4 m pattern. Treatments were established in three replicated plots of 300 m^2, where secondary crops were grown in the alleys, and crop residues incorporated into the soil as green manure. GHG were measured using the dynamic chamber method. The chamber was made of stainless steel, with an inlet and outlet to connect to an ultrasensitive cantilever photoacoustic infrared spectroscopy analyzer. Gas measurements were made once a week between 9:00 and 13:00. Cumulative CO_2 and N_2O emissions for each treatment were estimated by numerical integration. CO_2 emission rates were significantly influenced by the sampling date and cropping system. Average CO_2 rate in the diversified system was 193 mg m^{-2} h^{-1}, while in the monocrop was 135 mg m^{-2} h^{-1}. Regarding cropping system, CO_2 emission rate was higher in the diversified mandarin crops compared to the mandarin monoculture. As a consequence, cumulative CO_2 emissions were higher in the diversified system compared, with an increase of 30.47 % (1611 g m^{-2}). N_2O emissions were not significantly affected by the sampling date or cropping system. On the other hand, crop diversification led to a better land profit, with a land equivalent ratio of 3.31. The increase in CO_2 emissions of diversified mandarin crops is linked to an additional C input to the soil as a result of the plant residues decomposition or the organic substances release thought root exudation. In order to counteract this increase in CO_2 emissions, it is necessary to study C sequestration thought the analysis of different C forms (organic carbon, recalcitrant carbon and labile carbon) in the soil.

Keywords: greenhouse gas emission; Vicia faba; Hordeum vulgare; Vicia sativa; Citrus reticulate.

0040

DOES COMPLEX MIXTURES INCREASE PERFORMANCES OF ORGANIC TEMPORARY GRASSLAND?

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Diversity and complementarity of species are important regulators of grassland ecosystem productivity, regardless of changes in other drivers of ecosystem function (Craven et al., 2016). Nevertheless, there isn't a unique relationship between herbage yield and plant biodiversity (Jamar et al. 2014). Everything would be function of the initial pair of grass-legume species persistency and potential to exploit the resources under a given soil-climate context. This is particularly true for mowed temporary grassland. To explore this hypothesis, in a context of drought occurrence increase, we compared, in a mowed temporary grassland, the performances of a simple grass-legume mixture (dactyle-lucerne (DL)), adapted to mowing and to dry conditions, to the performances of three more complex mixtures with, for two of them, 5 species and, one of them, 10 species (10L), including 2 and 4 legumes species respectively. One of the 5 species' mixtures included lucerne (5L) while the other included only clover species (5C).

This trial was performed in Belgium (410m asl, average temperature of 9.0°C, 800mm of annual rainfall). The mixtures were compared, in an organic farm, in a three complete blocks design. They were sown in 2015 and followed till the end of 2017. They were mowed once in 2015 and four times per year in 2016 and 2017.

2015 and 2017 were characterised by dry and, in 2017, hot springs. 2016's spring was rainier and colder than the average. Under these conditions, the complex mixtures led to an increase of cumulated DM yield of 18 (5C) to 25% (5L) in comparison to the DL binary mixture (15.4 10^3kgDM ha^{-1}). Concerning protein yield, the mixtures with 5 species, especially the one without lucerne, overcome the 10 species mixture by 5%. While focussing on spring yield, we underlined that under rainy conditions (2016), the complex mixture with clover led to similar performances than complex mixtures including lucerne. Under dry spring the complex mixtures including lucerne (2.6 10^3kgDM ha^{-1}) outperformed the mixture with clovers (2.2 10^3kgDM ha^{-1}).

In conclusions, under the conditions of this trial and organic farming system, complex mixtures outperformed the binary DL mix. Moreover, the inclusion of a diversity of legumes ecological groups within the complex mixtures allow to sustain their performances under contrasted climatic conditions.

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0054

INTERCROPPING OF MELON AND COWPEA CAN IMPROVE MELON PRODUCTION IN ORGANIC SYSTEMS

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Including legumes in intercropping systems may help maintain soil fertility, increase biodiversity and soil organic matter, and facilitate a reduction in the use of N fertilizers. The aim of this study was to assess the effect of different combinations of melon (*Cucumis melo*) and cowpea (*V. unguiculata*) intercropping on crop yields, land equivalent ratio (LER) and crop quality under Mediterranean semiarid conditions. We compared sole crops of melon and cowpea with different melon-cowpea intercropping systems in the summers of 2018 and 2019: row intercropping 1:1 (melon:cowpea), row intercropping 2:1 (melon:cowpea) and mixed intercropping. intercroppingWe performed a treatments of the complete randomized experimental design incomplete swith three replications, and each plot was 150 m^2. Fertilization was reduced by 30% in the intercropped treatments. The sole crop situated the attracted Intercropping combinations significantly increased melon yield both years, with no significant difference among intercropping combinations. Melon yield in the monoculture was 15.1 Mg ha^{-1} and 35.3 Mg ha^{-1} in 2018 and 2019, respectively, while the average melon yield in intercropped systems was 23.8 Mg ha^{-1} and 46.5 Mg ha^{-1} in 2018 and 2019, respectively. Cowpea yield in the monoculture was XX2.1 Mg ha^{-1} and 3.4X.X Mg ha^{-1} in 2018 and 2019, respectively, while the average cowpea yield in intercropped systems was 1.5X.X Mg ha^{-1} and X.X1.1 Mg ha^{-1} in 2018 and 2019, respectively. Land equivalent ratio (LER) did not differ significantly among intercropped systems, with average values of 1.88 and 1.51 in 2018 and 2019, respectively. Increases in melon yield were associated to higher number of melons per ha and higher melon weight in intercropped systems. ,Soil bioavailable nutrients were also higher in the intercropped systems. The active rhizodeposition of cowpea with stimulation of soil microbial communities may have also contributed to increase soil fertility, with positive effects on crop yield. The necessary separation of sole cropped treatment from the intercropped cause an uncertainty in the interpretation, but tThe results of the present experiments indicate that intercropping of cowpea and melon is a more sustainable system than sole cropping of melon. Melon yields and LER were higher in spite of less use of fertilizer, with no negative effect on melon quality. We also conclude that the crop distribution in the intercropping is not critical for performance.

Keywords: melon, cowpea, intercropping, production

0055

INTERCROPPED BROCCOLI-FAVA BEAN SYSTEM CAN IMPROVE OVERALL PRODUCTION AND ECOSYSTEM SERVICES

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Including legumes in intercropping systems may be a good alternative to increase soil fertility, biodiversity and soil organic matter while enhancing crop production, and reduce the use of N fertilizers. The aim of this study was to assess the effect of the association between broccoli (*Brassica oleracea var italica*) and fava bean (*Vicia faba*) grown under different intercropping patterns on crop production, land equivalent ratio (LER), soil organic carbon (SOC), total nitrogen (Nt), soil aggregate stability (SAS) and soil nutrients. We compared a broccoli monocrop with different broccoli-fava intercropping systems in the cycle November 2018-February 2019: Row intercropping 1:1 (broccoli:-fava), row intercropping 2:1 (broccoli:fava) and mixed intercropping. A fava bean monocrop was also established for comparisons. The field experiment was designed as a randomized block with three replications, and each plot had 150 m^2. All crops were drip irrigated and grown under organic management. Results showed that the broccoli-fava bean intercropping significantly increased the general land production, with similar broccoli yield of 20,000 kg ha^{-1} in all treatments, plus 8000 kg ha^{-1} coming from fava bean. Land equivalent ratio (LER) showed an average value of 1.3 in intercropping systems. Crop diversification and fava bean cultivation in monocrop significantly increased SOC and Nt compared to broccoli monocrop. SOC and Nt were 1.06% and 0.09%, respectively for broccoli monocrop, while they had average values of 1.29% and 0.12%, respectively for the intercropped systems. SAS was also significantly affected by crop diversification, with increases in the proportion of the macroaggregates (size >2 mm) with intercropping. Broccoli monocrop showed an average proportion of these macroaggregates of 9.19%, while they increased up to 17.51% in intercropped systems. Cation exchange capacity was not significantly affected by intercropping. Available P significantly increased in intercropped systems from 12.5 mg kg^{-1} average in monocultures to 38 mg kg^{-1} average in intercropping systems, likely due to increased microbial activity with the simultaneous growth of the two crop species. However, no significant effect of intercropping was observed with any other nutrients (Ca, Mg, K, Mn, Cu, Fe, Zn and B), suggesting that microbial communities activated by the crop association are highly related to P mobilization but not so intensively involved in other nutrients. Thus, intercropping systems like broccoli-fava bean association can be regarded as a viable alternative for sustainable crop production while increasing soil fertility despite reducing the addition of external fertilization. However, more crop cycles are needed to confirm this trend.

Keywords: melon, cowpea, intercropping, production

0057

THE CONTEXT DEPENDENCE OF RESOURCE PARTITIONING IN CROP MIXTURES

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Biodiversity-ecosystem functioning relationships are a major research topic in ecology. It is widely acknowledged that increasing diversity in plant communities affects plant interactions which in turn influence ecosystem functioning. These ecological concepts are well studied in natural ecosystems; however, applying them to agricultural settings such as intercropping has rarely been done. Here, we present data of a biodiversity experiment with annual crop species where we related differences in crop yields of mixtures compared with monocultures to underlying complementarity effects and further analysed the dependence of these effects on surrounding environmental conditions. We expected an increase in crop yield in mixture compared to the average yield of monoculture plots. We further expected that higher crop yields in mixtures compared with monocultures were due to positive complementarity effects - such as resource partitioning or facilitation and that these effects would be context-dependent. To test these hypotheses we established experimental communities of monocultures and mixtures of two and four crop species, including wheat, oat, lentil, lupine, quinoa, coriander, flax and camelina at two different levels of soil fertility and in two different climates (Switzerland: temperate humid; Spain: warm semi-arid). To assess ecological processes underlying diversity effects we measured four plant traits: Leaf dry matter content (LDMC), specific leaf area (SLA), carbon-to-nitrogen ratio in the crop leaf (C:N ratio) and plant height. Furthermore, we surveyed volumetric water content (VWC) and the fraction of intercepted photosynthetically active radiation by the crop canopy (FPAR). Yield increased with increasing diversity in Switzerland but not in Spain. These yield increases were mainly related to plant height and LDMC. We observed that complementarity in plant height in mixtures could enhance mixture yields, presumably by enhancing light interception. LDMC was negatively correlated with yield increases in mixtures, thus indicating that leaf water content was another driver for yield increases in mixtures. Higher leaf N and SLA further contributed to yield advantages in mixtures, presumably by improving efficiency of light acquisition in the crop. Beyond that, leaf N concentrations in mixtures were improved by the facilitative presence of legumes under low soil N conditions in Spain. VWC and FPAR were negatively correlated with LDMC, thus more light interception and higher soil water content both increased leaf water contents. A better understanding of underlying ecological processes that drive positive productivity effects, could pave the way for diversity in agricultural systems and thus to a more sustainable method of food production.

Keywords: Intercropping, complementarity effects, resource partitioning, facilitation

0065

CHARACTERIZATION OF PERFORMANCE OF NINE SPECIES AS COVER CROPS INTERSEEDED INTO MAIZE

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Cover crops can provide many environmental benefits in annual rotations, including erosion control, nutrient recycling and weed suppression. However, the farmer adoption of cover crops may be limited by a short planting windows after the cash crop harvest. To overcome this limitation, cover crops can be interseeded, i.e, established into the cash crop rows during the growing season (between V4-V7 stages, in maize).

Field experiments were carried out during two consecutive seasons in Central Spain with the objective to evaluate the performance of different species as cover crops interseeded into maize, and the impact on maize productivity. Moreover, performance of interseeded species was compared to cover crops sown in autumn. The evaluated species included eight legumes: burr medic (*Medicago polymorpha* L.), barrel medic (*Medicago truncatula* L.), yellow sweetclover (*Melilotus officinalis* L.), berseem clover (*Trifolium alexandrinum* L.), balansa clover (*Trifolium michelanium* L.), red clover (*Trifolium pratense* L.), Persian clover (*Trifolium resupinatum* L.), and common vetch (*Vicia sativa* L.), as well as annual ryegrass (*Lolium multiflorum* L.). A bare soil (interrows without interseeding) was included as a control. After the maize harvest, the four interseeded species with the best performance were also sown as cover crops in adjacent plots. The ground cover evolution, biomass and N content of each species were determined in the autumn and in the following spring. The soil inorganic N was determined in spring.

Annual ryegrass, common vetch, barrel medic and yellow sweetclover were the interseeded species with the best performance. None of the species had a negative impact on maize productivity. In autumn, interseeeded species had a higher biomass and covered more the ground than cover crops sown in October. Therefore, the longer soil coverage of interseeded species implies a greater potential for soil quality increase and weed suppression. Moreover, the higher biomass accumulated when interseeded, ensured the survival of yellow sweetclover, which was winter killed when sown in autumn. In spring, the interseeded treatments showed a lower soil inorganic N content than autumn cover crops, and differences were observed between species.

The experiment highlights the benefits of interseeding cover crops, a promising strategy to diversify rotations and increase environmental benefits in Mediterranean regions.

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Keywords: intercropping; diversity; legumes; ryegrass; vetch

0068

CROP YIELD AND WATER USE EFFICIENCY IN THREE IRRIGATED MAIZE CROPPING SYSTEMS UNDER DIFFERENT NITROGEN FERTILIZATION RATES

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In NE Spain, traditional management of irrigated maize (*Zea mays* L.) includes monocultures and large additions of N fertilizers. Monocultures have been marked for their detrimental effects on the sustainability and resource conservation of these agroecosystems. This study presents the first season data of an experiment established in fall 2018 in Zaragoza (Spain), under the framework of the H2020 project Diverfarming, to evaluate the effects of the adoption of diversified cropping systems and adjusted N rates on maize grain yield and water use efficiency (WUE). Thus, two diversified cropping systems, pea (*Pisum sativum* L.)-maize and barley (*Hordem vulgare* L.)-maize, were compared with the traditional maize monoculture in a flood irrigated system. Concurrently, three N rates (0, control; MN, medium rate; HN, high rate) were also compared in each cropping system.

Maize under monoculture produced greater grain yields compared with the maize after barley or pea. The mean maize grain yields (averaged for the three N rates) were: 12.5, 7.4 and 7.0 Mg ha^{-1} for maize monoculture, maize after barley and maize after pea, respectively. However, it is important to highlight the barley and pea yields obtained during the season (4.3 and 7.1 Mg ha^{-1}, respectively, as average values for the three N rates). Differences among N rates were only observed between the unfertilized and the fertilized treatments with the lowest maize yields observed in the control (unfertilized) plots. No differences were observed between the medium and the high N rates.

The water use (WU) of the maize phase was similar in the two diversified maize systems (972 and 1000 mm for maize after barley and maize after pea, respectively) but greater compared with the maize monoculture (800 mm). Nitrogen rates did not affect WU in any cropping system. Significantly greater WUE was measured in the maize monoculture system compared with the diversified maize systems (maize phase). Averaged for the three N rates, WUE values were 15.6, 7.6 and 7.0 respectively for maize monoculture, maize after barley and maize after pea. Furthermore, addition of N fertilizer resulted in an increase of WUE compared with the control treatment.

These first season results showed that the adoption of diversified systems, as an alternative to the traditional maize monoculture, did not increase maize yields and WUE. However, this study only showed data from one cropping season and it did not consider possible positive effects of cropping diversification on other ecosystem services.

Keywords: Irrigated maize; cropping diversification; nitrogen fertilization

0072

SOYBEAN INTRODUCTION IN MEDITERRANEAN CROPPING SYSTEMS CAN REDUCE THEIR CARBON FOOTPRINT

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Maize monocropping in Mediterranean irrigated areas can lead to agronomic and environmental problems due to high N demand and intensively tilled winter fallows**.** Crop diversification with soybean might be an alternative to deal with these problems and, meanwhile, contributing to the EU protein self-sufficiency. We quantified the carbon footprint (CFP) for the maize or soybean rotation phase of four cropping systems: maize monocropping (MM) and soybean-maize rotation (SM) as single cropping systems (during winter, these systems include rye as a cover crop), and barley-maize (BM) and barley-soybean (BS) as double cropping systems in an on-farm field experiment located in Sucs (Lleida, Spain) in the framework of the EU project LegumeGap. Aboveground biomass, grain yield, yield components, and biomass N, grain N and soil N contents were measured. All the inputs and crop operations were recorded, and external (E_{em}) and on-site (O_{em}) GHG emissions were calculated. Emission factors were obtained from the literature and soil processes such as NO_3^- leaching, NH_3 volatilization and N_2O emissions were simulated using STICS model. Maize phase in MM and BM had a higher CFP (9642 and 9182 kg CO_2 eq ha^{-1}, respectively) compared to soybean phase in SM and BS (6990 and 7271 kg CO_2 eq ha^{-1}, respectively). E_{em} accounted, on average, for the 74 % of total CFP for all treatments. Manure E_{em} were 4190 kg CO_2 eq ha^{-1} in the four systems, representing 44 and 58 % of the total CFP in maize and soybean, respectively. Also, E_{em} linked to top-dress N fertilization in maize represented up to 15 % of the CFP in MM and BM. Regarding O_{em} (which represented on average 26 % of the total CFP), STICS simulations showed that cropping systems including soybean had 50% lower N_2O emissions**.** MM and SM showed very similar CFP:grain N ratio (42 and 46 kg CO_2 eq kg^{-1} N, respectively) and so did BM and BS (57 kg CO_2 eq kg^{-1} N for both). The next step will be to gather and analyze data for the full three-year rotations: (i) evaluate other potential benefits of soybean introduction in cropping systems (e.g. increases in maize productivity, weed control,…) and (ii) account for soil organic carbon changes and potential carbon sequestration into the CFP. Our preliminary results show that systems including soybean might be a suitable alternative to break maize monocropping while reducing GHG emissions and contributing to the EU protein self-sufficiency.

Keywords: EU protein self-sufficiency, STICS model, crop diversification, soybean production

0081

PERENNIAL GRAIN ROOTS DIFFER FROM ANNUAL ONES, AFFECTING SOIL FUNCTIONING AND MICROBIOLOGY

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A range of 'agroecological practices' are currently proposed to increase the sustainability of intensive grain systems. However, little attention has been paid to the use of perennial grains in the crop successions. The use of the perennial grain 'intermediate wheatgrass' (Thinopyrum intermedium (Host) Barkworth & D.R. Dewey) may have the potential to sustain soil fertility through the development of an extensive root system beneficial to a range of soil functions. In the context of cereal grain crop rotation, we compared young stands of intermediate wheatgrass to annual grains during two growing seasons, with the aim to determine how the rooting system of a perennial crop differs from an annual crop along a 1.6 m deep soil profile.

Our results indicate that the two-year-old intermediate wheatgrass promotes denser and deeper rooting systems with proportionally higher root distribution and biomass downward the soil profile. In the first growing season, higher root biomass was observed under the perennial grain than under the annual wheat at 0-10 cm depth. In 12 months, between the first and second spring growing seasons, perennial belowground biomass increased by 111%. Consequently, root biomass was larger under the perennial treatment at each soil layer, leading to 5.3 average more tons of roots (dry weight) per hectare compared to the annual grain at the same time. Looking at the root to shoot ratio, perennial roots represented 38.6% of the aerial biomass produced during the first growing season, compared with 24.4% for the annual grain; while reaching 55.3% the second year, compared to 22.9% for the annual grain. Higher level of soil colonization were also observed under the perennial grain between 10 and 160 cm depth, including greater evenness of the roots vertical distribution and improved soil structure between 10 and 20 cm. From the first growing season, the perennial grain also harbors a suite of root traits (specific root length, root diameter, root tissue density) typical of a more resource-conservative strategy, and more belowground-oriented resource allocation. Additionally, soil fungal biomass indicators, including those of arbuscular mycorrhizal fungi, were enhanced under perennial grain, which potentially show improved soil quality under such management.

Overall, this study brings evidence that grain agriculture would benefit from the possibility to rely on deeper and long-lived root systems to manage soils. The periodic use of a perennial phase in the crop rotation has the potential to improve soil functioning in the long term, while allowing both forage and grain production.

Keywords: perennial grains, rooting system, root traits, soil microbial indicators, soil quality

0083

SELECTION OF SUITABLE LEGUMES FOR RELAY INTERCROPPING WITH DURUM WHEAT IN MEDITERRANEAN CEREAL-BASED CROPPING SYSTEMS

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The increased interest in sustainable agricultural systems has led to significant developments in cropping practices that allow to preserve crop productivity and reduce the reliance on herbicides and nitrogen fertilizers.

Relay intercropping of legumes in wheat may represent a proficient practice to maintain crop productivity, improve soil fertility and support weed control at crop rotation level, if appropriate associated legumes are used.

The objective of this study is to select suited legumes for relay intercropping with durum wheat in central Italy among a wide range of taxa (*Medicago sativa*, *Medicago varia*, *Medicago lupulina*, *Trifolium repens*, *Hedysarum coronarium*, *Trifolium alexandrinum*, *Trifolium incarnatum*, *Trifolium resupinatum*, *Vicia villosa*, *Medicago polymorpha*, *Medicago rotata*, *Medicago scutellata*, *Medicago truncatula*, and, 3 subsp. of *Trifolium subterraneum*).

This study was carried out at the Centre for Agro-Environmental Research "Enrico Avanzi" in Pisa (Italy) in 2017/18 and repeated in the 2018/19 cropping season. According to the results obtained during 2017/18, legumes were reduced in 2018/19 excluding the least performing ones. The experiment was organized in a randomized complete block design with four replicates and the sole wheat crop as control. No pesticides or fertilizers were used. The evaluation was focused on i) legume establishment in the already developed wheat, ii) grain production and quality, iii) weed control before and after the wheat harvest, iv) legume persistence and growth after wheat harvest and, v) effects on the following crop. Legumes, indeed, were incorporated into the soil the following spring and forage sorghum was seeded.

Results of this study showed that relay intercropped legumes preserved wheat production and reduced weed biomass up to the 70% in comparison with the control. After wheat harvest legumes persisted in the field, as dead mulch or cover crop according to the different life cycle of the tested legumes, until the sowing of sorghum. Dead mulch of annual legumes resulted unsuitable to contrast weeds while, perennial and annual self-seeding legumes as *M.polymorpha* and *T.subterraneum,* showed overall good weed control and biomass accumulation.

Legume biomass at spring soil incorporation, was the most important factor related with sorghum production. Sorghum, preceded by *T. subterranum*, *H. coronarium* and *T. repens*, had a higher biomass production than the control and was comparable with the productive level that can be obtained under conventional systems.

The overall assessment of legumes used in this study, allows to select the most suited ones for relay intercropping with durum wheat for the local environmental condition.

Keywords: Relay intercropping, weed control, legumes, cover crop

0090

A SET OF INDICATORS TO ASSESS THE AGRO-ENVIRONMENTAL PERFORMANCE OF TWO MEDITERRANEAN DIVERSIFIED CROPPING SYSTEMS

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The H2020-Diverfarming project (www.diverfarming.eu) aims to promote crop diversification and inputs reduction across European farms, by means of new agronomic solutions. In this framework, the implementation of easy-to-use tools for the assessment of agro-environmental impacts of the diversified agricultural systems is a key factor.

In this regard, three indicators were implemented at farm level. The Carbon Pool Index (CPI) (the higher the better) is a simple index, which relates the soil organic carbon (SOC) content in the diversified system to the SOC content of a conventional system (CS). Two complex indicators, based on fuzzy-logic multiple-metrics, are i) the Nutrition Index (NI), calculated using soil properties (pH, electrical conductivity, total N, available P, Cu, Zn, Fe and Mn, and exchangeable Ca and Mg), and ii) the Crop Diversification Index (CDI), based on crop management information. The latter is composed of the Intensification Sequence Index (ISI) and the Crop Variability (CV), which in turn accounts for the number of crops and the duration of soil cover by crops in the field. Both NI and CDI range from 0 (best) to 1 (worst).

The three indicators were tested using data collected in two long-term experiments in Spain and Italy during the growing season 2017-18.

The compared cropping systems were: i) vegetable rotations (lettuces, cabbages, broccoli, leek, celery, melon, pumpkin) under conventional (CS), organic and biodynamic management in Spain, and ii) durum wheat in monocropping and in rotation with faba bean, under both conventional tillage (CT) and no-tillage (NT) in Italy - durum wheat under CT represented the CS.

The CPI was 20% higher in the biodynamic system than in CS in Spain, and 4% higher in the rotation than in monocropping in Italy, irrespective of tillage. NI values in Spain were 6% and 14% lower (i.e. better) in organic and biodynamic systems, respectively, than in CS, while in Italy they were 19% lower in NT than in CT. The CDI value in Spain was higher in the biodynamic system than in the CS, due to the presence of cover crops, while in Italy it scored higher in rotations than in monocropping systems. We conclude that the proposed indicators are potentially useful for evaluating agro-environmental performance of cropping systems.

Keywords: crop diversification, tillage, soil organic carbon, fuzzy-logic multiple-metrics; indicators

0109

CHOOSING SERVICE PLANT FOR INTERCROPPING WITH RAPESEED BASED ON PLANT-PLANT AND PLANT-SOIL INTERACTIONS

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Intercropping of winter oilseed rape (WOSR) with frost sensitive service plants (legumes or legume-based mixtures) has recently become more common in Switzerland. The introduction of such mixtures in cropping systems could help enhance ecosystem services, such as pest regulation and nutrient cycling, and could potentially be a way to reduce the use of N fertilizers inputs, due to service plants degradation in spring. However, some gap of knowledge remains, eg regarding root-soil interactions. The purpose of the present study is to better understand plant-soil and plant-plant interactions and their consequences on niche complementarity in WOSR - service plant intercropping.

A first greenhouse experiment aimed to assess the capacity of 11 service plant species to enhance soil microbial activity. Faba bean (*Vicia faba* L.) and grass pea (*Lathyrus sativus* L.) were, then, selected for a second greenhouse experiment, because of their contrasting effect on soil microbial activity and morphological traits. Six combinations made of these two legumes and niger (*Guizotia abyssinica* (L.f.) Cass.) intercropped with WOSR were compared in an additive design. Root and shoot biomasses and nitrogen contents were assessed. The soil adherent to the roots were sampled for microbial respiration. In addition, another field experiment was conducted where WOSR, faba bean and niger were grown, either as sole crops or in mixtures, in order to assess the plant-plant interactions and grain yield under field conditions.

Faba bean had the highest soil microbial respiration, WOSR the lowest and the other tested legume species were intermediate. The N total accumulation by the cover (WOSR and services plants together) significantly increased when WOSR was intercropped with Faba bean. That is not the case with grass pea. Indeed, grass pea fixed less N than faba bean when grown with WOSR, with WOSR and niger or in pure stand. These results are consistent with the fact that faba bean biomass was less sensitive than grass pea to competition with WOSR. The WOSR biomass and plant density before winter was impacted by the services plants, but these differences did not affect the final grain yield. The high capacity of faba bean to fix nitrogen, its ability to produce biomass even intercropped with a WOSR and its positive potential effect on soil microbial activity confer to faba bean a higher capacity to provide N related services than grass pea or species mixtures.

Keywords: ecosystem services, service/companion plant, microbial activity.

0119

WATER USE AND WATER SOURCE OF SIX DIFFERENT CROP SPECIES IN MIXED CULTURES

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Water is a limiting resource for crop production in dry regions, and with ongoing climate change it is predicted that high ambient temperatures will become more frequent throughout Europe. Furthermore, while irrigation already accounts for 70% of water withdrawals globally, the question remains as to how food security is to be achieved while the world human population continues to increase. Thus, we urgently need solutions by which we may increase agricultural water use efficiency (WUE) and crop production. Planting different crops in the same field with at least partially overlapping growing seasons (mixed cultures) has the potential to increase yield compared to monocultures. Mixed cultures can also improve WUE due to complementary traits of the different species - such as root structure and/or distribution. This complementary root distribution may alter water uptake pattern of the different crop species involved, including water source (e.g. water uptake in a specific soil depth) and water use (e.g. water uptake after rain events). To test for alternating water uptake patterns in mixed cultures, a field experiment was conducted in Summer 2019. Six different crop species from different functional groups including cereals (*Triticum aestivum* and *Hordeum vulgare*), legumes (*Vicia faba* and*Pisum sativum*) and oilseed herbs (*Linum usitatissimum* and *Brassica napus* subsp. *Napus*) were grown in monoculture, 2-species and 3-species mixtures. Water source (e.g. soil depth) was investigated with natural abundance of stable hydrogen isotope (^2H) in water. Plant and soil core samples were collected after several days without any rain event and analysed for δ^2H. To study water use, ^2H-enriched water was applied to the different cultures. After three days, plant and soil core samples were collected and analysed for δ^2H. Comparison of natural and enriched δ^2H of soil cores and plant may indicate water source and water use in the different cultures and between species resp. functional groups.

Keywords: water use; water source; intercropping; mixed cropping

0122

WHY SWISS FARMERS CHOOSE TO SOW WINTER OILSEED RAPE WITH COMPANION PLANTS?

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Intercropping winter oilseed rape (WORS) with companion plants has known a fast increase in the last few years in Switzerland. This technique has been encouraged by farmers' advisers to reduce herbicide use, leading seed retailers to propose various seed packages to be sown together with WOSR. The ecosystem services that companion plants could provide are often presented like a good opportunity to reduce the use of chemical inputs, and the results of field trials seem to confirm the possibility of reaching similar yields with less inputs. The objective of this work is to draw an overview of Swiss farmers' practices and understand their fears and motivations concerning the development of this technique.

A survey collected data from 1063 WOSR producers in 2018. It concerned i) the general organization of the farm, ii) WOSR management and iii) farmers' opinion on intercropping.

This survey showed great disparities between Western and Eastern Switzerland. Whereas in the first one intercropping has become more and more popular in the last few years, it remains confidential in the latter. This could be linked to difference in practices between the two regions, the first one being as well more inclined to extensive management or reduced tillage. The implication of farmers' advisors in the Western part of the country, setting up strip demonstration trials, testing various species as companion plants and publishing extension papers on the subject could also be part of the explanation.

Farmers who have experienced growing WOSR with companion plants have a general positive opinion. However, less than a third believe that the impact on yield could be positive. The main goal for them was herbicide suppression, which is supported by subsidies, provided that tillage was reduced as well. Most farmers acknowledged the efficiency on companion plants in reducing weeds, but opinion was divided concerning a possible impact on pest management or nitrogen nutrition.

The diversity of species used as companion plant comes from both the various offers from seed retailers, and "home-made mixtures" by farmers. Frost sensitive legumes are part of all the mixture but they can be completed by non-legume frost sensitive species, or perennial legumes. Better understanding of the role of each species could improve farmers' interest for intercropping and contribute to the reduction of both pesticides and mineral fertilizers in WORS production.

Keywords: rapeseed, companion plants, legumes, survey

0124

INCREASING PLANT DIVERSITY REDUCES REPRODUCTIVE EFFORT IN ANNUAL CROPS

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Resource allocation to reproduction is a critical trait for plant fitness. In agriculture, this trait, called harvest index, determines yield and consequently financial revenue of grain crops. While plant diversity has been demonstrated to increase primary productivity, plant diversity effects on grain yield of crops are ambiguous. This discrepancy could be explained through changes in the proportion of resources invested into reproduction in response to changes in plant neighbourhood diversity, namely through changes of ecological interactions and micro-environmental conditions. Here we show that increasing crop plant diversity from pure stands, over 2- to 4-species mixtures, increased primary productivity, i.e. vegetative and reproductive biomass, and resulted in an overall higher crop yield in mixtures than in pure stands. However, increasing plant diversity reduced the reproductive effort across eight common European grain crops, thereby compromising the yield benefits of mixtures. While crop diversification provides a sustainable measure of agricultural intensification, currently available crop cultivars bred for maximum performance in pure stands may compromise the significant yield benefits of intercropping. We therefore advocate regional breeding programs for crop mixtures based on local germplasm and targeting in particular the exploitation of facilitative interactions among crop species.

Keywords: crop yield, diversity-ecosystem functioning *relationship, harvest index, intercropping*

0150

DO CROPS GROW BETTER IN OLIVE AGROFORESTRY UNDER DROUGHT ? A TEST FROM NORTHERN MOROCCO

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Agroforestry systems can be an effective means of maintaining or even enhancing crop yields under climate change. In agroforestry, trees compete with crops for soil resources, but they can also improve the growing conditions of crops under drought by providing shade. They can promote higher crop yields and higher harvest quality. However, the beneficial effect of tree shade may depend on the seasonal pattern of rainfall which determines the compensation between yield components. In this study, we evaluated the production of two annual crops (durum wheat and faba bean) in olive agroforestry in northern Morocco. We manipulated water supply in a field experiment to span the high inter-annual rainfall variability at the site and tested whether olive trees reduce or improve crop yields. We assessed the effect of water addition on crop growth, yield components and final yields and estimated the land equivalent ratio of olive agroforestry. Agroforestry penalized crop growth and yield whatever the water regime. The number of grains per unit area was the most impacted yield component. However, agroforestry improved individual grain weight and the protein content of grains but not sufficiently to compensate for yield loss. Overall, we show that agroforestry systems are generally more land productive than sole crops and trees and we present examples of how changing water supply may impact the performance of olive agroforestry in a drier future.

Keywords: cereals, intercropping, land equivalent ratio, legumes, yield components

0162

FINANCIAL ANALYSIS OF INTERCROPPING PRACTICES. THE CASE OF MANDARIN ORCHARD IN THE SE OF SPAIN.

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Irrigated crops are mainly grown in monocropping systems. Despite the high yield achieved, these farming systems may provide many negative environmental impacts (erosion and soil loss, greenhouse and gases emissions, soil and water pollution, etc.). Diversified farming system seems to be a feasible alternative to overcome many of these environmental issues maintaining farm profitability. Within these systems, intercropping practices consist of growing more than one crop at the same time in the same parcel. Intercropping allows farmer to mitigate market risks and an improvement of farm sustainability in the long term. However, these practices could imply high start-up costs and an increment of the production cost that compromise the far financial performance.

In this context, this study aims to evaluate the financial feasibility of implementing intercropping from plantation in a mandarin orchard. To this end, two intercropping systems are evaluated together with conventional irrigated mandarin monocrop. Diversification 1 (D1) consist of mandarin intercropped with multiple cropping of vetch/barley (*Vicia sativa/Hordeum vulgare*) for feed and fava bean (*Vicia faba*) for food, during 2018 and 2019. Diversification 2 (D2) consists of mandarin intercropped with a rotation of vetch/barley and fava bean during 2018, and purslane (*Portulaca oleracea*) during 2019. Data have been obtained from a field experiment located in the Region of Murcia (SE Spain). Revenues, costs and gross margins for both diversifications and monocrop during 2018 and 2019 have been estimate and differences between financial indicators have been checked.

Results show that intercropping practices in mandarin orchard could imply significant costs increases that does not necessary involved significant changes in gross margins and, consequently, in the farm profitability. Furthermore, in spite of the financial analysis results, intercropping could lead associated farm benefits that improve the financial performance in the long term, such as environmental and biodiversity benefits, and risk mitigation by a higher resilience and price volatility.

Keywords: crop diversification, Intercropping, gross margin.

0184

USE OF APPROPRIATE CULTIVARS IN INTERCROPPING CAN IMPROVE RESOURCE USE EFFICIENCY UNDER MEDITERRANEAN CONDITIONS

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Intercropping is the cultivation of two or more crop species on the same area of land and received a great attention the last decade because of the significant advantages as it may improve yield, product quality, and soil health. Despite the fact that in most intercropping experiments they used cultivars that are bred under sole crop the performance of a cultivar grown as a sole crop does not necessarily represent its performance in a mixed cropping system due to local selection pressures generated by inter-specific neighbor interactions in mixtures. Little work has been carried out on how the different cultivars respond to intercropping conditions compared with sole cropping. The objective of the present study was to determine the effect of using different cultivars of wheat and pea on agronomical, physiological characteristics of intercropping. The experiment was conducted at the University farm of Aristotle University of Thessaloniki, Greece during two growing seasons 2017-2018 and 2018-2019, using five different cultivars from pea and six from wheat. The different treatments were evaluated using a number of physiological (leaf area index, chlorophyll meter readings, chlorophyll fluorescence) and agronomic traits (yield components and grain yield). It was found that the use of proper cultivar affects the performance of intercropping. Both pea and wheat showed significant genotypic variation for total and partial yield and also land equivalent ratio (LER). Therefore, the intercropping of wheat with pea uses the environmental resources more efficiently and can be used in dry land conditions for higher yield. This study provides new information for the importance of using the appropriate cultivar in order to achieve high-performing mixed cropping systems.

Keywords: cultivars, combination, competition, facilitation.

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0190

CONTRIBUTION OF CEREAL-LEGUME INTERCROPPING TO AGROECOLOGICAL WEED MANAGEMENT

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Weeds are very harmful to crop production and essential for biodiversity in agricultural landscapes. As herbicide use must be reduced because of environmental and health issues, we need new weed management strategies that replace the highly efficient and easy-to-use herbicides. For this, it is necessary to combine multiple (mostly preventive) techniques, each of which is partially effective. Intercropping is a key lever to design cropping systems that reconcile crop production, biodiversity and low herbicide use. Simulation models are an essential tool to evaluate intercropping because of the many techniques and objectives to consider. Moreover, weed management must be reasoned over several years because weed seeds survive for several years and decisions made today influence weed infestation in future crops. Here, we (1) tested the ability of the existing FLORSYS model (Colbach et al., Weed Res 2014) to simulate weed dynamics and impacts in intercropping by comparing simulations to independent observations from a long-term field trial at INRAE Toulouse (Southwest France), (2) ran virtual experiments with FLORSYS to assess weed impacts on crop production and biodiversity in a series of intercropping scenarios co-designed with farmers. Four cropping systems were compared: (1) the control system based on a barley / camelina / maize / wheat / buckwheat / soybean rotation, (2) a system replacing wheat with wheat+faba bean intercropping, (3) a system replacing barley with barley+pea intercropping, and (4) a system replacing both wheat and barley by intercropping. Each system was run twice, once with cover crops prior to maize and soybean, and once with bare soil during fallow and mouldboard ploughing, resulting in a total of eight cropping systems. Each was simulated twice, once starting with a regional weed species pool and once without weeds, to estimate potential yield. All scenarios were simulated over 30 years and repeated with 10 weather series. Statistical analyses will provide a multicriteria assessment of the cropping systems in terms of production (potential and actual yield), weed harmfulness for production (yield loss, harvest contamination by weed seeds and debris, harvesting problems, field infestation) and weed contribution to biodiversity (wild plant biodiversity, contribution to feeding farm birds, pollinators and seed-eating insects). The main management techniques driving crop production and weed impact will be identified as well as key weed traits contributing to their impact and selected by crop management.

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Keywords: intercropping, weed, simulation model, ex ante evaluation

0244

IMPACT OF CLIMATE ON GRAIN LEGUME YIELD STABILITY IN LONG-TERM EXPERIMENTS

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Diversifying rotations with grain legumes could contribute to the resilience of agricultural systems for adapting to climate change. Yield stability is an important goal in agricultural production and is particularly relevant in Europe-grown grain legumes. Their yields tend to be more variable than yields of some other crops and there is some evidence of a decrease in their yield stability over the last few decades. Currently, little is known about the relationship between yield stability of different grain legume species and changes in climate variability and extreme weather events. Analyses of

such relationships and a fundamental understanding of the processes involved are needed to inform agronomy and plant breeding efforts to adapt grain legume cropping systems to climate change. We quantified changes in temporal yield stability using an adjusted coefficient of variation (aCV) and the influence of climate for pea and faba bean in three long-term experiments (LTE) in Borgeby (Sweden, 1960-2015), Berlin-Dahlem (Germany, 1953-2008) and Halle (Germany, 1950-2012). The objectives were to (i) quantify the relationship between climatic variability and yield stability for grain legumes under different bio-physical conditions, and (ii) quantify the effect of precipitation and temperature on yield stability. During the trial periods, temperature increased significantly in Borgeby, Berlin-Dahlem and Halle, by 1.7 °C, 1.6 °C and 1.3 °C, respectively. There was no trend in the annual precipitation across the sites. While yield instability of grain legumes increased significantly in Borgeby and Berlin-Dahlem this was not the case in Halle. In Borgeby and Berlin-Dahlem, there was a positive association between temperature (annual and April-July) and yield instability, and a positive relationship between temperature variability and yield instability. Annual precipitation did not affect yield stability but precipitation during specific periods did. In Halle, precipitation (April, June and July) was significantly and negatively correlated with yield stability of pea. We conclude that the analysis of LTEs enables detecting trends in yield stability changes over time. In the two sites with a higher increase in temperature (Borgeby and Berlin-Dahlem) there was a strong positive association between climate variability and yield instability for grain legumes which was not observed in Halle. This knowledge supports efforts in plant breeding and adapting the agronomic management of grain legumes to support the protein transition in Europe.

Keywords: Climate change, faba bean, pea, pulses, yield variability.

0246

INTERCROPPING: A TOOL FOR CROPPING SYSTEM DIVERSIFICATION

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Diversification of crops in cropping systems is one solution for reducing the environmental impact of crop productions. Legume crops are not much cultivated in Europe. However, they can provide high protein grains and contribute fixed nitrogen to the cropping systems, making them good candidates for cropping system diversification. Nonetheless, they face two major constraints: high yield variability and high pressure from weeds, pests and diseases, with sometimes little or no chemical control solutions available. Consequently, farmers are not inclined to introduce them into their cropping systems.

Intercropping has properties that could help overcome some of the problems associated with legume production. It has been shown that intercropping generates higher yield stability than sole cropping and can reduce weed, pest and disease pressures. The originality of our approach is to propose to use intercropping as a management tool to facilitate the introduction of new crops in cropping systems. Nonetheless, different technical levers need to be optimized to reach the expected services of intercrops.

In Europe, there is an increasing demand for locally produced soybean and early cultivars may extend its area of production, e.g. in western France where demand for animal feed is high. However, yields of soybean are quite variable and weed control difficult. We investigated four services from intercropped soybean: grain yield, N provisioning, weed control and grain production from the associated crop.

In an analytical experiment with buckwheat, lentil, sorghum and sunflower intercropped with soybean in replacement design (0.50: 0.50) and following two different spatial arrangements: alternate row intercropping and within row intercropping, we quantified the aforementioned services and studied the biological processes involved. The N provisioning service, as preceding crop effect, was evaluated in the following wheat crop.

Our results show that soybean grain production and weed control services were antagonists. However alternate row arrangement helped to mitigate this trade-off by increasing soybean yield, while maintaining sufficient weed control for soybean intercropped with sorghum or buckwheat compared to within row arrangement. While for soybean intercropped with either sunflower or lentil, spatial separation of crops did not improve yield. The species intercropped with soybean influenced the quantity of residues and the dynamic of soil N availability after harvest. Thus, with the proper management choices intercropping can be a solution to facilitate new crop introduction in cropping systems and provide multiple services.

Keywords: Intercropping, Soybean, Cropping systems

0251

A CONCEPTUAL MODEL TO LINK CROP DIVERSIFICATION WITH ECOSYSTEM SERVICES

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Dominant agricultural systems contribute to environmental degradations such as the reduction of biodiversity, the simplification of landscapes, the contamination of water, the emission of greenhouse gases or the decline in soil quality. Crop diversification can contribute to alleviate these impacts. Increasing plant diversity is possible through management practices chosen by farmers such as temporal (crop rotation) and spatial (intercropping) diversification. Indirectly, these management practices benefit on the crop-associated biodiversity (e.g., soil biota diversity and functioning, pest auxiliaries). In these biodiversity-based systems, we hypothesize that crop diversification improves (i) the number and (ii) the intensity of ecosystem services (production, support, and regulation). But we also hypothesize that the intensity of the ecosystem services provided by biodiversity-based systems varies from one pedoclimatic situation to another, and evolves over time, linked with the functioning of the soil, the nature of the crops and their management by the farmer. The aim of our work is to propose realistic scenarios for crop diversification promoting ecosystem services. To achieve our objective, we used the protocol described by Lamanda et al. (2012) to draw a conceptual framework of the relationships between biodiversity-based systems, production services (biomass production), support services (cycle of carbon, nitrogen and phosphorus elements) and regulation services (quality of the water, carbon storage in soils) over the medium term (5-10 years). We defined the structural, functional and dynamic processes in biodiversity-based systems by encapsulating different forms of knowledge (strong or weak). Our conceptual model was then used to compare three different crop models that can be used to design biodiversity-based systems (APSIM, DSSAT, STICS). The three crop models were compared in their capacity to represent the inputs, outputs and main biological processes and theirs interlinkages represented in our conceptual model. We finally selected APSIM for its ability to better model soil phosphorus dynamics and intercrops. We tested its performance in a temperate climate, in Brittany (France), using data from a long-term experiment (EFELE experiment, INRAE). APSIM is a promising model for our purpose but parametrization is necessary to adapt it to temperate climate, especially regarding the characteristics of cultivars.

Keywords: APSIM, biodiversity-based system, cropping system design, mid term

0276

PROSPECTS FOR GROWING ORGANIC OILSEED RAPE IN SCOTLAND: THE SCOTTISH ORGANIC CANOLA (SCOCAN) PROJECT

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Oilseed rape (Canola) is not traditionally grown under organically certified standards in Scotland, or other parts of the UK. Canola is a potentially high-value break crop and there is demand for its oil for inclusion in the diets of specialist livestock such as egg laying hens, while the high-protein meal also has significant value as a ruminant feed. A participatory farm led project funded through a Scottish Government initiative, the Knowledge Transfer Innovation Fund (KTIF) was developed in order to co-ordinate the activities of a small group of farmers, and other partners within the supply chain. The initiative was originated by Norvite, an animal feed company, with a view to expanding the activities at its NEOS crushing plant facility in Aberdeenshire, NE Scotland. The animal feed company now has certification which allows its crushing facilities to be used for oil that is produced organically, as well as for it to be sold for human use. In total, there are five farms involved in the SCOCAN project that are growing oilseed rape (Canola) organically, with three of these farms hosting demonstrations to the public during the 2019-20 growing season allowing interested parties to follow progress of the crops. The on-farm trials have provided the opportunity to compare a range of factors linked to the agronomy of the crop. Several varieties of spring and autumn sown types were tested, and fertility options and approaches to manage pest, disease and weed control were investigated based on approaches allowed within organic management standards. The SCOCAN project uniquely links the whole organic supply chain from Scottish soils through to consumers, which includes both livestock and human end use of the products, and explores the potential to open up new regional and export markets for the Scottish grown crop. These include locally produced organic high protein cake for livestock, as well as oil, for example for specialist poultry rations, or for human consumption. This paper will provide details of some of the early findings from this project.

Keywords: organic, oilseed rape, canola, oil, protein

0282

NOVEL AND MINOR PROTEIN CROPS IN SCOTLAND

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The ability for a country to be self-sufficient in its own protein production is of increasing importance to numerous governments given the current reliance by many, particularly in Europe, on imported soya. Given this background, a series of experiments were undertaken in NE Scotland, which were used to investigate the potential of growing a range of both minor protein crops. These included grain legumes peas, field beans and lupins, grown either as sole crops or intercropped with a spring barley. Also, a selection of other more exotic crops which are not typically grown in Scotland, such as lentils and soya. These experiments ran from 2016 onwards, and were used to develop agronomic approaches intended to provide more reliable and environmentally acceptable methods of production of the minor protein crops in this region, as well as evaluate the potential for commercial development of other less familiar protein crops. The investigations also include an evaluation of the carry-over effect of the protein crops under test; the majority of which are leguminous, and therefore have the potential to fix N though the associated rhizobia bacteria present on their root nodules. This was tested by superimposing the spring barley on the plots occupied by the protein crops in the previous year. Thus, allowing the influence of the protein crop on the soil and the following cereal crop to be measured. This paper explores some of the data associated with this series of experiments, focusing on the carry-over impact of the protein crops on the following year's spring barley test crops which were grown with applications of either zero-N or 60kg N ha^{-1}.

Keywords: protein, grain legume, cereal, intercrop, novel

Sesión 2.3: Crop-Livestock integration

0267

SOYBEAN NON-GM INNOVATIVE SOLUTIONS IN CULTIVATION AND FEEDING OF ANIMALS IN FARMS IN NORTH POLAND - EPI GROUP RESULTS, 'MY SOYBEAN' CONSORTIUM

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The unique chemical composition of the seeds, which contain 18-22% oil and 33-45% protein, makes soybean one of the most valuable crops. It is widely used in human and animal nutrition, and is also a raw material for many industries. The annual production of soybean seeds on an annual basis is about 340 million tons, and soybean meal about 240 million tons, which is almost 70% of the production of all vegetable meal. In Europe, soybean is grown in 22 countries, including all neighboring Poland. The area of soybean cultivation in Poland is not large and amounts to about 15,000. ha, this is mainly due to habitat conditions and the import of soybean meal. The purpose of the EPI project was to strengthen scientific and research cooperation with the development of soybean production on farms rearing pigs or dairy cattle based on feeds free from genetically modified protein. Geographical location of farms is between 52 and 53 ° north latitude and between 17 and 19 ° east longitude.

Non-GMO soybeans came from the own crops of Consortium members. On three farms (two in the Kuyavian-Pomeranian voivodship - A and B and one in the Greater Poland voivodship - dairy cattle farming - E), the seeds were extruded using extruders purchased by farmers with co-financing under the RDP Program - Action 16 Cooperation, Agreement No. 00003. DDD.6509.00029.2017.02. In the case of two farms from the Greater Poland Voivodship (C and D) keeping pigs, provision was made for extrusion services by external entities - service companies.

Innovative solutions in the soybean cropping concerned the selection of early ("000") cultivars from European breeding for a given region, selection of the habitats (crop rotation), inoculants for seeds, optimization of fertilization, protection against weeds and plantation monitoring against pests and diseases, harvesting technician and storage of soybean seeds.

The following chemical analyzes were carried out in the samples of feed collected on farms: determination of dry matter, crude ash, total protein, raw fat and crude fiber, content of neutral (NDF) and acid (ADF) detergent fiber, starch and in extruded soybean content of calcium and phosphorus, lysine, methionine, cystine, threonine and tryptophan, fatty acid profile and the presence of some plant bioactive nutrients of anti-nutritional nature - stachyose and raffinose and trypsin inhibitors. On one farm, weaned piglets (C), on one farm (D) on piglets, on two farms for pigs (A and B) and on one farm on calves (E). The selection of animals for groups was random. Nutrition at will, with constant access to water (drinking bowls). The experimental mixes used extruded full-fat non-GMO soybeans grown on the farms of the Consortium members instead of GMO soybean meal extraction (pigs) or deoiled non-GMO soybean extruded seeds were introduced, replacing non-GMO extraction soybean meal (calves). The content of raffinose and stachyose several sugars not decomposed in the digestive tract of monogastric animals in the tested non-GMO soybean seeds was within the range of values given in the literature for seeds not subjected to baroteric treatment. However, after extrusion, the seeds contained less trypsin inhibitors than presented in the literature. Extruded seeds of non-genetically modified soybeans cultivated in Kuyavian-Pomeranian and Greater Poland voivodships in terms of nutritional and nutritional quality are valuable protein and energy feed. In the weaning of piglets and weaners, the share of extruded whole seeds in the complete mixture was 10%, in the complete mixture of the grower type for fattening pigs 16%, and in the type of finisher - 15%, while in complementary feed for calves from 3 months to 3 months half a year old - 21% of extruded partially deoiled seeds.

Keywords: soybean, cultivation, GMO free feeding

Session 2.4: Mitigating climate change: modelling, prediction, and strategies

0157 KEYNOTE

EXPECTED IMPACT OF CLIMATE CHANGE ON FOOD PRODUCING SYSTEM IN THE MEDITERRANEAN REGION: HOW SMART AGRICULTURE CAN IMPROVE THE RESILIENCE

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Climate change is already affecting different economic sectors (e.g. agriculture, forestry, energy consumption, tourism) (IPCC, 2014) and understanding its potential effects on natural and human-based systems in the next future it's a fundamental step for reshaping our productive system. Under this perspective, the agricultural sector is expected to be one of the sectors particularly exposed climate risk since its profitsà are largely dependent on the weather conditions during the growing season. Future climate projections indicate that, even if global warming will be kept within 1.5°C, impacts of climate change are expected to be different depending on the considered region (Giannakopoulos et al. 2009). On a global scale, both present climate trend and future climate simulations indicated that Mediterranean basin must be considered a hotspot since it is expected particularly exposed to extreme climate conditions with a decreasing trend in rainfall rate and high increase in temperature especially in summer (Lionello, 2012). These changes will affect the most typical valuable crops of this region such as grapevine and olive tree.

To date many indicators put already in evidence that these typical crops are exposed to the effect of climate change with negative consequences on the economic viability of the agricultural sector. For instance, the production of premium quality wines is the result of the interactions between the environmental conditions (e.g. climate and soil), grapevine varieties and human factors (Van Leeuwen and Seguin 2006). The impact of climate change is already threatening some components of this interaction, in turn affecting both yield and

grape quality, with relevant consequences on wine industry (Ollat et al. 2016). Climate warming is expected to decrease olive tree net primary production, resulting in reduced olives productivity (Brilli et al., 2019) when adaptation measures are not considered, as well as increases the range of olive fly northward and in coastal areas (Ponti et al., 2014). On a wider scale, warmer temperatures and drier conditions are expected to shift both grapes and olive trees towards higher altitudes (Hannah et al. 2013, Moriondo et al. 2013, Leolini et al. 2018), where their climatic demands can be suitably met.

Besides their economic importance, the presence of these cultivation is associated to ecosystem services that will be very difficult to replace. As an example, while agricultural sector is a source of greenhouse gases (GHGs) emission, olive tree cultivan has been demonstrated to be an active sink in carbon sequestration so contributing to global mitigation. The same may be applied to grapevine, provided the the adoption of cover crops that improve biodiversity, soil organic matter (SOM) and soil erosion control (Garcia et al., 2018 Baiamonte et al.; 2019).

As such, the defense of these crops from climate change impacts should be considered as fundamental for maintaining the balance between economic and environmental sustainability of the agricultural ecosystems in the Mediterranean region. Despite adaptation may be considered as the first tool to counteract the impact of climate change and variability, thus maintaining the economic viability of the system, the sole contribution of these measures could be not sufficient to limit the climate change impacts on these systems. In this context, the climate-smart agriculture (CSA) approach (Ziebelman et al., 2018) is gaining considerable attention at international levels, by involving an array of tools that aim at harmonizing farmers' objective to increase productivity and incomes with the capacity of providing environmental services, finally reducing at the gap between adaptation and mitigation under climate change. Advancements in technology play a fundamental role in providing effective tools for monitoring crop growing conditions and therefore are essential for decision making. Among these tools, crop models may helpful to test the effectiveness of different adaptation/mitigation management strategies. This would help to support long-term investment decision-making on agricultural sector across the Mediterranean under current and future climate. In the last few years, different studies put in evidence the potential of both olive tree and grapevine for carbon sequestration is still underestimated both in present and future climate. For olive trees, irrigation has been observed to be fundamental over Mediterranean olive orchards in the next future by reducing the expected productivity decrease in rain fed conditions (Brilli et al., 2019). The results of Mairech et al. (2020) pointed out that even in case of deficit irrigation, intensive olive orchards have a high efficiency in carbon sequestration, finally increasing water use efficiency, crop productivity and GHGs mitigation. The same may be applied to grapevine grown in temperate-climate that has demonstrated to be an effective carbon sink (Meggio and Pitacco, 2016) and therefore a good candidate to store carbon in agricultural system in future periods. Management practices can be defined to preserve this storage, possibly contributing to the global carbon budget.

These few examples demonstrated how adaptation and mitigation strategies are not in contrast, but preserving the Mediterranean cultural landscape in future decades requires suitable tools for tailoring crop management on the local scale.

Keywords: climate change, adaptation, mitigation

0006

MULTIPLE CROP MODELS PROJECTION OF WHEAT PRODUCTION UNDER FUTURE CLIMATE CHANGE SCENARIOS IN THE GUANZHONG PLAIN, CHINA

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Climate change can have negative implications on the food security of a region. The current study assesses the impact of climate change on winter wheat crop in Guanzhong Plain, China. The downscaled ensemble projections of 17 general circulation models (GCMs), under two representative concentration pathways (RCP 6.0 and RCP 8.5), were used as input into the calibrated APSIM (Agricultural Production System Simulator) and CERES (Crop Estimation through Resource and Environment Synthesis)-Wheat models. Three types of future simulation were carried out representing no adaptation, elevated CO2, and irrigation adaptation for decades between 2020-2080. No adaptation showed a 4.6-30% decrease in winter wheat yield compared to baseline yield. Under elevated CO_2 (380 ppm-886 ppm), yield was increased by 0.95-10%, and under irrigation adaptation (180 mm-380 mm irrigation over the growing season), yield increased by 5.6-25.5%. On an average water use efficiency (WUE) with irrigation adaptation strategies and elevated CO_2 concentration was improved by 26.5% relative to baseline WUE during 2020-2080 years. When CO_2 concentration reached about 550-866 ppm, the WUE improved by 60% with third irrigation strategy relative to the baseline conditions. It is thus, concluded that based on predicted average yield with the combination of crop modeling, GCM, and RCP data, wheat production in the Guanzhong Plain can be improved in future climate change if irrigation adaptation strategies are adopted in this region.

Keywords: Multiple crop models, Climate change, Adaptations, Irrigation, Wheat yield

00015

HARNESSING CROP MODELS TO PINPOINT THE ESTABLISHMENT QUALITY OF FIELD CROPS UNDER THE 21ST CENTURY CLIMATE CHANGE: CASE STUDIES OF SOYBEAN AND SUGAR BEET IN NORTHERN FRANCE

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Ongoing climate change has been reported to have far-reaching impact on agriculture worldwide owing to increased mean temperatures, higher precipitation variability and higher frequency of extreme temperature events. However, there is paucity of information on the potential effect of climate change on crop establishment that includes three stages: seed germination, seedling emergence and beginning of competition among young plantlets. A better understanding on the evolution of seedbed conditions under future climate change not only facilitates adaptation of crops in their original area of production but also helps explore new areas that were not suitable in the past for a given field crop establishment, but may result opportune in the future.

Here we used a model-based framework to pinpoint whether the establishment quality of soybean and sugar beet in northern France will be affected by future climate change. To this objective, we first parameterized the SIMPLE crop emergence model and tested its prediction quality on seed germination and seedling emergence in relation to temperatures, water content, and soil structure. We then performed a simulation study over the 2020-2100 period, for early, conventional and late sowing dates. We generated soil temperatures and water contents of seedbeds for these three sowing dates using the STICS soil-crop model with the most pessimistic IPCC scenario (RCP 8.5). We then used these data to feed the SIMPLE crop emergence model to run simulations.

Our results showed that, when analyzed by sowing date and for successive 20-year period from 2020 to 2100, there was a significant increase in average seedbed temperatures 30 days after sowing by 2 °C after 2060, while no change in cumulative rainfall 30 days after sowing was found, compared with the past. Emergence rate of sugar beet was generally higher for 2081-2100 while there was no significant change for that of soybean. Main causes of non-emergence for both crops were: seedling death due to clods or soil surface crust, non-germination, and seedling mortality due to drought. Our study shows that the use of future climate scenarios coupled with crop models provide an important insight into future sowing conditions, and result particularly helpful to better project future adaptation of cropping systems.

Keywords: seed germination, seedling emergence, seedbed conditions, modeling

0053

ADAPTATION STRATEGIES TO HIGH NIGHT TEMPERATURE IN WINTER CEREALES AND INTERACTION WITH MANAGEMENT PRACTICES

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Climate change represents one the most important challenges for agriculture around the world. A rising mean temperature is the weather variable consistently predicted by a range of different climate models for the 21st century. In some countries, a distinctive characteristic of this phenomenon is an asymmetric temperature increase, retrospective climate analyses demonstrated that minimum temperature (i.e. night temperature) has increased at a faster rate than maximum temperature (i.e. day temperature). The Argen-

tinean Pampas, one of the most important agricultural areas in the world, has experienced such trend in the winter crop season (wheat and barley). To understand and quantify the impact of high night temperatures in wheat and barley a series of different field experiments using heated chambers placed on the crop between 7PM to 7AM during different stages of the crop cycle were combined with different planting densities, nitrogen and water availability. This approach was extended by using the Agricultural Production Systems sIMulator v 7.7 (APSIM) to quantify and compare the impact of increased night temperature (NTI) in wheat and barley on the Argentinean Pampas in a historical climate series. Field experiments showed that NTI accelerated crop development reducing solar radiation capture and negatively affecting biomass production without changes in harvest index. Night temperature increases reduced yield in both wheat and barley at a rate of ca. 7% °C-1 and 4% °C-1, when warming was applied during pre-and post-flowering, respectively. When NTI applied during the pre-flowering phase were combined with different fertilizer nitrogen rates and densities, the results showed that yield was penalized only at high nitrogen rates (ca. 7% °C-1). In the same way, warmer nights increased tiller mortality only under high nitrogen availability, reducing the final number of spikes established at flowering. Warmer nights reduced grain yield similarly across plant densities. Modelling showed that wheat and barley yields declined across the Pampas between ca. 2% and 9% °C-1 during the critical period, depending on the location. In summary, field experiments and modelling showed that NTI accelerated the crop development, reducing the cumulated intercepted radiation and thereby grain number and/or grain weight. Increases in resources availability (water and nutrients) and some management practices as plant density did nor reduce the negative effects of warmer nights. Changes in sowing date and flowering time seems to be the most suitable management practice to counterbalance the negative effects of warmer nights.

Keywords: Climate Change, Night Temperature, Yield, Wheat and Barley

0131

LAND MANAGEMENT CHANGE EFFECTS ON SOIL ORGANIC CARBON STOCK IN OLIVE GROVE HILLSIDES. IMPLICATIONS IN THE 4‰ NOTION

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The set of abnormal phenomena that give rise to the so-called climate change and its consequences, is currently one of the most significant problems that human beings face worldwide. Within the factors that can reduce the greenhouse effect caused by the Climate change is the soils ability to store organic carbon being therefore a key factor for climate regulation and for other soil functions. Therefore, the study of soils as carbon sinks to reduce these greenhouses gases and improve the living conditions of the planet, advances and is real, but requires further study.

If we talk about the carbon content that we can find in the soil, the land use and management affect to the carbon C in the soil. Given this situation, the so-called 4‰ is implemented, which is a voluntary action plan to improve SOC content in the world at a depth of 40 cm with an annual rate of 0.4%.

At regional level there are zones, such as the Mediterranean areas where the 4‰ target (0.6 t ha^{-1} y^{-1}) could be achieved, since the Mediterranean soils are characterized by low OM content (~1%), due to the climatic conditions, to the low C addition from plant waste, at the low plants density and the intense tillage that has dominated over time in these areas. Therefore, by tillage reducing and acting on the plant cover, the soil recarbonization could be achieved.

Land management change (conventional tillage to no tillage) showed soil carbonization (Summit and Toeslope position) and decarbonization (Backslope position) processes along hillsides. The SOC-S increased 1.88 Mg ha^{-1} y^{-1} and 0.47 Mg ha^{-1} y^{-1} for S and T topographic position respectively, however the SOC-S decreased in B position 5.27 Mg ha^{-1} y^{-1}. Therefore, land management change has a positive effect on soil carbon reserves in S and T position, however in B position, this effect is negative. In addition, to indicate that in certain parts of the world, under certain climatic characteristics (Mediterranean areas) the soil regeneration is possible. This study demonstrates the importance of SOC-S assessment after LUC for a proper management planning in Mediterranean areas.

Keywords: Toposequence; Conventional tillage; four per thousand; Olive grove.

0137

EFFECT OF TILLAGE AND TOPOGRAPHIC POSITION ON SOIL QUALITY IN MEDITERRANEAN OLIVE GROVE HILLSDIES

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Among soil scientists, the ecosystem services concept is often used in conjunction with the concept of soil functions. This is due to in many ecosystems, services depend on the soil health and the biodiversity of the soil biota. So that, by focusing attention on these ecosystem services provided by the soil and its functions, reference will be made to its capacity as a carbon reservoir and how this soil capacity affects its quality.

Based on this, it should be known that atmospheric concentrations of greenhouse gases (GHG), among which including: carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O), have increased considerably due to human activities, such as the combustion of fossil fuels and the uncontrolled land use change of the Earth.

In this framework, agriculture has important effects on the emission and fixation of atmospheric CO_2, in fact it is estimated that agriculture continues to be responsible for approximately a third of GHG emissions. In this line, olive grove cultivation, has long been considered for the great potential it presents to reduce CO2 emissions into the atmosphere, therefore increasing the carbon sinks.

Furthermore, knowing that the traditional olive grove has undergone a profound transformation in recent decades, mainly due to the high cost of conventional tillage, its profitability is sometimes questioned. For this reason, farmers are applying different management techniques to reduce these costs, sometimes even making new plantations. In all cases, these changes in soil management involve variations in its physical-chemical properties as well as in its quality. This fact is especially relevant in Mediterranean climates since climatic conditions decisively affect soil formation processes.

Therefore, the use, management and topographic position are three factors that affect the SOC accumulation in eroded regions, thus affecting the soil quality in these regions, influencing soil temperature and the water content, in addition to also affecting permeability, stratification, stability, and macro and microporosity.

Keywords: soil quality, traditional olive grove, ecosystem services, conventional tillage.

0146

APPROXIMATION OF GREENHOUSE GAS EMISSIONS FOR A FARM NETWORK USING READILY AVAILABLE DATA

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Agriculture contributes significantly to climate change. The Swiss agriculture sector emitted 6.5 million tonnes of CO_2-equivalent in 2016, accounting for 13 percent of total emissions.

Together with the research institute Agroscope, the Swiss farming association IP-SUISSE has launched a project for promoting measures to reduce greenhouse gas (GHG) emissions on farm level of all IP-SUISSE farms by 10% compared to 2016 levels by the year 2022. This requires to estimate the total GHG emissions of all IP-SUISSE farms in 2016. Because data acquisition is an overly time-consuming process, however, computing GHG emissions in detail is not feasible for all 10'000 IP-SUISSE farms. As part of this project, GHG emissions were therefore computed for 33 IP-SUISSE pilot farms for the year 2016 using the Swiss Agricultural Life Cycle Assessment (SALCA) method. Based on these results, we derived a regression model that predicts the GHG emissions for all IP-SUISSE farms with sufficient accuracy by using data that are available for all IP-SUISSE farms. Such a regression model allows to estimate the cumulative GHG emissions for the whole IP-SUISSE farm network.

Based on readily available farm level data and a number of theoretical considerations concerning key factors driving the GHG emissions of the individual farm, the following parameters were selected as predictor variables for the dependent variable GHG emissions: (i) utilised agricultural area UAA, (ii) open arable land OA, (iii) total livestock TL, and (iv) total cattle TC. After applying stepwise model selection by AIC for elimi-

nating the insignificant variables and removing scaling effects by predicting the farm's GHG emissions per UAA [in t CO_2eq / ha], the following quadratic polynomial regression model was obtained:

*GHG/UAA= 10.56 - 2.73 * TLD + 1.48 * TLD* ^{2} *- 23.61 * POA + 17.91 * POA*^{2}, (1)

where *TLD= TL/UAA=* total livestock density and *POA= OA/UAA=* proportion of open arable land.

Eq. (1) explains 92% (*R*=0.96) of the total GHG variance for the pilot farms. Extrapolation to the entire Swiss agricultural sector using Eq. (1) showed good agreement with available independent estimates, but further validation is certainly needed due to the relatively small number of pilot farms and their limited representativeness.

Keywords: *greenhouse gas emissions, LCA, extrapolation, polynomial regression model*

0156

MODELLING DORMANT SEEDING OF RAINFED CHICKPEA AS AN ADAPTATION STRATEGY TO SUSTAIN PRODUCTIVITY UNDER CLIMATE CHANGE

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Dormant seeding management (DSM) is a useful adaptation strategy to sustain chickpea productivity particularly under climate change. Accordingly, the SSM-Legumes model employed to evaluate the effects of DSM versus fixed sowing dates (at three levels) and cultivars (early-, mid- and late-maturity) on chickpea production and water use efficiency in eight locations in west and northwest of Iran. Daily climatic data from 1980 to 2010 was collected from the Meteorological Organization of Iran as baseline. Projections of the future climate was accomplished in Miroc5 (Model for Interdisciplinary Research on Climate) GCM for the future of 2040-2070 under RCP4.5 and RCP8.5 emission scenarios using the methodology presented by AgMIP (Agricultural Model Intercomparison and Improvement Project). The results showed that DSM2 (dormant seeding around late February) × a mid-maturity cultivar produced much higher grain yield (1382 kg ha-1) in comparison to other combinations of sowing dates and cultivars in baseline. However, in the future, ILC482 × DSM1 (dormant seeding around 20 December) showed the best performance in terms of grain yield (1350 and 1484 kg ha-1 for RCP4.5 and RCP8.5, respectively. Results also indicated that water use efficiency was much higher in DSM1 and DSM2 (3.6 and 4.6 kg ha-1 mm-1, respectively) compared to the fixed sowing dates in baseline. However, combination of DSM2×ILC482 in baseline, resulted in 1.3 kg ha^{-1} mm-1 greater water use efficiency than DSM1×ILC482. In the future, ILC482 cultivar under DSM1 showed highest water use efficiency (5.2 and 5.8 kg ha-1 mm-1 for RCP4.5 and RCP8.5, respectively). Overall, DSM in combination of a mid-maturity cultivar under climate change could be considered as a suitable adaptation strategy to increase the length of growing season, coincide winter and early-spring rainfalls with the critical period of chickpea growth and consequently increase grain yield and water use efficiency.

Keywords: Cultivar, Grain yield, Modelling, Sowing date, Water use efficiency.

0160

STRATEGIES FOR ADAPTING VITICULTURE TO CLIMATE CHANGE: A PARTICIPATORY MODELING APPROACH WITHIN A MEDITERRANEAN CATCHMENT

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Climate change may have negative impacts on agriculture, especially under Mediterranean climate. In the South of France, grapevine is mostly grown under rainfed conditions and water management will be more and more determinant to maintain a wine-growing activity. Various adaptation levers to water scarcity have been explored: irrigation, plant material, planting density, training system, soil management, etc. Local adaptation strategies may combine these adaptation levers into diverse cropping and farming systems, when considering current and future water resources.

This paper presents a methodology that articulates a participatory approach with modeling tools, in order to carry out a multi-scale assessment of strategies of adaptation to climate change. The study starts with the design of site specific adaptation strategies with stakeholders in a medium-sized catchment of the South of France. Then, these adaptation strategies are evaluated through the development of an ad-hoc model. First, we built a conceptual model with the stakeholders to raise climate events, impacted processes, adaptation levers, their implications and requirements. Second, we coupled numeric models to fit the stakeholders' conceptual model. Third, spatialized strategies were defined with stakeholders and quantitatively evaluated under future climate scenarios RCP 4.5 and RCP 8.5.

First results show that not all the practices and processes highlighted by stakeholders can be simulated with the existing tools, e.g. vine microclimate, sunburn damages, vine mortality, etc. This gap tends to be reduced through interactions with stakeholders and collective validation. The ad-hoc model is composed of three field-scale models - phenology, water balance, yield formation - integrated in a landscape modeling platform. The final model allows to capture part of the diversity of cropping and farming systems within the catchment as described by stakeholders in the baseline situation. The next step is to build and evaluate the alternative strategies. Through this study, we suggest that an integrative assessment combining adaptation levers in time and space, is relevant to define locally adapted response to climate change.

Keywords: Climate change, water management, modeling, farming system

0175

IDENTIFICATION AND EVALUATION OF CROP ADAPTATION STRATEGIES TO CLIMATE CHANGE FOR WHEAT, POTATO, AND SUNFLOWER IN FRANCE.

To face Climate Change (CC), plant sectors focus on the development of cropping and breeding strategies that limit the impacts of increasing abiotic stresses on production. This often overlooks plant health risks that are either directly induced by CC, or indirectly through adaptations of agricultural practices.

In this context, the project "crOP disEase Response to climATE change adaptation", aims to address this issue for wheat, sunflower and potato.

The first step of the project consists in prioritizing future scenarios for adaptation to abiotic stresses, for two French regions with contrasting climates. Surveys conducted among stakeholders have highlighted the following strategies (Fig 1):

1. compensation for limited water resources, and improvement of water uptake and water use efficiencies by crop species and varieties;
2. avoidance of unfavourable conditions by shifting sowing dates and using the diversity of variety earliness, including the relocation of crops in time and/or space;
3. redesigning supply chains by introducing new species (sole or in mixtures) and/or diversifying cropping systems;
4. moving toward agroecological crop management with the addition of cover crops or intercropping.

The second step consists in simulating several adaptations and their impacts on production, environment, and plant health. Different crop and disease models were combined (Fig 2) to simulate the consequences of adaptation strategies considering three soil water content and two CC scenarios, either the moderate RCP 4.5 or the alarmist RCP 8.5. For wheat, biotic risks seem to decrease in the future for Septoria and Fusarium without adaptation. However, further compromises arise with necessary irrigations to maintain yield. The combination of several levers allows identifying best compromises considering multiple pathosystems (rusts, Septoria, Fusarium and eyespot). For potato, an increased late blight risk in spring was shown; anticipating planting dates and developing varieties more resistant to late blight and drought-tolerant are two relevant adaptation paths, but with the variability in quantity and quality remains unknown.

Finally, for sunflower, a more rustic species, CC could be an opportunity to expand in new, further north growing areas, thus diversifying crop sequences, and probably reducing the risk of fungal diseases due to short rotations (e.g. Downy Mildew, Phomopsis stem canker).

The third step consists in identifying the most promising adaptation strategies using a multi-criteria analysis. A method based on a qualitative multi-attribute decision making will be applied for each crop. Three main categories of evaluation criteria will be considered: quantity and quality of production, environmental impacts, health risks, economic or environmental indicators (Fig 2).

Most promising strategies will be presented to the sector stakeholders to be further improved and their feasibility will be discussed.

Keywords: modeling, simulation analysis, abiotic risk, biotic risk, cropping practices

Figure 1. How do you plan to adapt your practices to face climate change?

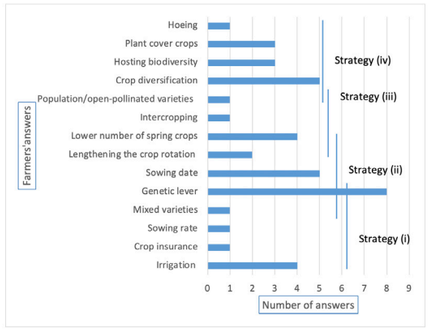
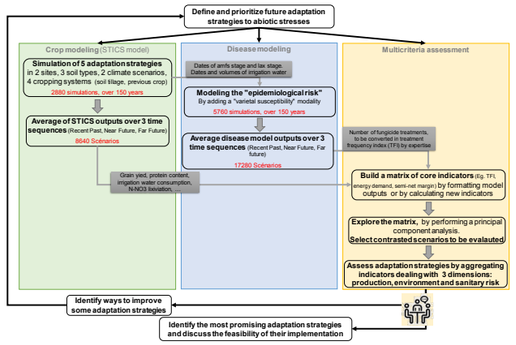


Figure 2. The different steps of the approach for the wheat case study. Some models' variables are given in example to illustrate the combination of the models used, as well as the indicators integrated in the multicriteria assessment.



0239

SOIL ORGANIC CARBON SEQUESTRATION IN MEDITERRANEAN AND HUMID SUBTROPICAL CLIMATES UNDER CONSERVATION AGRICULTURE: FIRST STEPS OF A META-ANALYSIS

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Organic carbon sequestration in agricultural soil has a crucial role to address the lastest challenge about crop productivity and climate change. In this context also conservation agriculture (CA) has a great impact enhancing soil organic carbon (SOC) stock and crop yield. Due to the large amount of SOC data available comparing conventional and conservation agriculture, it is difficult to draw conclusions about the effect of CA practises in specific climate/agronomic conditions. The meta-analysis approach allows to overcome this issue, quantifying the effect of CA on SOC sequestration.

This preliminary work shows the methodology used to collect, extract and summarise data to perform a meta-analysis on soil organic carbon sequestration in the Mediterranean and temperate soil under CA in field crop experiments.

The *first step* was the definition of a nested query and its application to both Scopus and Web of Science databases. The *second main step* consisted in the geographical screening: only field work conducted within Cfa, Csa, Csb, Csc Köppen climate area have been selected. Then, as a *third step*, we choose the agronomic characteristic to analyse for both treatment and control: a clear definition of their properties has the potential to make conclusions stronger and unambiguous within the specific climatic and agronomic criteria selected.

The *last step* refers to the carbon data extraction methodology, useful to access to the data and their standard deviation (SD). A tool for extraction of missing SD data was developed as well as a mathematical approach to compute SD when different carbon stock soil layers were added or a product between bulk density and carbon concentration has been done.

The bibliometric database approach results in more than 900 articles of which only 199 have been selected due to the geographical restrictions (step two). Our control and treatment characteristics (third step) and the effective availability of carbon data in the articles reduced to 60 the final number of field experiments available. Finally, data were organized into a database with five main sections: papers reference (authors, year etc.), experimental timing (duration, sampling timing etc.), control and treatment features (tillage, crop etc.) and experimental data (C data, soil texture, fertilization type etc.).

The methodology applied in this study represents a reproducible way to collect and analyze single-study results. The organized database obtained will be utilized to perform a meta-analysis about the effect of agronomic management factors (tillage, soil coverage, N etc.) on SOC in CA.

Keywords: soil organic carbon, conservation agriculture, meta-analysis, Mediterranean climate

0243

CARBON AND NITROGEN FOOTPRINT OF DRIP-FERTIGATED GREENHOUSE TOMATO CROPS

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Intensive vegetable production systems are of major economic relevance in many areas of the world, such as in SE Spain, with the largest concentration of greenhouses in Europe, allowing the production of all-season high-quality vegetables. However, these systems present an important potential for high emissions losses because of high nitrogen (N) inputs and excessive irrigation. The Carbon Footprint (CF) and more recently, the Nitrogen Footprint (NF), can be used to improve our understanding on the pressure exerted to the environment by agricultural activities. The CF quantifies the greenhouse gas emissions (GHGs) and removals in a system and it is widely accepted to assess climate change. The NF on the other hand, reflects the total amount of reactive N (Nr) losses as N_2O emissions, NH_3 volatilization and NO_3 leaching, mainly related to the application of N fertilizers. The total GHG and Nr emissions were calculated following a life cycle assessment approach, considering the inputs associated to the fertigation management of greenhouse tomato crops (N, P and K production and transport). A total of fourteen different scenarios were used comprising the fall-winter and spring seasons, and soil and substrate growing media. Different seasonal N application rates were applied with values ranging from a minimum of 28 to a maximum of 731 kg N ha^{-1} in soil and from 379 to 479 kg N ha^{-1} in substrate. GHG emissions were lowest for a fall-winter soil grown tomato and highest for a spring soil grown tomato (1,398 and 12,395 kg-CO_2eq ha^{-1}, respectively), and were directly related to the lowest and highest N application rates. The contribution from fertilizer production and transport to these emissions accounted up to 92% in a spring crop. The lowest and highest CF values of 18.7 and 139.4 kgCO_2eq t^{-1} were obtained for the fall-winter 2011/2012 soil crop with N rates of 28 and 677 kg N ha^{-1}. Reactive N losses increased by 68% and 49% when N application increased by 44% and 59% for a spring and a fall-winter crop, respectively, with respect to the optimum rate, with no significant effect on commercial production. The highest contribution to Nr losses was from NO_3 leaching in most scenarios (up to 49%). The scenario with the highest Nr losses also showed the highest NF value of 2.3 kgN t^{-1}. This study highlights that better adjusting irrigation and N fertilization can reduce the environmental footprint and contribute to sustainable greenhouse tomato production.

Keywords: Modeling; Environmental impact; Fertilization; Making-decision tools; Horticulture

0270

GRASSLAND RESILIENCE TO CLIMATE VARIABILITY ON NITRATE LEACHING

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Introduction

The aim of this paper is to describe data collected over 5 years on estimated leaching levels using a simple computational procedure and measurements of soil, water content and water balance, nitrate concentrations in drainage water and meteorological data, and to assess the impacts of the type of culture and the level of nitrogen fertilization on the drainage water quality.

The nitrate leaching follow-up was carried out with a ceramic cups device. 168 candles were planted under 12 plots so that several types of ground cover, grassland or cereal crops could be evenly distributed. Each plot was divided into 2 sites, one respecting a specification limiting the supply of nitrogen or risk crops, and the other according to the desires of the farmers. Samples are taken every 40 mm of rain and sent to the Nestlé waters analysis laboratory. Nitrate concentrations in $mg.L^{-1}$ are then converted to kg nitrogen.

Results

This study collected data from the 5 main drainage periods during the 6 last years, marked by two years of intense consecutive drought (2017 and 2018), followed by a year of heavy rain.

The results show no significant correlation between the nitrogen supplied and the quantity of nitrogen less when these contain the data for all the plots. Same observation on the effect of the draining water flow.

As a result, we have been able to demonstrate the role of grasslands on water quality, grassland nitrate leaching is 225% lower than cropland (rapeseed, winter

wheat, winter barley) leaching, and very good annual grassland resilience on leached nitrate concentration. Grazing has been identified as the main factor in increasing nitrate concentrations in water, but intensively grazed grasslands still have a better effect on water quality than annual crop.

This study demonstrates the importance of grassland on water quality, and the fact that plant cover has priority over management mode. Furthermore, its strong resilience to the impacts of climatic variations, which will probably be more and more present, shows the need to develop new permanent grassland all over Europe.

Keywords: climatology, monitoring, water quality,

Session 2.5: Protecting natural resources and the human environment

0046

MODELLING OF SOIL NITROGEN DYNAMICS IN CROPPING SYSTEM WITH LEACHM IN RAINFED SEMIARID MEDITERRANEAN REGION

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Quantification of N dynamics in the ecosystem has taken on major significance in today's society, for economic and environmental reasons. It is difficult to understand the N-dynamics of agricultural ecosystems without the support of deterministic and stochastic simulation tools. LEACHM is a deterministic model for simulating N-dynamics in soil. In this research study, soil nitrate-N (NO3-N) content was simulated for a 7-year period in N-fertilized barley (Hordeum vulgare L.) and wheat (Triticum aestivum L.) in a rainfed semiarid Mediterranean area, located in a Northeastern Spanish region. Simulation was applied to two levels of N mineral fertilization treatments, which included a control (no N applied) and 120 kg N ha-1 yr-1 fertilization applied in the whole study period. Model results were compared with data originating from a field experimental site. Firstly, a global sensitivity analysis method called LH-OAT (Latin Hypercube-One factor At a Time) was performed to select the most sensitive parameters of LEACHM model. Then, the model was calibrated and validated using the field data. Our results showed a good agreement between simulated and measured NO3-N contents in the whole soil profile. The LEACHM model also predicted a considerable amount of leached NO3-N contents in the soil profile. In this research study, the soil NO3-N leaching losses varied from 0.1 kg ha-1 yr-1 in 2006-07 to 149.3 kg ha-1 yr-1 in 2009-10 which means that nitrate-N leaching exists despite the low annual precipitation. The agreement index (d), R2, MD, RMSE, and NRMSE supported the model performance. The d and R2 ranged from 0.87 to 0.99 and 0.80 to 0.99 (0-90 cm), respectively. These results suggest that the LEACHM is an useful tool to simulate the soil NO3-N contents and nitrate leaching under the winter cereal cropping period when mineral N fertilizer has been applied for the long-term in a rainfed semiarid region.

Keywords: LEACHM, LH-OAT, mineral fertilizer, nitrate leaching, rainfed cereal system.

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0086

PRESERVING ENVIRONMENT THROUGH FARMLAND MANAGEMENT PRACTICES (FMP)? A GENERIC REVIEW

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Our research work examined the overall environmental impacts of farmland management practices (FMP). Based on a review of the international literature and using an analytical framework at the interface of sociology and agronomy (landscape agronomy), it explored the links between FMP and changes in agricultural practices for the achievement of environmental goals. The Web of Science (WOS) and SCOPUS bibliographic databases were used to identify references on the environmental effects of farmland management practices. A corpus of 108 references from 40 scientific journals was selected and read in depth. We considered farmland management practices as land uses generally dependent on the overall functioning of the farm and resulting in changes in terms of agricultural property rights.

Our main finding is a typology of management practices based on the distinction between bottom-up strategies (relying on local initiatives from farmers) and implementation strategies (following either public administrations or private firm's policies). Our results also highlight the environmental impacts of FMP: tenure arrangements (rental or exchange of land parcels) may induce changes in crop succession and reduce phytosanitary pressure without implying any change in cropping plan. Considering the very direct agronomic implications of farmers' land dynamics, we conclude considering FMP as a lever to reduce the environmental impacts of agricultural activities and protecting natural resources. This lever is currently being explored within the framework of a PhD research at INRAE (France), which explores temporary land recombination's between farms.

Keywords: farmland management, environmental impact, farming system

0147

SIMULATING NITRATE LEACHING FROM AGRICULTURAL LAND USE IN GERMANY

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Germany is under high pressure to further reduce nitrate emissions into water bodies from agriculture. Currently, the connection between observed nitrate concentrations in wells across Germany and agricultural management is not sufficiently understood. We use the mechanistic agro-ecosystem simulation model MONICA on a high-performance cluster computer to simulate crop growth, management and resulting nitrate leaching on a hectare scale. The simulations are based on exemplary crop rotations and a baseline management. Against this baseline, several options to reduce nitrate leaching are tested. The simulations feed into an online marketplace for ecosystem service trade.

We use the mechanistic agro-ecosystem simulation model MONICA (Nendel et al. 2011) on a 5000 core high-performance cluster computer to simulate crop growth, management and resulting nitrate leaching on a hectare scale. Weather and phenology data was taken from the 1 km² product of the German Weather Service (DWD). Simulations for 2m deep soil profiles based on the BÜK200 soil map were conducted to produce 30y averages on 16.6 M grid cells.

MONICA simulations reflect well the average and inter-annual yield gradients across Germany, exemplarily shown for wheat and silage maize when compared to county-level yield statistics.

The results display the different effect of the measures across the different soil-climate zones of Germany. The simulations serve to evaluate the compensation target and as incentive for positive engagement that is initially directed towards the conservation of biological diversity. At this stage, results do not yet help intermediaries to find the best areas for their measures and to assess where the highest values can be achieved in the most cost-effective way and with further high ES relevant for an offer on the market place.

Keywords: high-resolution modelling, EU Nitrate Directive, ecosystem service trade

0159

SOIL PHOSPHORUS (P) MINING IN AGRICULTURE - IMPACTS ON P AVAILABILITY, CROP YIELDS AND SOIL ORGANIC CARBON STOCKS

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Leaching of phosphorus (P) to the groundwater, and eventually increasing P concentrations in surface waters, is one of the major causes of diffuse P losses towards the environment in north west Europe. Although the P fertilizer application rates have decreased markedly over the past decade, P leaching continues to be a problem, and additional measures will be needed. One such drastic measure could be the complete omission of P inputs in the rotation (P mining). Greenhouse experiments have shown that the plant available P pool can be reduced rapidly with crops not receiving any P inputs, but field trials confirming these findings are rare. There is a need for scientific evidence on (i) evolution of crop yields as a function of P mining time, (ii) which crops would be most efficient at P mining, and (iii) how soil organic carbon (SOC) levels can be maintained in the absence of exogenous organic matter application. In order to address these questions we set up two P mining (0 P application) field experiments in soils with very high initial soil P status, and compared crop yields, and evoluation of soil P status and SOC level to a business as usual scenario with organic P fertilization. In one site, we compared the inclusion of a (harvested) catch crop with a scenario without catch crops after the main crop. In the other site, we compared the mining effect of a vegetable crop rotation and an arable crop rotation including two years of grass. Four consecutive years of 0 P fertilization had no effect on neither the crop yield nor the crop P uptake. Further, grass, maize, celeriac and Chinese cabbage most strongly contributed to P removal. The strong negative P balances of 102 to 121 kg P ha^{-1} over four years had no measurable effect yet on soil P stocks. Simulations of the evolution of the SOC content over a thirty year period showed that the use of grass as green manure or as main crop only partially compensate the SOC losses resulting from omission of organic fertilizers. In conclusion, a significant reduction of excessive soil P stocks can only be achieved by an extended period of P mining, and negative effects on SOC can be balanced by adapting the crop rotation. However, this would obviously come at a significant cost for the farmer.

Keywords: P leaching - P mining - Soil P stocks - Soil organic carbon levels

0223

LONG TERM RESPONSES OF CROP YIELD, SOILS AND NITRATE LOSSES TO BEST AGRICULTURAL PRACTICES AT THE CATCHMENT SCALE.

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Facing the nitrate pollution problem, the European Union has encouraged a code of "Good Agricultural Practices" (GAPs) in order to recover a good biochemical and ecological status of waterbodies. However, the efficiency of GAPs application remains greatly unknown on the long term and at a large spatial scale. In this work, we studied the water and nitrogen fluxes in a small (187 ha) agricultural catchment during 22 years after GAPs implementation (Beaudoin et al., submitted, J. of Environ. management).

This prevention action relied on the hypothesis that a systematical GAPS application would allow nitrate at the outlet to meet the US standard (50 mg NO_3 L^{-1}). GAPs consisted in adjusting N fertilization rates, establishing catch crops and converting two fields into grassland. The aquifer outlet is a set of water springs which were monitored for water flow and nitrate concentration. The water (RN) and solute (RS) renewal times in the catchment were assessed by three methods. RS was estimated at 13-25 years and RN was 14-74 years, all indicating a strong inertia of the hydrological system.

Soil water and mineral N were measured two or three times per year on 36 permanent sites representative of soil and crop variability. These data were used to initialize the STICS model which predicted water drainage and N leaching. At field scale, without integrating set-aside fields, drained water below rooting depth was on average 179 mm yr^{-1}, N leached 19 kg N ha^{-1} yr^{-1} and nitrate concentration 44 mg NO_3 L^{-1}. Nitrate concentration decreased with soil water retention capacity.

Nitrate concentration in the main water spring began to decline 11 years after GAP implementation and levelled off to 49 mg NO_3 L^{-1}. The STICS-MODCOU agro-hydrogeological modelling chain satisfactorily predicted water flow and nitrate concentration of the springs but overestimated the response time. Observations and modelling proved the positive impact of GAPs which appear economically competitive, as compared to the curative water treatment, but require long term management. The role of set-aside was here marginal and with higher costly/efficiency ratio than GAPs. A more flexible land occupation could combine land sparing and land sharing. GAPs are expected to be components of the transition towards agro-ecological systems within a loop of progress.

Keywords: cropping systems, nitrate pollution, N surplus, deep aquifer, STICS model.

0278

PARTICIPATORY CONSTRUCTION OF FERTILITY AND HEALTH INDICATORS IN AGRICULTURAL SYSTEMS WITH A MEDITERRANEAN CLIMATE IN CHILE

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Objective: To build indicators of fertility and health of agricultural systems, which allow visualizing and understanding the areas that are influencing the transition towards sustainable agricultural systems. The aim is to recognize the social, economic, and ecological variables that influence this transition, helping to maintain or improve the aspects linked to a fertile and healthy agricultural system. Methodology: The hermeneutic perspective was used, which allows the revision of theoretical antecedents and their subsequent empirical contrast with the collection of data through semi-structured interviews and participatory workshops, which allowed the visualization of the diverse perspectives of five farmers from the central zone of Chile. Results: Six indicators are elaborated, covering in a holistic way the social, economic and ecological spheres, present in the transition towards sustainable agricultural systems, managing to recognize and incorporate elements, both quantitative and qualitative, that are identified through the farmers' discourse. Conclusions: The fertility and health indicators developed, by presenting a participatory character in the methodology, have facilitated the approach of themes that have scarcely been described in similar investigations, managing to incorporate and visualize the different environments that influence the transition to fertile and healthy agricultural systems in an integral manner.

Keywords: Sustainable Agriculture- Indicators- Participatory research

Session 3.
Efficient use of resources in agriculture

Session 3.1:
Sustainable intensification In farming systems

0034

EXCELLENCE IN AGRONOMY 2030: A CGIAR-WIDE INITIATIVE TO TAKE DATA-DRIVEN AGRONOMY TO SCALE IN THE GLOBAL SOUTH

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Major advances in crop productivity, climate resilience, and resource use efficiencies have been achieved through agronomic interventions. Various projects are building on revolutions in data availability and analytics, including high-resolution soil and weather data, to design decision support systems that allow farmers and partners to make better-informed choices, in their specific context and according to their specific production objectives. While these projects have shown that the advice delivered is highly contextual, the principles and approaches to develop and deliver such advice are not. Moreover, the demand for agronomic solutions that apply to large production areas while recognizing diversity in production conditions at various scales has grown considerably in the past decade, mainly driving by a growing number of last-mile advisory providers.

As a coordinated effort of nine CGIAR centers, Excellence in Agronomy 2030 (EiA 2030) will leverage advances in spatial and process-based agronomy, remote sensing, big data analytics, and decision science to make transformative contributions towards improving the productivity and profitability of crops, increasing climate resilience, and rehabilitating soil health in the context of sustainable intensification. EiA 2030 will respond to specific demand from public and private scaling partners, engaged in delivering agronomy solutions at scale in the Global South.

Progress with implementing agronomy R&D at scale will be presented through a number of case studies focusing on various crops in diverse agro-ecologies, including site-specific fertilizer recommendations for rice, maize, and cassava, and with a diversity of scaling partners. Future efforts will focus, amongst others, on supporting decision-making at farming system level, diversification of farming systems to deal with climate variability, and using agronomy interventions towards the sustainable intensification of smallholder farming systems.

EiA 2030 aims to be an international initiative in collaboration with National Agricultural Research Systems, private and public sector partners, and Advanced Research Institutes. During its Incubation Phase (2020-2021), innovation projects will be initiated with direct engagement of the above stakeholders.

Keywords: global agronomy, sustainable intensification, cropping systems, crop management

0095

CONTRIBUTION OF IMPROVED IRRIGATION ON NARROWING FARMERS' WHEAT YIELD GAPS IN NORTH-EAST IRAN

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Yield gap describes the difference between the potential yield of a specific crop genotype in a given environment and farmers' actual yield. Narrowing yield gaps offers the opportunity to increase production without expanding cropland. Quantifying and explaining farmers' yield gaps allows identifying the constraints that farmers face regarding productivity and evaluate opportunities to narrow yield gaps. Golestan province in northeastern Iran is an important national base for wheat production and contributor to food security. Here we collected primary production data of 540 wheat producing farm households, which we selected through a stratified random sampling procedure. Building on farmers' reported crop management as well as site-specific soil information and daily weather data, we employed the AquaCrop model to estimate each individual farmer's water limited and potential wheat yields under current and optimized management. With average actual yields of 3.5 t ha^{-1} and potential non-water limited yields of 8.2 t ha^{-1}, we identified a wheat yield gap of nearly 60%. By solely optimizing irrigation management, yield gaps could be reduced from 60% to around 50%. If farmers could overcome all other yield limitations including weeds, pest and diseases as well as suboptimal timing of management measures, yield gaps could even be reduced to around 20% using current (suboptimal) irrigation practices. The analysis shows that the often-claimed necessity and potential of improving irrigation water supply and management is only one (relatively small) part of the solution. To narrow yield gaps in Iranian wheat production it requires a broader approach that integrates stable input supply and training of farmers in all aspects of crop management.

Keywords: AquaCrop, farm survey, attainable yield

0114

TYPOLOGY OF LOWLAND RAINFED RICE PRODUCTION AND ITS IMPLICATION FOR SMALLHOLDER AGRICULTURAL INTENSIFICATION IN NORTHERN GHANA

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The adoption of Green Revolution type technologies in Africa has been generally greeted with pessimism as the expected yield increases obtained in Asia failed to materialize on the continent. This pessimism is supported by evidence of low technology adoption rates and low productivity over several decades (Evenson and Gollin 2003). The dominant narrative is that the conditions pertaining in Asia that saw significant productivity increases under the Green Revolution do not exist in Africa. In recent times, however, there has been renewed interest in Green Revolution-type intervention by most countries in Africa including Ghana. This is characterized by state intervention in the form of input subsidy aimed at spurring agricultural transformation as a means to achieve economic development. It is argued that the prevailing conditions for agricultural production in Africa have become much more similar to those that existed in Asia during the Green Revolution namely; increased population, improved access to markets, improved rural infrastructure, growing land scarcity, improved access to modern input, growing demand for food and an improved urban environment (Pingali 2012). This study seeks to understand the pattern of intensification and transformation in smallholder lowland rainfed rice production and pathways for agricultural intensification in northern Ghana. The study focuses on household plot level interventions in two valleys in the Savelugu District of the northern region. The paper examines changes in the farming system among smallholder rainfed farmers and the role of endogenous factors mainly land, inputs, and labour use in driving intensification of rice production among households and whether in a direction similar to that of the Asian style Green Revolution. Methodologically, the study will construct typologies of smallholder rainfed rice production in the two valleys based on the intensity of input, labour and land use. Multivariate statistical techniques will be employed to categorize farm households and factors accounting for the differences among the households determined by taking into consideration socio-economic and institutional factors impacting household adoption of sustainable intensification strategies. The study aims to contribute to the debate on the nature and conditions for agricultural intensification among smallholder farmers in Africa and the limited knowledge in smallholder intensification in Ghana.

Keywords: Intensification, adoption, typology, technology, agriculture

0241

SYNERGIES AND TRADE-OFFS BETWEEN YIELD, QUALITY, RESOURCE USE EFFICIENCY AND ENVIRONMENTAL IMPACT OF POTATO PRODUCTION IN CHINA

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Potato is the fourth most important food crop in China. However, the yield is relatively low and the production is associated with high resource inputs and serious environmental problems. Potato production should be enhanced with sustainable practices that strike the right balance between multiple sustainable development objectives (agronomic, economic and environmental). The major aim of the present study was to explore the theoretical possibilities and demonstrate pathways for sustainable intensification of potato cultivation in China that optimize yield and quality, use natural resources efficiently, and minimize environmental impacts simultaneously. Crop modelling and farm surveys were used to assess these objectives at national and regional level, while on-farm experiments were performed to evaluate sustainable practices at local level.

The biophysical potential of the potato crop in China was explored and the scope for enhancing yield was estimated. There is large potential to improve potato yield across the country under both irrigated and rainfed conditions (the yield gap is 66% and 61%, respectively, for irrigated and rainfed potato crops). Improving environmental sustainability of potato cultivation should also be economically viable, and both yield and quality are key components driving the revenues for farmers. It was found that enhancing yield up to the maximum yield obtained by farmers in the case study was strongly associated to improvement in quality and revenue, suggesting synergies for reaching different objectives. An integrated assessment on yield, resource use efficiencies (nitrogen use efficiency and water productivity) and environmental impacts (nitrogen surplus and water surplus) was performed for large-scale commercial farms in three major potato production regions in northern China (Inner Mongolia, Gansu and Heilongjiang). Potato production was associated with moderate resource use efficiencies and substantial environmental impacts due to the application of excessive amounts of fertiliser and irrigation. We assessed that a higher nitrogen use efficiency was achievable with more efficient nitrogen management. The pathways towards sustainable intensification were explored experimentally on large-scale commercial farms in Inner Mongolia in two years (2017–2018). In both years, irrigation contributed significantly to a higher yield and better quality in comparison with rainfed conditions. Under irrigated conditions, reducing nitrogen fertiliser from the current rates to lower levels did not affect yield nor quality, while it largely improved nitrogen use efficiency and reduced N surplus. The present study provides crucial knowledge and contextualized suggestions to underpin sustainable intensification of potato production in China.

Keywords: Potato; yield; quality; resource use efficiency; environmental impacts

0255

DEVELOPMENT OF AN ECONOMIC THRESHOLD FOR HERBICIDE APPLICATION IN COMMON WHEAT

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ESA: Efficient use of resources in agriculture

The development of Integrated Pest Management (IPM) systems has been a goal in agriculture for many years. For many important insect pests and plant disease IPM has been reached remarkable results. However development of IPM systems for weeds has lagged behind other pest management disciplines (Hartzler and Buhler, 2007).

The Integrated Weed Management System defined that a treatment is justified only if the damage that could be caused by the weeds is greater than the cost of the intervention itself (Berti et al., 2001). In this context, monitoring activities are crucial to avoid calendar-based herbicide applications especially at lower weeds that do not warrant treatments. In addition, strategies to control weeds with less herbicide to reduce production costs and to protect the environment can represent an interesting challenge, also in developing countries. To reach this object, monitoring activities were organized in 4 farms located in Emilia Romagna Region (Italy), during the 2019/2020 growing season. A randomized complete block design was adopted, with 2 replicate blocks, comparing for the herbicide treatment factor (treated and no-treated). At BBCH 23-30, in 10 areas (1 m2) within each experimental plot an assessment of site-specific evaluation was realized, which included the identification of weed species and the measurement of the number of plants for each species. Using the competitive index “i” and “a” calculated by Berti and Zanin (1998), a prediction of yield loss based on weed density were estimated based on the rectangular hyperbola model (Cousens, 1985). Data on yield and quality production (i.e. protein content, % of impurities in the harvested wheat), and the cost of the herbicide treatments carried out in the field will be used to verify the accuracy of the model, and to establish an economic threshold. In conclusion, the monitoring activities with a validate economic threshold can improve and consolidate a more sustainable weed management system.

Keywords: Cereals, Weed management, Environmental impact

0259

ACHIEVING PRECISION IN ON-FARM EXPERIMENTS

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The potential for farmers, advisors, industry and science to learn from on-farm experiments and data sharing is increasingly being recognized. Since 2017 we have worked with a group of 50 farmers and BASF to compare products on-farm in simple ‘Line Trials’, with the new ‘Agronomics’ statistical approach applied to yield maps to provide robust ‘Real Results’. This paper demonstrates the methods used and experience gained from conducting on-farm experiments to test farm decisions with large numbers of farmers. We show that analysis of combine harvester yield maps of on-farm experiments can give precision comparable to conventional small-plot experiments, if the trials are designed with reference to underlying variation and managed with care. Large series of on-farm experiments can therefore be used to achieve much greater precision in testing a decision than would normally be possible, at a commercially relevant scale with modest cost and with the benefit of real farmer engagement.

A series of 51 winter wheat experiments across the UK in 2019 compared the new fungicide Revysol against ‘farm standard’ competitor products at either one or two application timings. Host farmers chose trial fields, applied products and harvested the crops using commercial combine harvesters capable of providing spatially referenced yield maps. Researchers proposed site-specific trial designs based on examination of underlying variation, to avoid bias due to former field splits or other soil variation; marked out treatment areas before application to reduce the risk of application errors; assessed disease severity; advised on best harvest practice; and analysed yield map data. In each trial, treatment areas consisted of alternating single or double spray bouts running the full length of the field, replicated up to four times depending on the constraints of field size and shape.

Yield map data were received from 47 out of 51 experiments, and weighbridge results from a further two experiments where yield mapping was unavailable; this high ‘success rate’ for on-farm research is the result of relationship building over multiple years and farmer engagement throughout the season. The standard error of the yield differences in individual experiments ranged from 0.05 to 0.63 t/ha, with an average of 0.26 t/ha. A cross-site analysis of the results, weighted by precision, gave a yield advantage of Revysol over farm standard programmes of 0.20 t/ha (SE 0.06 t/ha). We believe that precision farming technologies with farm-centric research can enable the wider testing of any decision, product, system or innovation, potentially transforming the science of agronomy.

Keywords: On-farm experimentation; spatial statistics; Agronomics;

0263

STABILITY OF QUALITY AND YIELD IN WHEAT COMPOSITE CROSS POPULATIONS

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A composite cross (CC) is a mixture of F1 hybrids of the same plant species. These populations are maintained by cultivating the seeds of the precedent year. As a matter of fact, each plant in a composite cross is a particular, independent genotype. This diversity holds an elevated genetic elasticity and confers good adaptation capacity to pathogens and environmental conditions. It is conceivable that well adapted genotypes produce more grain and dominate in the population while infected and weakly adapted genotypes are penalised. For wheat composite crosses, a multitude of studies has described their particular properties and their capacity to adapt to adverse environmental conditions and to inhibit the dispersal of fungal pathogens. Today, only little effort has been invested into agronomic, technical and baking quality evaluations. Recently, such practical information has become useful, with the temporary authorisation of composite crosses for experimentation and use in the European Union. In this experiment, we study in which measure CCs are comparable with homozygote, pure varieties, with a particular regard on yield performance and baking quality. The project relies on a trial network at 8 sites in Germany and Switzerland including four experimental composite crosses, the two commercially available populations LIOCHARLS and BRANDEX (organic breeding centre Dottenfelderhof, Germany) and four standard varieties. The results of two years of observations show that CCs have yields well comparable with pure varieties. CCs also show similar differences between the trial sites. Yet, yield of the six CCs could vary between the different trial sites and years, suggesting a population X environment interactions for this trait. Baking quality was assessed as protein content, gluten content, Zeleny index, water absorption capacity and dough stability. Overall, the protein content and the sedimentation index showed a superior stability with regard to the pure varieties. Similarly, the stability of the gluten content, water absorption and dough stability was higher in the population than in most pure varieties. Interestingly, these latter traits also were conditioned by population

X environment interactions.

The evaluation of the first two year of trials at 8 sites allows the preliminary conclusion that CCs can provide similar yields and technological quality as pure varieties. CCs do not outperform pure varieties by no means, yet they seem to increase stability. This property shall be of utmost importance with the unpredictable climate change

The performances are subject to population X environmental interactions. Future trials on the same material will provide information in which measure these dynamic populations can adapt to the local environment conditions and will by this reduce the local variability and increase the differences between sites.

It is conceivable that the choice and the number of initial hybrids determine the adaptability and the agronomic performance of such populations. In fact, CCs, even though offering a sort of on-farm breeding opportunity, do not mean redundancy of wheat breeding, but offer new challenges for the creation of innovative germplasm.

0265

USING FARM INNOVATION GROUPS TO ACCELERATE PROGRESS IN AGRICULTURE.

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The Yield Enhancement Network (YEN) Yield Testing (YYT) project developed and successfully demonstrated new approaches and resources that will now enable commercial farms to test their own ideas i.e. embrace 'action research'. At the onset of the project, three key industry problems which commonly prevent or compromise farmers undertaking such 'action research' were identified: i) Farm staff seldom measure yields accurately and are not trained or able to analyse yields rigorously ii) Farms cannot compare yields fairly within fields and iii) field tests cannot be trusted in isolation. This project focussed on targetting improvements in yield in combinable crops - on-farm crop yields have not increased for approximately 20 years, but potential yields are estimated to far exceed average yields.

To address the issues that prevent farms undestanding the success of yield enhancing ideas, five Farm Innovation Groups were established with farms across the UK. Each FIG consisted of between three and eleven farms who each carried out a trial, or in some cases multiple trials, an ADAS facilitator, and in some instances a representative from industry or academia. Yield Enhancing ideas were selected following YEN Ideas Labs, in which an 'Ideas Treasury' was collated with scientifically credible hypotheses. The five FIGs were focussed around the following topic areas, with trials carried out to address a specific question in each case: i) Amino Acids ii) Spring Potash iii) Crop Momentum iv) Oilseed Rape Cross Drilling and v) Deep Rooting.

This paper will summarise the results from each FIG, and evaluate the success of the FIG approach. Line trials to address key hypotheses determined by each FIG were performed by each participating farm. Rigorous trial planning including identifying intra-field variation, careful trial design and agreement of key metrics & measurements was fundamental to the success of the trials. Use of the new 'Agronomics' statistical approach was applied to yield maps provided by each farm to determine the effects of the yield enhancing idea. The results were a crucial component of the success of each FIG, but equally was the discussion between farmers & scientists. FIG members were actively encouraged to share their thoughts, experiences and results with other members of the FIG. A 'Change of Practice' survey conducted at the end of the project highlighted the postitive experiences of the farms involved, potential barriers for uptake of on-farm trials and how these could be resolved.

Keywords: On-farm experimentation; yield enhancement; Agronomics;

0268

STRUVITE AS A SUSTAINABLE BIO-FERTILIZER FOR THE REDUCTION OF PHOSPHATE ROCK DEPENDENCY AND BETTER DELOCALIZATION OF LIQUID DIGESTATE

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Anaerobic digestion is a commonly applied technology worldwide for the treatment of organic waste including livestock waste. However, it results in the production of high amounts of liquid digestate effluent, characterized by high nutrient content and organic matter. Most of the times this effluent is either underutilized or is discharged into surface waters or left in open lagoons. Both of these practices are causing additional problems such as eutrophication and unpleasant odors. Currently, several technologies have been developed for nutrient recovery from these effluents and the production of marketable products and high-value bio-fertilizers. Struvite crystallization is promising technology for the simultaneous removal and recovery of more than 90% of P and N from wastewater effluents. Struvite is a crystalline mineral and fertilizer composed of Mg2+, NH4+ and PO43- ions in isomolar ratios, thus an alternative to synthetic fertilizers. Feeding biogas plants with local agricultural waste and livestock manure make struvite crystallization a cost-effective process in large-scale facilities. In this study, treated and untreated livestock wastes were processed in four different pilot configurations (in Italy, Cyprus, Spain, and Bosnia-Herzegovina) for the production of struvite and struvite enriched precipitate. This comprised the main objective of RE-LIVE WASTE project, funded by Interreg MED, where sustainable bio-fertilizers were produced and assessed in various agricultural systems. The obtained struvite was analyzed for its main physical-chemical characteristics (crystallinity and purity, N, P, K, etc.) and subsequently assessed on different crops (lettuce, radish, zucchini) and in different cropping systems (greenhouse and open field). Taking into account that commercial phosphorus fertilizers are generally manufactured from phosphate rocks which are non-renewable resources, struvite obtained from the liquid fraction of digestate, might be used as a renewable and sustainable resource of phosphorous, enabling at the same time a higher delocalization of manure. Preliminary studies indicate that struvite could be an eco-friendly fertilizer for baby leaf lettuce and radish productions, reducing the dependence on commercial fertilizer. Currently, RE-LIVE WASTE project is working on to study in-depth the environmental and economic sustainability of struvite as a potential marketable CE marked fertilizer, while assessing its agronomic performance also on other crops.

Keywords: Sustainable Fertilizer, Wastes, Manures, Smart agriculture, Recycle

0277

ECOSYSTEM FUNCTIONS OF MICROBIAL CONSORTIA IN SUSTAINABLE AGRICULTURE

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Soil is the most biodiverse ecosystem on Earth, but it is also the least known. More than any other ecosystem, soils have been impacted by humans primarily through agricultural activity, but the consequences for soil biodiversity continue to be ignored. The beneficial microbiota in soil has enormous potential to improve plant health and food security. Microorganisms can improve plant nutrient acquisition, defense and stress tolerance without environmental and socio-economic costs associated with agrochemical inputs.Knowledge of agricultural soil microbiota, the use of selected microbial consortia and the promotion of agricultural practices that maintain and encourage them is a promising way to improve the nutrient quality of crops in sustainable agriculture and provide food security. Although numerous studies have demonstrated the positive effects of beneficial soil microorganisms on crop yields and quality, the use of microbial consortia in agriculture is still scarce in Chile and Latin America. Microbial consortia possess more properties than an individual microbial inoculum, through the synergism of the microorganisms that make them up. This review describes the main characteristics, ecosystem functions, crop benefits and biotechnological applications of a microbial consortium composed of arbuscular mycorrhizal fungi, plant growth promoting bacteria and actinomycetes to promote the restoration of agricultural soils and thus the quality and health of agricultural crops. To be successful in the long term in global food, it is necessary to develop sustainable and sufficiently productive agriculture, to keep pace with the growing human population and climate change. Future research related to sustainable agriculture is expected to focus on the importance of the soil microbiome, focusing on both the morphology of cultivable microorganisms and the metagenomics of all species found in the soil, in order to formulate distribution maps that will allow informed decisions to be made about the effect of agricultural practices on microbiomes.

Keywords: Microbial consortium, Arbuscular mycorrhizas, plant growth-promoting rhizobacteria, ecosystem functions

0280

SUST-FARM: A MODEL TO ASSESS SUSTAINABLE INTENSIFICATION AND CLIMATE CHANGE ADAPTATION AT FARM SCALE

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In the framework of the SUSTAg and MASCUR2 projects (JPI-FACCE), several sustainable intensification options (SIOs) under climate change scenarios have been identified for a study case located in Andalusia (Spain), focused in the Genil-Cabra Irrigation Scheme (GCIS), which is located in the Mid-section of Guadalquivir River and encompasses over 15000ha. The SIOs were identified with inputs from previous projects in consultation with the irrigation scheme staff. Crop and farm simulations were conducted to evaluate a wide range of the SIOs, including different combinations of crops rotations, management and assumptions on water availability. For this purpose, the outputs of a crop model have been used as inputs to the farm model specifically developed for this project, the Sust-FARM model.

Crop simulations were done by using DSSAT model on two contrasting soil types and considering two climate ensemble data sets (CMIP5 and ISIMIP) for current and future periods and two RCPs (4.5 and 8.5). Sust-FARM model was built for evaluating net margin of SIOs under future scenarios at farm scale, assuming that net margin will depend on market prices and PAC incentives (e.g. for legumes). The theoretical framework of the farm model was adapted from Castañeda (2016). The model calculates the expected farm net margin ranges for the farmer in the future period using as inputs the proportion of the crop in the rotation, the direct costs associated to crop, the fixed costs (e.g. water access), the annual price and yield crop and the direct payment received by the farmer. Results at farm level showed farm income to be consistently higher with the soil higher water holding capacity, reflecting a great dependency of farm income of yield levels, with scenario and RCP having lower influence on results. The higher farm income of the baseline options was obtained for maize monoculture. The SIO consisting of rotating wheat, irrigated maize and sunflower, with maize fully irrigated and with 3 events of 40 mm of supplementary irrigation for wheat and sunflower allowed to maintain approximately farm income, but with high income variability. More incentives would be necessary to promote diversified rotation-based options, as only few of the SIOs tested exceeded farm income as provided by monoculture under future climate scenarios.

Castañeda A (2016). Agricultural insurance policies in Spain and the EU: an analysis of existent and new risk management tools focusing on indirect risk assessment, and asymmetric information. Tesis Doctoral, U. Politécnica de Madrid

Keywords: farm model, crop rotation, net margin

Session 3.2: Efficient resource management: sils, water, nutrients, and energy

0293 KEYNOTE

INTEGRATED MANAGEMENT TO ENHANCECOVER CROPS BENEFITS AND RESOURCE EFFICIENCY

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The role of cover cropping in enhancing soil quality, controlling nitrate leaching and modifying gaseous exchange with the atmosphere will be discussed. Limitations and challenges for adoption of cover crops in the short and the long term such as pre-emptive competition with the cash crop and increasing N2O emissions after legume introduction will be explored. An integrated nitrogen (N) management approach that involves the use of organic inputs and synthetic fertilizers together with strategies of crop sequencing involving cover crops adapted to site-specific characteristics is proposed to maximize yields and minimize environmental trade-offs. The underlying principle is to reduce the need for additional synthetic N by accounting for the N supply by biological fixation and mineralization of soil reservoirs that is made available by the C and N biogeochemical cycles. Results from short and long-term field experiments under Mediterranean conditions were used to support this approach. Application of a biochemistry model to the sites of the LUCAS dataset was used to analyze benefits and trade-offs of integrated management based on cover cropping on soil organic carbon accumulation, nitrate leaching, greenhouse gas balance and cash crop yield in Europe. A discussion on knowledge gaps and future research interests related to the introduction of cover crops in arable crop rotations will precede the conclusion. Only the adoption of integrated crop management considering the site-specific agro-environmental conditions will optimize agronomic and environmental outcomes.

Keywords: cover crops; greenhouse gas emissions; integrated management; nitrate leaching; resource efficiency; soil carbon sequestration.

0014

KORONEIKI OLIVE TREE PHYSIOLOGY RESPONSES UNDER TWO DEFICIT IRRIGATION TREATMENTS IN CYPRUS

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Semi-arid environments are characterized by variable and scarce precipitation and water resources, a phenomenon exacerbated by climate change. Soil moisture deficit has an impact on plant physiology, the severity of which may increase during drought-sensitive plant growth stages. To assess the effects of water deficit, this study evaluated stem water potential and stomatal conductance responses to soil moisture availability and environmental conditions. Accordingly, an experiment was set up in a commercial, organic olive orchard of 17-year-old 'Koroneiki' trees, located in Nicosia, Cyprus. In 2019, two deficit irrigation treatments were applied to the trees from May to October, based on FAO Penman-Monteith-evapotranspiration estimations. Evapotranspiration estimations were based on meteorological data collected from a station located inside the orchard. Sustained Deficit irrigation (SDI) provided 70% of evapotranspiration to the trees throughout the irrigation season. Regulated Deficit irrigation (RDI) provided 70% of evapotranspiration in drought-sensitive plant stages and 35% of evapotranspiration at pit hardening and oil accumulation stages. Stomatal conductance was measured between 10 and 11 AM and stem water potential was measured between 12 AM and 1 PM, for 15 trees per treatment. Measurements were made weekly; starting from the onset of shoot growth in March. During the irrigation season, measurements were made on the day before each weekly irrigation. The soil moisture of the 70-cm root zone of 6 trees per treatment was continuously monitored. Results show that stem water potential followed soil moisture changes over time. Between mid-July and mid-October soil was near wilting point before irrigation, while stem water potentials decreased to -3.5 and -4.0 MPa in SDI and RDI treatments, respectively. At the same time, stomatal conductance reached approximately 140 and 160 mmol m-2 s-1 in SDI and RDI treatments, respectively. After rainfall, stem water potential reached approximately -1.5 MPa and stomatal conductance reached 220 mmol m-2 s-1 in both treatments. The data indicate that stem water potential is related to

soil moisture change when soil moisture is not limiting. With soil moisture availability remaining low, stem water potential further decreases, which could be attributed to the increasing force required for water uptake by the roots. However, the rate of stomatal conductance is maintained throughout the season with lower conductance observed at high vapor pressure deficits. Further research is required to elucidate the interactions between plant physiological indicators in this water-limited environment.

Keywords: Stomatal conductance, Stem water potentials, Soil moisture.

0027

EVALUATION OF INNOVATIVE FERTILIZER ADDITIVES ON THE PHYSIOLOGICAL IMPACTS, AGRONOMIC PERFORMANCES AND PROTEIN QUALITY IN WINTER WHEAT

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This work is supported by a PEI-FEADER project called FIELD-Prot which is funded by European Union and Région Normandie (France)

Nitrogen (N) fertilization is essential for the productivity and quality of winter wheat. Nevertheless, when N fertilizers are not efficiently absorbed, assimilated and remobilized by the crop, the losses of N in environment led to pollution risks (NH_3 and N_2O emissions and/or NO_3^- leaching). Previously, we have tested new additives (containing organo-mineral complex with amino acids) in association with urea/ammonium/nitrate solution (UAN) on the N use efficiency (NUE), seed yield and quality under controlled conditions. While N uptake was maintained after heading stage by additives, we observed a significant acceleration of the senescence processes and strong induction of N remobilization from roots and straws towards the grains (Maignan et al., in prep.). This efficient N remobilization allowed to significantly increase seed yield (until +52%), N Harvest Index (until +101%) and NUE (until +35%). Analysis of seed proteome also revealed that formulations mainly reduced the abundance of α/β-gliadins proteins (initiators of the inflammatory response to human celiac disease).

The FIELD-Prot project aimed to confirm the beneficial effect of these new additives on three pedoclimatic contrasting sites in Normandy (France) in 2018-20. Three additives (A1, A2 and Glutacetine) were supplied to the N fertilizers (ammonitrate, urea and UAN) and then compared to the fertilizer alone in randomized 24 m² micro-plots. The meta-analyze of the three sites in 2019 showed a significant improvement of the seed yield when additives were associated to urea and when A2 and Glutacetine were applied with UAN (until +6%). These results were explained mainly by the increase of thousand grain weight and/or the grain number per m². In contrast, when additives were associated to ammonitrate, any positive effect was observed.

Protein content increased with Glutacetine (+2,5%) but decreased with A2 (-2,4%) when there were associated with urea, while there was no consistent change with UAN. Total N grain increased (i) when urea was supplied with Glutacetine and A2, and (ii) when UAN was associated with Glutacetine and A2. Interestingly, all additives increased NUE of urea and UAN (until +4,1%). N content in straw decreased when additives were associated with urea, suggesting a strong N remobilization. Straw and seed ionome and grain proteomics are being analyzed and will allow us to complete the understanding of the mechanisms of these additives. These first-year results are being confirmed with the 2019-20 campaign which includes a ^{15}N-labelling method for determination of environmental and agronomical appraisal of each innovative N fertilizers.

Keywords: Cereals, Innovative N-fertilizers, Seed quality, Low-input agriculture, Sustainability

0032

EVALUATION OF INNOVATIVE FERTILIZER ADDITIVES ON THE ENVIRONMENTAL BALANCE, AGRONOMIC PERFORMANCES AND PROTEIN QUALITY IN WINTER WHEAT

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This work is supported by a PEI-FEADER project called FIELD-Prot which is funded by European Union and Région Normandie (France)

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Keywords: Cereals, Innovative N-fertilizers, Seed quality, Low-input agriculture, Sustainability

0047

ENHANCING DROUGHT TOLERANCE IN PERENNIAL RYEGRASS

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Perennial ryegrass (Lolium perenne L.) is one of the most important forage and turf grass species in temperate regions worldwide. Its yield and persistency will be severely affected by global climate change, because it reacts sensitive to heat and drought. We studied the tolerance for periodical drought in various L. perenne genebank accessions and in breeding material in rain-out-shelter experiments. Based on this, six genotypes gradually differing in drought response were selected and crossed in a diallelic way (tolerant x tolerant and susceptible x tolerant). In total 14 crossing populations were produced, and the F1-progenies with 140 individual genotypes per population were phenotyped in rain-out-shelters in 2017 and 2018 at two sites (Malchow/Poel, Freising/Pulling, Germany). These where compared to the parent plants and standards in an augmented randomized block design. Drought phases were applied twice a year (early spring and midsummer) by keeping the soil moisture below the permanent wilting point for six weeks. One half set of genotypes was cultivated under field conditions at each trial site. Biomass formation before and after cut, heading date, disease as well as drought susceptibility were scored on a scale from 1 (lowest) to 9 (highest). Biomass yield was determined after cutting and oven-drying at 60 °C for two days.

At Malchow/Poel, an increasing differentiation in biomass development within and between the crossing populations became visible during the experiment. The biomass scoring in November 2018 revealed a low share (13-37 %) of genotypes with medium to high vitality (score 4-9) but a high share of dead plants (32-62 %) in worst performing crossings. In contrast, best crossing populations still exhibited a high number of medium to very vital genotypes (80-90 %) at the end of the experiment in 2018. These observations were consistent with the harvested dry matter. Comparisons of the results from the field and rain-out-shelter identified three crossing populations which produced high yield under natural conditions and were amongst the

highest yielding populations after drought stress in the shelter. The results obtained at Malchow/Poel coincide well with the results recorded at Freising/Pulling. From ten crossing populations the most tolerant genotypes were selected at the end of the experiment, multiplied and included as new drought tolerant L. perenne accessions in the IPK Gene Bank. Furthermore, based on results from populations sharing a common parent, we identified parent plants which were very successful in producing drought tolerant progenies.

Keywords: Lolium perenne L., drought tolerance, phenotyping

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0064

ANALYSIS OF THE FREQUENCY OF DISTRIBUTION OF THE RELATIVE IRRIGATION SUPPLY INDEX IN THE WATER USERS ASSOCIATION OF SECTOR BXII OF THE LOWER GUADALQUIVIR RIVER

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The Relative Irrigation Supply index (RIS) allows the evaluation of water use from the applied water and the estimation of the water needs of the crops. This work analyzes the tail of the RIS distribution frequency in the area of Sector BXII of the Lower Guadalquivir, where previously the irrigation needs were estimated by remote sensing for the spring campaign of 2017 and the data of the hydrants of each plot for the same period were analyzed. If the index is greater than 1 it will indicate over irrigation and if it is less, deficit irrigation. Sector BXII is characterized by being a marsh area with a typically Mediterranean climate where crops are grown throughout the year and where the high salinity of the soil requires salt washing tasks with some frequency. 56% of the plots obtained a RIS between 0.8 and 1.2, so it was considered that the applied irrigation was around the water needs of the crops and the agricultural management of the area. 13% of the plots had a RIS <0.8 and 30% a RIS> 1.2. In this work, all the plots with a RIS greater than 1.2 and less than 0.8 were examined. For this purpose, satellite images for the study period, the supervised crop classification used to estimate irrigation needs and the database of the Water Users Association (WUA) were re-evaluated. From this information, common errors were identified in the infra and overestimation of the RIS values obtaining the following results: in 43% of the plots with RIS> 1.2, other crops not declared in the WUAs database were detected, 24% were incorrectly classified, 19% declared horticultural crops whose irrigation needs were not taken into account by the classification, and 14% assumed that the farmer made an over use of water. This error, the smallest in percentage, was more common as RIS values approached to values of 1.2. As for the plots with values of RIS <0.8, in half of the cases the application of deficit irrigation was detected in crops such as cotton, sunflower and wheat and the remaining 50% was divided between an error in the crop classification or the presence of horticultural crops not detected by the supervised classification.

Keywords: Water management, Remote Sensing, Monitoring tools, Crop management, Horticulture

0080

MAIZE MONOCULTURE UNDER MEDITERRANEAN CONDITIONS: ASSESSING THE EFFECT OF DIFFERENT IRRIGATION AND TILLAGE SYSTEMS

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Irrigation is a needed for most of the summer crops under Mediterranean conditions. In the NE Spain, maize (*Zea mays* L.) is one of the predominant summer crops, and usually cultivated under intensive tillage practice and in different irrigations systems. Therefore, the objective of this work was to assess the impact of two irrigation systems (i.e. sprinkler irrigation, S, and flood irrigation, F) and three different tillage systems (i.e. conventional tillage, CT, no-tillage maintaining the crop stover, NTr and no-tillage maintaining the crop stover, NT) on the performance of maize crop on a four year monoculture (2015-2018).

Over the four years, S irrigation resulted in an increase of 15% of the maize yield compared with F irrigation, with an average grain yield value of 14.76 and 12.49 Mg ha^{-1} for S and F irrigation, respectively. In contrast, tillage system only presented significant differences in two of the four years, observing a trend to obtain greater grain yields under CT tillage system. On average of the four years, CT increased grain yield by a 6% compared with both no-tillage systems.

Likewise, grain nitrogen use efficiency, NUEg, was 18% greater under S irrigation than under F irrigation, respectively, over the four maize growing season. However, the different tillage systems showed similar NUEg values, presenting average NUEg values over the four years of 55, 53 and 54 kg N kg^{-1} grain for CT, NTr and NT, respectively. Grain water use efficiency, WUEg, showed the largest difference between irrigation systems, being 30% greater under S irrigation compared with F irrigation. However, during the four maize seasons, tillage systems did not show significant differences in WUEg.

The greater irrigation frequency provided by S irrigation favored a steadier soil water content values and allowed to apply less irrigation water compared to F irrigation. This fact explained the highest grain yield observed in S irrigation and thus the greater efficiency in the use of N and water compared with F irrigation.

This work highlight the importance of an adequate selection of irrigation system, and showed the feasibility of no-tillage together with sprinkler irrigation as an alternative to conventional tillage for maize monocultures under Mediterranean conditions.

Keywords: Irrigation system; conventional tillage; no-tillage; NUE; WUE

0087

OPTIONS TO ENHANCE WHEAT YIELD AND WATER PRODUCTIVITY IN A MEDITERRANEAN RAINFED ENVIRONMENT BY AGRONOMIC INNOVATIONS

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Wheat is the main staple food crop grown in the Mediterranean rainfed regions, but productivity is insufficient to meet the demand. The existence of large attainable yield gap suggests potential for increasing wheat yield in the region. However, high variability in inter- and intra-season rainfall presents a big risk for the farmers to invest in best practices. Optimizing genotype selection, seeding time, and crop demand-based water management have the potential to alleviate the risk associated with rainfall variability and enhance the stability of yield. The objective of this paper is to present the results of different agronomic practices implemented in different research trials to enhance yield and water productivity (WP) of wheat in the Mediterranean rainfed environment. Combining appropriate genotype and management is more effective than solely relying on choice of genotypes. Effect of seeding time on yield and WP was influenced by rainfall amount and distribution. In the two low rainfall years (270 and 181 mm versus 440 mm long-term average), early sowing enhanced yield and water productivity by 45-100% compared to late seeding. Similarly, in the one dry year, the application of supplemental irrigation increased yield by 2.1 to 2.5 t ha-1 (72-90%). More than 50% yield variability was explained by variation in rainfall followed by supplemental irrigation (by 14%), and seeding time (by 12%). Grain yield and water productivity in rainfed wheat can be enhanced by approx 20% by switching from conventional to conservation tillage practice. In the dry year, inclusion of lentil as pre-crop, enhanced the following wheat yield by 21% than wheat mono-crop. Selection of appropriate genotype, conservation agriculture practice, crop rotation, adjustment in seeding time, and application of crop demand-based supplemental irrigation help to enhance the stability of yield and WP of wheat under Mediterranean rainfed environment.

Keywords: water productivity; agronomy; rainfed; wheat; Mediterranean

0105

AGRONOMIC NUTRIENT USE EFFICIENCY AND GREENHOUSE GAS EMISSIONS FOR CEREAL SELF-SUFFICIENCY IN SUB-SAHARAN AFRICA TOWARDS 2050

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Steep growth in population and dietary changes in sub-Saharan Africa (SSA) will bring a vast rise in food demand. To obtain cereal self-sufficiency by 2050, 2015 production must triple. Increasing cereal production by intensification on existing cropland is generally preferred over expansion of agricultural area to prevent biodiversity loss and massive emissions of greenhouse gas (GHG) from biomass removal and soil carbon losses. Intensification implies narrowing the yield gap, i.e. the difference between actual farmers' yields and potential yield. This gap is currently large mainly due to

low nutrient inputs and low agronomic nutrient use efficiencies (AE).

This study investigates for 10 SSA countries the impacts of potential cereal self-sufficiency on required nutrient use and GHG emissions. This is done for a range of scenarios that differ in degree of intensification (yield gap closure) and complementary area expansion, under various levels of agronomic nitrogen use efficiencies (N-AE). We analysed a large range of on-farm fertiliser experiments to assess current N-AE and used a simple equilibrium model to estimate theoretical benchmarks for N-AE.

Our results show that current N-AE of maize, sorghum, millet and wheat are only half of what could be attained in the short term with good management (attainable N-AE) and are only one third of the maximum N-AE. For rice (irrigated and rainfed combined), the current N-AE is around the attainable level, which is half of the maximum N-AE. Narrowing the yield gap to fulfill future cereal demand will come with a large increase in nutrient inputs (as current nutrient input is very low) and associated GHG emissions will quadruple, even under efficient management GHG emissions will double in 2050 compared to 2015. Yet, matching food demand through area expansion will results in much higher GHG emissions, irrespective of N-AE. Thus, to confine the increases in GHG emission that will inevitably be associated with achieving cereal self-sufficiency in SSA, intensification is a far better option than area expansion, but it must be paired with drastic improvement of nutrient management to achieve high N-AE.

Keywords: agronomic nutrient use efficiency, Africa, GHG emissions, yield gap, fertilizer input

0106

EFFECT OF SOIL AVAILABLE PHOSPHORUS AND NITROGEN ON WINTER WHEAT PRODUCTION

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Available nitrogen (Ns) and phosphorus (Ps) in soil influence the wheat quality and quantity production in many environments where fertilization rates don't match crops requirement. Nutrients availability in the soil is highly variable, even within small fields. The aim was to verify the effect of Ns and Ps on the production of local and improved winter wheat cultivars. A field experiment was conducted in Monteroni d'Arbia (Tuscany Region) during two growing seasons, starting from September 2016 to August 2018, under rainfed conditions. The experiment included 24 treatments, each cultivated over 1250 m^2, which were the combinations of four bread wheat cultivars (one improved variety and three old local varieties), three nitrogen fertilization levels (Nf: 35, 85 and 135 kg N ha^{-1}), two seeding rates (90 and 180 kg of seed ha^{-1}) and one phosphorus (P) level (75 kg P_2O_5 ha^{-1}). A total of 3 soil samples for each treatment were collected, before the beginning of the cropping season, and then chemically analyzed to determine the Ns and Ps. At harvesting, 3 samples of aboveground biomass were collected for each treatment in order to determine the biomass for both grain (Bg) and straw (Bs) and the nitrogen concentration for both grain (Ncg) and straw (Ncs).

Results indicated that Ps varied between 13.7 and 17.4 mg kg^{-1}, while Ns between 101 and 149.9 mg kg^{-1}. The Bg and Bs ranged between 680 and 6840 kg ha^{-1} and between 1135 and 10407 kg ha^{-1} of grain, respectively. The Ncg and Ncs ranged between 1.4% and 3.3% and between 0.1% and 0.8%, respectively. Principal component analysis (PCA) indicated that Bg, Bs and Nf were mainly affected in decreasing order by Ps, Ncg and Nf. The PCA also indicated that Nf mainly affected Ncs. Correlation analysis results showed significant positive correlations ($p<0.01$; df=143) between Bg and Ps (R=0.87), Ncg (R=0.60) and Nf (R= 0.57). Further, correlation analysis also indicated that Ncg was significantly ($p<0.01$) and positively correlated with Ps (R= 0.55), Nf (R= 0.51) and Ncg (R=0.44). In similar soils, characterized by low Ps, literature reported that even small Ps variations can result in higher variations of production. In conclusion, this study suggests that the within field Ps variability need to be managed by means of sito-specific fertilization to optimize the wheat production.

Keywords: Phosphorus variability, Precision farming, Grain production, Soil fertility

0110

DRONE BASED PHENOTYPING OF NUE RELATED PARAMETERS OF VAROIUS WINTER RAPSEED GENOTYPES

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The utilization of highly efficient winter rapeseed hybrids is supposed to reduce nitrogen inputs which in turn will positively affect nitrogen leaching and GHG emissions and thereby nitrogen use efficiency (NUE). Modern advancements in remote sensing and the development of reliable crop growth models can facilitate the efforts of breeders in the development of these hybrids. A diverse set of 8 genotypes of winter rapeseed was established under different N supply rates in a two year field experiment in northern Germany. Data from this experiments are used to parameterize and enhance the HUMEOSR cropgrowth model for analyzing traits for effects on NUE. Measurements include weather, soil-characteristics, N-uptake, Green Area Index (GAI) and destructive biomass data collected by destructive sampling during the vegetation period. Additionally, a GAI was estimated from sequentially calibrated drone-based multispectral data in conjunction with a calibrated prediction model. As spectral reflection properties of rapeseed vary for different development stages, especially flowering, multiple calibrations for different parameters at different development stages were used to cover most of the growth period with GAI and dry matter performing best at the early development stages (R2>0.8 and R^2>0.7) while losing accuracy during ripening and where not satisfying for flowering.

Keywords: Rapeseed, NUE, Drone

0112

PRECISION LIME MANAGEMENT: A SENSOR-BASED SOIL MAPPING APPROACH

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The knowledge about the small-scale soil fertility status, e.g. nutrient availability or soil structure is of central relevance in modern yield-optimized and resource-efficient crop production systems. The soil fertility is, among other factors, influenced by the soil acidity, which is caused by natural pedogenetic processes, such as nutrient leaching through precipitation or respiration of soil organisms and plants, or anthropogenic impacts, e.g. enhanced turnover processes through manuring. To counteract the soil acidification and obtain optimum growth conditions for crops, farmers in Central Europe usually apply lime fertilizers in intervals of 4-6 years following the VDLUFA guidelines from Germany. However, by applying this procedure, farmers most often assume a total field homogeneity or sometimes subdivide fields into more or less homogeneous sub-plots of 3-5 ha. Moreover, to assess the required lime demand, the relevant parameters soil pH, soil organic matter and soil texture are roughly derived from a few or only one bulk sample. Although this system represents the best management practice for liming, it leads to an over or under supply in certain parts of the field and causes yield losses. To address a more precise application management, the EU-funded research project 'pH-BB: Precision liming in Brandenburg - Germany' therefore aims to demonstrate a site-specific variable rate liming approach based on proximal soil sensing, digital soil mapping and the adaption of a well-established lime recommendation algorithm. Calibrated high-resolution soil maps of the three soil parameters were generated in the first place using multiple on-the-go proximal soil sensors and geostatistical interpolation methods. The soil texture is predicted by a combination of apparent electrical resistivity (ERa) measurements and natural soil-born gamma (γ) emissions, the actual soil acidity by two ion selective antimony electrodes on naturally moist soil material and the soil organic matter status by a combination of red (660 nm) and near-infra-red (NIR, 970 nm) reflectance from optical measurements. In a second step, lime rates are derived from an adapted lookup table system, which takes the higher resolution of the soil texture and soil organic matter into account. The calculated liming demand was, eventually, aggregated to applicable amounts in order to address technical possibilities. The details of the methodological workflow are described based on a test site of 25.6 ha in northeast Germany. First results show that 48% of the field are over fertilized by about 11 t of lime, while 20% received about 10 t too less than the actual required demand and 32% are adequate limed (± 0.4 t).

Keywords: Soil liming, soil sensing, precision agriculture

0121

(LITTLE) SHORT-TERM IMPACTS OF P FERTILIZER MANAGEMENT IN A LONG-TERM FIELD EXPERIMENT

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Agronomic effects of phosphorus (P) supply are not always apparent and other growing conditions, for example periods of drought, often overlay a P fertilizer effect. Therefore, long-term field experiments are necessary as they can provide more robust data on the ef-

fectiveness of fertilizer strategies under consideration of annual growing conditions and processes of nutrient mobilization and translocation in soil. At the Rostock field experiment the effects of single and combined organic (cattle manure, compost) and inorganic (Triple-Super-P (TSP), biomass ash) P treatments on soil P pools and plant nutrition are investigated since 1998. Beside investigations on crop characteristics, samples of the topsoil and subsoil were taken twice each year and analyzed regarding different P pools and enzymes involved in the P turnover.

Crop yields depended only partly on P supply and even after 20 years of P management P supply must not result in higher crop yields in comparison to the control without any P supply during the experimental time. Crops showed different sensitivity to P supply with lowest sensitivity for winter cereals and highest sensitivity for maize and potatoes. Differences in the P budgets (P input - P output) are generally reflected by the soil P concentration but considerable differences in dependence of the sampling date, mainly for the high soluble P fractions, should be taken into account. Usually, the amount of P applied had a greater effect soil P pools than the type of the P source and the P fractions were mainly increased in the combined treatments with high P surplus. However, in the subsoil the labile and moderate labile fractions (P-water, P-lactate, P-$NaHCO_3$, P-NaOH) were most increased in combination with a TSP application. In the control the deeper soil layers (60-90 cm) contained about 20% of the bio-available P in the soil profile (0-90 cm). In the combined treatments this portion was lower with about 15% which indicates an accumulation of P supplied mainly in the upper soil layers.

The experiment also showed significant annual cropping effect on soil characteristics, mainly on the activity of enzymes.

Phosphorus budgets and soil test P are important tools for the fertilizer practice. However, different sensitivity of crops, variations in soil P fractions in depending of the sampling time and other growing factors should be more considered. Here, results of long-term experiments could help to derive more appropriate P fertilizer recommendations.

Keywords: phosphorus fractions, enzymes, fertilizer recommendations.

0125

FERTIGATION WITH SLURRY LIQUID FRACTION IS AGRONOMIC AND ENVIROMENTALLY SUSTAINABLE

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Nitrogen fertilization is necessary to obtain profitable crops yields, but has associated environmental risks if it is not adequately managed, such as water contamination by nitrate or ammonia and nitrous oxide emissions to the atmosphere. The substitution of synthetic fertilizers by manures is a must in order to reinforce circular economy, but manure management needs to be improved to avoid increasing environmental impacts. The adoption of new technologies able to improve manures nutrient recycling is essential. The fertigation with the liquid fraction of slurries (LFS) is a promising technology that allows splitting slurry-N applications and a better adjustment of N rates to crop needs than surface slurry application. The objective of this work is to evaluate the sustainability of fertigation with LFS in comparison to traditional practice: broadcast of raw slurry before sowing and synthetic fertilizer at side-dressing.

A field trial was conducted in a pivot of 6.4 ha in the middle Ebro river valley in a maize crop. The pre-existent irrigation system was adapted to inject the LFS obtained in a solid/liquid separator that removes mechanically particles larger than 500 μm. The pivot was equipped with Nelson D3000 spray heads working at 6 PSI (0.4 bars) that provide large size drops. Water emitters were lowered to 40 cm above the ground and were spaced 1.4 m. The slurry fertigation plan included a complete nitrogen supply in split events with 1:8 average LFS:water ratios.

Environmental and agronomic performance were evaluated for 2 years. Ammonia emissions were monitored with passive samplers (ALPHA®) coupled with an inverse dispersion model (WindTrax software). The nitrate in soil solution below crop root zone was monitored with ceramic suction cups and the nitrogen use efficiency (NUE) was calculated as the ratio between N uptake and N applied.

Yield was not significantly different in the pivot and in the reference plot. Nitrate concentration in soil solution in the pivot was steady (average±standard error of 5.4±1.7 mg/l in 2018 and 42.7±6.2 mg/l in 2019) and lower than in the reference plot (116.7±17.5 mg/l in 2018 and 110.5±31.5 in 2019). Ammonia emission in the fertigation was reduced by more than 60%. NUE raised in the pivot against the reference from 0.60 to 1.20 in 2018 and from 0.65 to 0.88 in 2019. These results were obtained thanks to a better distribution of slurry and associated lower N rates in the pivot.

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Keywords: Fertigation, slurry, NUE, ammonia, nitrate

0142

HYPERSPECTRAL AND THERMAL IMAGERY TO ASSES NITROGEN AND WATER STATUS IN WINTER WHEAT

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Remote sensing imagery is a valuable tool to detect Nitrogen (N) and water stress that allow adjusting N fertilization and irrigation to crop demand. Interaction between N and water status may affect the signal acquired by sensors covering different spectral regions. This study proposes two different vegetation indices (VIs) sensitive to N and water status with reduced interaction effects. For this purpose, a field experiment with winter wheat (*Triticum aestivum* L.) was conducted in Central Spain during 2018/2019. Four different N treatments, from non-N-fertilized (N_0) to over-fertilized (N_3), combined with two irrigation levels were established with four replications in 32 plots (22 x 22 m^2). The Nitrogen Nutrition Index (NNI) was used to determine crop N status by relating the biomass and %N of two wheat samples (0.5 x 0.5 m^2) per plot at the beginning of flowering. The water status of each plot was determined with a leaf porometer that measured stomatal conductance. The imagery was acquired with a hyperspectral and thermal camera on-board a Cessna aircraft flying 300 m above the experiment, leading to <0.3 m spatial resolution. The VI proposed to determine N status was the Canopy Chlorophyll Content Index (CCCI), a planar domain vegetation index that combines a VI related to plant structure (NDVI) with another related to chlorophyll content (NDRE). The Water Deficit Index (WDI) estimates water status, and was calculated by plotting the Vegetation Index-Temperature (VIT) trapezoid in a two-dimensional space created by the surface-air temperature differential and a VI sensitive to the ground cover (SAVI). The results indicated that CCCI described better NNI (R^2 = 0.64) than NDVI (R^2 = 0.43) or NDRE (R^2 = 0.53). No differences were found for each N treatment between water levels, except for N_0. The stomatal conductance was better described by WDI (R^2 = 0.65) than canopy temperature (R^2 = 0.60) or other VIs based on SWIR bands, like $NDWI_{1240}$ (R^2 = 0.34) or $NDWI_{1640}$ (R^2 = 0.31). Differences of WDI were found between water treatments but not between N treatments. This study concluded that N and water status can be determined simultaneously when using spectral and thermal VIs.

Keywords: Critical Nitrogen Dilution Curve, Interaction effects, Precision agriculture, Remote sensing, Soil background

0144

POTENTIAL OF CONSERVATION TILLAGE COMBINED WITH REGULATED DEFICIT IRRIGATION FOR SAVING WATER

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Several studies around the world have shown that conservation tillage is effective protecting the soil against water and wind erosion. However, other claimed benefits like water conservation or yield improvement are less clear. In general, soil water infiltration is improved while residues on the ground reduce soil water evaporation. On the other hand, regulated deficit irrigation aims at conserving irrigation water without penalizing crop yield by reducing the applied amount during the less drought-sensitive crop phenological periods. In this study we explored the potential of combining conservation tillage and regulated deficit irrigation and evaluated its impact on maize performance in southern Spain. The experiment was carried out during three campaigns (2015-2017) in a long-term trial established in 2007 to compare conservation and conventional tillage. 1.8m access tubes to a neutron probe allowed

measuring soil water content regularly. The regulated deficit irrigation treatment was effective and used 100 mm less irrigation water than the reference irrigation treatment, which was established to cover full requirements. Moreover, drought was avoided during crop establishment and during the flowering period so that the small negative effect on crop growth and grain yield was not significant. The expected compensation to reduce this small negative effect thanks to conservation tillage was not observed. The reasons will be discussed.

Keywords: zero tillage, water productivity, water saving, irrigation strategy

0170

GROUND LEVEL AND AERIAL SENSORS TO ASSESS WHEAT N STATUS AND TO ADJUST N FERTILIZATION

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The use of mineral fertilizers has increased in the last decades, but >50% of N applied is not assimilated by crops, contributing to environmental pollution (Tilman et al., 2002). Sensoring crop performance could contribute to adjust N fertilization and to increase N recovery. The objective of this work was to evaluate the ability of ground level sensors and remote sensing to assess crop N status and to adjust fertilization. Specific objectives were: i) to evaluate the successful detection of different N levels, and ii) to compare the N fertilizer residual effect with and without nitrification inhibitors. A two-year field experiment (maize/wheat rotation) was established in Central Spain. Maize was sown in sixteen plots (8 x 10.5 m) randomly distributed in 4 treatments: calcium ammonium nitrate enriched with sulphur (CAN(S)), ammonium sulphate nitrate (ASN) blended with 3, 4-dimethylpyrazole phosphate (DMPP) (ASN+DMPP), CAN(S) blended with 3,4-dimethylpyrazole succinic (DMPSA) (CAN(S)+DMPSA) and not-fertilized, with 4 replications. After maize harvest, wheat was planted and each plot was split into three subplots, that received CAN(S) either at a recommended N rate (N_2), a reduced rate (N_1) or no N (N_0) applied. The residual N effect was evaluated by comparing the wheat response (N content (kg N ha^{-1}) and grain yield (kg ha^{-1})) at flowering and harvest. Vegetation indices obtained at ground-level (Dualex®, Greenseeker®) and from an airborne hyperspectral sensor covering the visible and near-infrared regions were compared with wheat parameters. Differences in wheat response to N rates were detected by ground and aerial sensors at various growth stages, yielding significant differences already at stem elongation. Residual N effect was observed in wheat at flowering in N_0 treatments, as the biomass and N content were higher following maize fertilization with CAN+DMPSA and ASN+DMPP compared to the control. At wheat harvest, the residual effect was observed in grain N content and %N. This residual effect was detected by ground level sensors at stem elongation, but not by narrow-band spectral indices calculated from the aerial sensor. Ground level and aerial sensors detected differences in wheat N status at stem elongation, opening the opportunity to adjust N fertilization rates to crop demand. However, only ground sensors detected differences in N fertilizer residual effect. Further research is needed to identify spectral-based indices and traits more sensitive to crop N status.

Keywords: remote sensing, vegetation indices, fertilizer, wheat

0202

EFFECT OF PRECEDING CROP ON NITROGEN EFFICIENCY FOR SOFT WINTER WHEAT IN SAIS REGION, MOROCCO

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Efficiency in use of non-renewable resources is becoming critical to favor sustainability and resilience goals of agricultural systems. In Southern Mediterranean countries, agricultural development leads to environmental concerns such as water-table decrease due to over-irrigation, and water pollution, together with issues related to the unequal access to the necessary inputs needed by farmers. Wheat is an important crop in these countries, however still with higher consumption than production. In this context, our study explores the nitrogen efficiency in wheat taking into consideration the role of cultivated previous crops (legumes, cereals, irrigated market gardening, or fallow). Using a large database of cropping practices of 205 farmers surveyed in 2011-2012 in the Saïs region (Morocco), we followed a three stages approach. First, we determined the farms displaying wheat yields as close as their potential (defined by N) by applying a Stochastic Frontier Analysis to the 205 farmers' dataset. This was performed according to the type of variety, local (150 farms) and improved (56 farms). Second, we used these farms to calibrate Cropsyst, derived the values of all parameters, and used it to simulate the performances of the other farms. Third, we calculated nitrogen efficiency of all farms, and built eco-efficiency frontiers between (observed) yields, (observed) N inputs and (calculated) N absorbed. The 1st step led us to use 17 and 16 farms to calibrate/validate Cropsyst for local and improved varieties, respectively. Performances showed a RMSE of 14.5% and 10.2% for local and improved varieties, respectively. Running simulations with CropSyst for the remaining farms, according to the optimized model parameters, lead to RMSE of 38.9% and 21.4% for local and improved varieties, respectively. For the third step, we observed the same trends while looking at observed yield vs. N input, and yield vs. N absorbed. For both, eco-efficiency trends distinguished two groups of preceding crops: legumes and irrigated market gardening showed better eco-efficiency as compared to cereals and fallow. Main differences between legumes and irrigated market gardening concern the workload, the N inputs, and the associated revenue, all being lower for legumes. In addition, the relationship between N input and N absorbed was closely determined by soil type, with three different types available in our database. These results confirm that, from a pure N efficiency point of view, legumes are "the best" preceding crops. It would be then necessary to compare these results with 2 years results regarding especially workload and raw margin.

0203

WHY AND WHY NOT MIDDAY STEM WATER POTENTIAL COULD BE A USEFULNESS DEFICIT IRRIGATION TOOL IN OLIVE TREES

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Midday stem water potential (SWP) is an old, non-continuous measurement of plant water status used from 60's of the last century. This technique has been essential for studying water relations in plants and has been suggested as irrigation tool in fruit trees. Most of irrigation works that discuss different irrigation scheduling have used this measurement as indicator of the water stress level of such recommendations. In recent works, SWP has been suggested as decision tool for regulated deficit irrigation scheduling in olive trees. The aim of this work is to present data from different authors to show limitations and benefits of this approach. Regulated deficit irrigation reduces applied water based on the affection of physiological processes which are not or minimum related with yield. In olive trees, there are three main processes that have to be considered, vegetative growth, fruit development and transpiration. Such processes could be related in different way with SWP. Vegetative growth is the physiological process more sensitive to water stress. Therefore, SWP would detect later their reduction in drought conditions. Fruit growth is also very sensitive to irrigation cut off but several works suggest that SWP could be sensitive enough to manage deficit irrigation from this point of view. Finally, transpiration has been the most important indicator in irrigation works using crop evapotranspiration (ETc) approach. The relationship between ETc and SWP is, apparently, not simple and could be affected for different sources such as evaporative demand or volume of soil moisture. On the other hand, the selection of a tool for irrigation supposes to consider different features. Cost, easy to use and interpret are three important characteristics. However, continuous monitoring and capacity for measuring great surfaces are, nowadays, the most valuable features of the new indicators. Discussion of these physiological relationships and the manage features will provide a complete frame of the useful of this technique in the deficit irrigation of olive trees.

Keywords: Fruit growth, Regulated deficit irrigation, Shoot growth, Water relations.

0232

A BORON RECYCLING FERTILIZER MADE FROM CELLULOSE INSULATION WASTE

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The production of N and P fertilizers from waste materials has been a major research focus in Europe in the last decade, aiming at increasing the recycling rates of valuable side streams, on reducing energy-intensive N fixation and on reducing the dependency on mineral P deposits. Similar to P, boron is a limited mineral resource on the global scale, with deposits being regionally concentrated (e.g. Turkey, USA). The current European boron utilization is linear without notable recycling rates. In the present study, we developed and tested a boron recycling fertilizer from a borated cellulose fiber insulation (CFI) material, in which boric acid serves as pest repellent and flame retardant. For this purpose, CFI was pyrolyzed and the resulting biochar was tested as a B source for rapeseed, sunflower and maize in pot and field experiments.

Hot water extracts of CFI biochar showed that the solubility of B in the biochar is lower than the solubility of borax (Na tetraborate), which is a conventional B fertilizer. The B uptake of sunflower and rapeseed from CFI biochar was not significantly different to that from borax in a pot experiment. Similarly, the B uptake of sunflower and maize in a field experiment was not significantly different between these two fertilizers. These results demonstrate, that CFI biochar is an equally efficient B source for crops like conventional, fully water-soluble fertilizers. Inorganic and organic contaminant levels determined in the CFI biochar complied largely with relevant regulations, only the PAH level was slightly higher than proposed for STRUBIAS-compliant materials. However, as organic contaminants are formed during pyrolysis and are not contained in the CFI, adaption of the pyrolysis process for reducing the PAH concentration should be possible.

These results show, that the recycling of borated cellulose fiber insulation as a fertilizer is a viable end-of-life strategy for this material. In Austria, waste materials with B concentrations >30 mg kg^{-1} are considered hazardous waste and have to be incinerated and landfilled costly. Therefore, recycling CFI as fertilizer is not only a replacement of borate fertilizers, but also a strategy to avoid landfilling this material as hazardous waste.

Keywords: circular economy, critical raw material, bioeconomy, nutrient availability

0233

RESOURCE MANAGEMENT FOR NUTRITIONAL QUALITY AND SOIL ACIDITY IN GRAZED GRASSLAND

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Efficient management of resources is always a preference to farmers, but the lack of priority of soil acidity management in the UK has likely impacted the nutritional quality of grazed grasslands. Since the removal of the UK liming subsidy in the 1970's, the rate of annual lime applied in the past two decades was observed to decrease by 86,000 t/year. Adding lime to improve a low pH soil to an optimum pH range without fertilizer has been shown to increase yield by at least 1 t/ha on average, with a seven-fold return on investment. While research on liming soils has demonstrated an increase in yield, a majority of these studies have focused on food crops rather than grasslands and have often not distinguished compositional changes along the pH gradient. An established field demonstration and greenhouse experiment were used to determine the impact of pH and soil type on the sward composition and subsequent nutritional quality using Scottish soils. Our research has tentatively shown that by improving soil pH values through applying lime, the grazed sward composition is significantly positively changed and yield significantly improved. Liming to reduce soil acidity creates a more suitable and successful growing environment for common legumes who increase their proportion from nearly 0.0% in pH 4.5 to approximately 50.0% in pH 6.5 in the field experiment. As important sward components, our research confirms legumes are both lower in less-digestible fibrous materials and higher in crude protein. Therefore, the increasing proportion of legumes due to higher soil pH values increases the overarching sward nutritional quality. Our research to this point suggests the improvement of soil pH values to the optimum range is fundamental to improving yield, sward composition and subsequent digestibility and overall protein yield of Scottish grasslands. As such, liming is recommended as a priority in pasture management above fertilization.

Keywords: crop management, soil management, legumes, farming systems

0235

GRAIN ANALYSIS CAN PROVIDE A COMPREHENSIVE POST-MORTEM ON THE ADEQUACY OF A CROP'S NUTRITION

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Decisions on crop nutrition are typically guided by soil analysis, which generally includes three to six nutrients. Soil analyses are designed to reflect nutrient availabilities but cannot quantify crop nutrient uptake, and critical thresholds in soil are commonly uncertain. To complement soil analysis, plant analyses are also used and can assess all known plant nutrients. Whole plant analyses, when accompanied by biomass measurements, can assess nutrient uptake, but critical thresholds change markedly and rapidly throughout early development, so diagnoses of nutritional adequacy are also uncertain.

Grain (i.e. seed) analysis has the potential to augment the value of soil and plant analyses in retrospectively diagnosing the adequacy of combinable crop nutrition. Grain analyses can include all known nutrients and, if grain yield is known, they enable accurate estimation of nutrient removals from land. This supports 'maintenance' strategies which aim to replace nutrient removals, as is common with phosphorus and potassium management.

At harvest, partitioning of whole crop nutrient uptake to grain varies hugely, being maximal with phosphorus (>0.8) and nitrogen and minimal with potassium and calcium (<0.2). Recent experiments in which supplies of nitrogen and phosphorus to crops were varied have shown that grain nutrient concentrations were more responsive than grain yield to nutrient supply. Critical nutrient concentrations were identified where further uptake of that nutrient did not result in additional yield. For phosphorus, a critical grain concentration of ~3.2 g/kg was consistent for different environments and genotypes; however, critical concentrations for nitrogen were more subject to genetic variation and to the proportion of nitrogen uptake derived from fertiliser. A review of previous research indicated that critical thresholds could be proposed with moderate certainty for six further nutrients.

Analyses of wheat grain from 936 UK crops entered by farmers into a yield-study from 2016 to 2019 showed that nutrient concentrations were commonly less than the proposed critical thresholds; only ~25% of samples showed no 'deficiencies'. Deficiencies were most common with phosphorus, then nitrogen, potassium, sulphur and manganese. Comparisons of each result against all other results (termed 'benchmarking') helped growers to assess the adequacy of all nutrient levels, including those with unknown critical thresholds. It is concluded that diagnosis of yield shortfalls due to nutrition cannot be achieved satisfactorily using just soil and leaf analyses, and that these can be usefully augmented by grain analysis. Grain analysis has the potential to provide a comprehensive 'post-mortem' on the nutrient status of combinable crops.

Keywords: Cereals; Monitoring tools; Fertilization; Soil management.

0273

EFFECT OF NITROGEN RATE AND VARIETY ON YIELD, AND YIELD COMPONENTS IN MOROCCAN VARIETIES OF RAPESEED (BRASSICA NAPUS L)

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Rapeseed is one of the most important oilseed crops in the world. It seems to be able to offer a good alternative for diversifying and intensifying annual oil crops in Morocco. The objective of this study was the evaluation of the responsiveness of different Moroccan rapeseed varieties to nitrogen application. A field trial was carried out during two cropping years. Five varieties (V) of rapeseed (V1, V2, V3, V4, and V5Lila) were combined to the different levels of nitrogen (N) (0, 30, 60, and 90 kg N ha^{-1}), according to a split plot experimental design with tree replications, where nitrogen treatment was affected to main plots and variety treatment to subplots. Overall, the effect of growing season was highly significant on all parameters studied. Also, yield and its components were significantly affected by nitrogen rate, with an upward trend in seed yield as the nitrogen dose increased. On average, seed yield rose up from 1.17 t ha^{-1} to 2.09 t ha^{-1} for 0 and 90 Kg N ha^{-1}, respectively. Additionally, for the other traits studied, the highest mean values were observed for 90 Kg N ha^{-1}, except dry matter which exhibited the greatest yield for 60 Kg N ha^{-1}, with 6.25 t ha^{-1}.

The varieties variation was statistically non-significant, for seed yield, dry matter, and harvest index. However, it was significant for the rest of yield components investigated. The variety V3 was the most interesting for seed yield (2,51 t ha^{-1}) pod number (149 pods $plant^{-1}$), pods weight per plant (17,61 g) and seed number per pod (24 seed pod^{-1}).

Finally, the interaction Treatment * Variety had no significant effect on seed yield, harvest index, dry matter, pods number per plant, pod weight and number of branches per plant, while it had a significant effect on plant high and seed number per pod.

We conclude that under Moroccan conditions we recommend variety V3 with an application of 90kg N/ha split as 30 N/kg at sowing, 30 at rosette growth stage and 30 N/kg at flowering This work will continue with assessment of nitrogen uptake by grain and by biomass to investigate nitrogen use efficiency and also by evaluation of grain oil content for assessment of oil production for every V*N combinations.

Keywords: Brassica napus, Nitrogen, variety.

0286

THE LEGACY OF DIFFERENT COVER CROPS ON MYCORRHIZATION AND PLANT NUTRITION

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The use of cover crops (CC) in annual rotations can promote the arbuscular mycorrhizal fungi in soil with the corresponding benefits that these microorganisms provide. However, this effect may depend on the type of CC and the type of the succeeding main crop. This research quantifies the effects of different CC (monocultures and mixtures) in rotation with two different main crops on selected mycorrhizal and plant variables. We established a microcosm experiment under semi-controlled conditions with two factors and five replicas during two consecutive rotation cycles, one during autumn-winter period and other during spring-summer. The type of CC included BAR (Hordeum vulgare L.), VET (Vicia sativa L.), MEL (Melilotus officinalis L. Pall), two mixtures (BAR+VET and BAR+MEL), plus a control without CC (No-CC). The two main crops were maize (Zea mays L.) or wheat (Triticum aestivum L.). Mycorrhizal colonization, extraradical hyphae length and the concentrations of macro and micronutrients in plant were measured at 8 weeks after seeding the main crop in both cycles.

All CCs increased mycorrhizal colonization compared with No-CC in both cycles, with greater values for VET and MEL in both main crops in the winter cycle, whereas in the summer cycle BAR+VET tended to performed better in maize. In winter cycle, BAR and BAR+MEL increased hyphae length in wheat, but they decreased it in maize. Whereas, in the summer cycle those CCs containing barley increased hyphae length regardless the main crop. Most CCs increased P and Zn concentrations in plant in both cycles as well as S, Mn and Cu in the winter one, but they reduced K, mainly in the winter, and VET decreased B in summer cycle. In general, legume CC enhanced nutrient concentrations as VET showed the greatest values for P, Zn and Cu in the winter cycle, and MEL, BAR+MEL and BAR+VET showed the greatest values for P in the summer cycle. Finally, some nutrients positively correlated with mycorrhizal colonization, mainly in the winter cycle, as P, Cu, Zn and Mg (r=0.58; 0.47; 0.42; 0.39 respectively, p-values <0.01).

The great differences found between the winter and the summer cycle, as well as the interactions between CC and the main crops suggest complex relationships that should be study in depth to provide practical support for agronomic decision-making. Meanwhile, our preliminary results confirm that the choice of CC species has important effects on mycorrhization and nutrition of the subsequent main crop.

Keywords: legumes, maize, wheat, greenhouse

Session 3.3: Instruments for resource management: models, monitoring, and decision-making tools

0295

DIGITAL AGRONOMY TO DESIGN AND SCALE SUSTAINABLE AGRICULTURAL SYSTEMS

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New Big-Data and sensing technologies have shown the potential for more effective precision management systems leading to widespread increases in productivity, profitability and environmental co-benefits. These scientific and technological advances suggest several alternative pathways to more sustainable agricultural systems, including improved spatial and temporal management of existing cropping systems, as well as system changes that involve new crops and alternative land uses. The presentation will introduce a novel approach that integrates Digital Agriculture technologies to guide precision management of land and N inputs that results in simultaneous improvement of environmental and financial performance of row crop production systems.

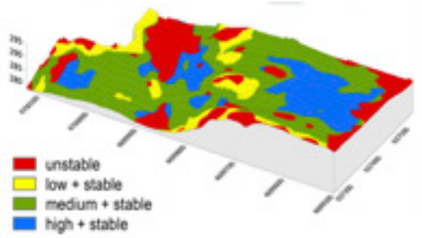

Figure 1. Example of a 3-D yield map obtained from yield monitor at 2 m spatial resolution for a farmer in Michigan.

Figure 1. Example of a 3-D yield map obtained from yield monitor at 2 m spatial resolution for a farmer in Michigan.

Although the precision agriculture technologies that allow for N fertilizer applications at different rates across a field have been available to US farmers since the 1990s, precisely matching crop N needs has remained a challenge. Thus, adopters of variable rate N technology often see slight increases in profitability and marginal reductions in input use, which translates to minimal environmental improvement. A possible explanation for this failure to achieve more substantial and widespread environmental benefits is that thus far, the algorithm developers for precision management have lacked the data and computational tools needed to convert complex geospatial information on soil and plant health status into appropriate crop management actions, leading in some instances to misinterpretation or misuse. For example, many farmers utilize precision technology to apply more N fertilizer to low-yielding areas in the hope of increasing yields, rather than less N to avoid loss of nutrient that crops cannot use. As such, the technology can become counterproductive toward N conservation goals.

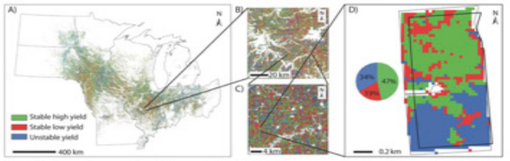

Figure 2. Crop yield temporal stability maps for ten U.S. Midwest states (A) and subregions of 10,000 km2 (B), 196 km2 (C), and 118 ha (D). Colors represent yield stability zones for 0.1 ha portions of fields planted to corn or corn soybean for three o or more years during 2010-2017 (~70 M acres total) (Basso et al., 2019).

To address this issue, we will apply the simple yet powerful concept of spatio-temporal yield stability (Figure 1). This is a characterization of the likelihood that a given area within a field will provide similar yields year after year. If sections of a field consistently produce high or low yields, then they are characterized as high-and-stable (HS) or low-and-stable (LS) zones, respectively. If crop productivity on a given area fluctuates between high and low yields from year to year, then it is classified as an unstable (U) zone (Figure 1). Based on previous work in which we used satellite imagery (at 30 m resolution) of corn and soybean growth across ~70 million acres in a 10-state region over ten years (2010-2019), we estimated that 46% of the cropland in the Midwest can be classified as HS, 26% as LS, and 28% as U. The analysis was performed at field level basis for over 8 million fields (Figure 2). These estimates were verified against data from growers' combine yield monitors (at 2m resolution) of thousands of corn fields across the region2. We estimate that overapplying N in low-yielding field areas costs Midwestern corn farmers US $500 million, wastes about 100 M GJ of energy, releases 1.1 Tg of reactive N to the environment, and emits 10 M tons of CO2 equivalent to the atmosphere every year. Furthermore, we have found that yield sta-

bility tightly correlates with profits; a trend that seems to hold across most of these fields. These findings paint an astounding picture: about a quarter of all US Midwest cropland is made up of low-yielding areas that constitute a financial burden on the farm enterprise (and the taxpayers), and an ecological burden on the environment.

However, they also reveal a golden opportunity for leveraging precision technologies to design system-level, turn-key N management solutions that can achieve the promise of financial and environmental improvement.

In summary, optimizing the multiple complex tradeoffs between agricultural productivity, food distribution and the environment is a daunting challenge that is becoming increasingly difficult in the face of accelerating food demand and a changing climate. This presentation illustrates how this challenge could be met in a way that balances the economic, environmental, and social dimensions of sustainable food production.

Keywords: Digital Agriculture, Remote sensing, Crop Modeling, Precision Plant Nutrition and Health, Precision Conservation, Farming Systems

0093

SMART INTEGRATED DATA ANALYSIS FOR AGRICULTURE SUPPORT DECISION -MAKING AND MANAGEMENT - SENSING4FARMING

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[1]GMV

Precision agriculture reduces crop waste along with the negative impact on the environment increasing the efficiency of the farm operations as much as possible. Current technological advancements allow to implement precision agriculture, although already started in the 90s, it is not up until now that there are more technologies that allow farmers to gather more precise data - sensors, satellite information, faster communications, stationary IoT solutions and so on.

Sensing4Farming is an innovative service based on applied technology, designed, and adapted to the agricultural sector after robust validations. In this way, the digitization of agriculture through an agronomic management system connected to IoT4.0, geospatial technologies and smart-automatized data analysis, is made available to support decision making and improve sustainability and competitiveness in the agricultural sector through the integration of knowledge and experience in different technological areas.

The platform integrates data from the European Union's Copernicus Earth Observation satellite constellation together with very high resolution imagery from commercial providers, weather stations and in-situ sensors and narrowband communications. WinEO is the orchestrator that integrates, process and analyses the different databases allowing the generation of georeferenced information with great precision. Large volumes of data from different sensors together with the use of long time series of historical data are integrated and analyzed through machine learning (ML) techniques for phenological state analysis, crop health status assessment, recommendations and precision treatments, zoning or site-specific management and yield prediction.

The analysis is performed at different levels. It's quite normal that same crops in a region show different phenological phases depending of planting dates, seed variety and weather behavior. Once identified the different phenological states, the analysis is performed at plot level and finally the evaluation of crop health status assessment intra-plot is performed. The system has been trained using machine learning and as input data a full dataset of eo-based standard and advanced products as evapotranspiration rates, LAI or FPAR. All this information combined with best practices knowledge leads to the provision of recommendations to the farmers, these recommendations apply to different areas like fertilization, irrigation or diseases treatment allowing the subsequent definition of site policies and the understanding of the insights behind the evolution of the crops. Finally, the analysis of the historical production figures combined with the time series produced allow to estimate yields at short and medium terms using ML regression methods with a direct impact in the farmer previsions.

Keywords: Sensing4Farming, WinEO, Copernicus, Machine Learning, Prescriptive /Predictive Analytics

0096

A SOLUTION TO OVERCOME SATURATION OF VEGETATION INDICES FOR CROP BIOMASS ESTIMATION

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Knowing the spatial variability of soil and crop properties is essential for planning variable rate application of agrochemicals in precision agriculture. Crop properties can be successfully estimated using aerial or satellite imaging sensors. Moreover, sensed data are spatially distributed and prescription maps for site-specific fertilization can be derived. For this reason, calibration curves for the estimation of aboveground biomass by remote sensed vegetation indices are widely studied. However, "saturation" is a common problem of these curves. Saturation occurs when vegetation indices reach their highest values, usually corresponding nearly to the full soil cover, while plants are still growing.

The objective of this research was to develop innovative vegetation indices, aimed at overcoming the problem of saturation by considering plant height.

We measured the "adjusted" vegetation indices in a two-year experiment with five different species of winter cover crops characterized by different plant and leaf habits: two grasses, Avena strigosa and Secale cereale; two legumes, Vicia villosa and Trifolium alexandrinum; one brassica, Sinapis alba. A multispectral camera was mounted on an unmanned aerial vehicle. Images of the field were acquired in autumn (two campaigns in 2017 and one in 2018), at the time of maximum crop ground cover. Classical vegetation indices were calculated based on red, green, red-edge and near-infrared bands. Red-based indices saturated at lower biomass levels than red-edge- and green-based indices, irrespective of crop species. The saturating biomass was on average 1.4 t DM ha-1 vs 2.5 t DM ha-1, respectively for the two groups of indices. We then calculated the adjusted vegetation indices by multiplying the indices by plant height. Plant height was collected from ground measurements, but was also estimated using digital surface models from aerial images. The most performing vegetation indices adjusted using measured crop height led to non-saturating calibration curves for all the species: R2 of 0.7, 0.8 and 0.9 for grasses, legumes and white mustard, respectively. Plant height estimated from digital images correlated well with measured height (Pearson's r= 0.84), with lower performance for smaller plants. We conclude that plant height provides information about vertical growth that, combined with vegetation indices, can lead to robust and global calibration curves for crop above ground biomass estimation from aerial digital images.

Keywords: cover crops, aboveground biomass, vegetation indices, plant height, unmanned aerial vehicle

0101

ASSESSMENT OF THE IMPACT ON WHEAT YIELD OF THE INTERACTION BETWEEN FERTILIZATION AND YELLOW RUST THROUGH MULTI-SENSOR MACHINE VISION

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This study combined manual measurements and imaging methods to characterize the interaction between yellow rust, *Puccinia striiformis* f. sp. *Tritici*, and plant nitrogen from the flag leaf stage to the grain maturation stage of wheat, *Triticum aestivum L.*. The first goal was to assess the effect of this interaction on yield elaboration. The second goal was to compare manual scoring and machine vision quantification of yellow rust.

The trial field was located at Lonzée (Gembloux, Belgium) and consisted of three fertilization modalities combined with three fungicide modalities. Images were acquired during the 2019 season by a RGB camera and a multi-band camera (filters centered at 680 and 800 nm) located at a nadir position 1 m above the canopy. Plant traits extracted from images were plant ratio, green ratio and yellow rust damage ratio. Those traits were integrated over the different acquisition dates to provide single yield predictors taking into account the crop dynamics.

Grain yield was highly correlated to integrated green cover (R^2 = 0.87 and RMSE = 0.53 t/ha) and integrated machine vision yellow rust damage (R^2 = 0.71 and RMSE = 0.83 t/ha). Yield was mainly determined by fungicide protection. Increasing the fertilization for unprotected micro-plots resulted in lower yields. As the ear density was sufficient for all modalities, it is suggested that the disease acted by first impacting the number of grains per ear and in a second time by limiting the photosynthetic green cover during the grain filling stage.

The comparison between human and machine scoring of yellow rust revealed that the two measurements may provide different and complementary information. Human observations were useful to detect the presence of spores under leaves at an early stage of the disease, allowing a first assessment of the presence of

yellow rust. At a later stage, after fungicide spraying for some micro-plots, machine vision allowed to quantify the damage of the disease more effectively that human scoring.

The study was funded by the Agriculture, Natural Resources and Environment Research Direction of the Public Service of Wallonia, Belgium (Project D31-1385) and the National Fund of Belgium FNRS-F.R.S. in the frame of a FRIA grant.

Keywords: wheat, yellow rust, RGB image, multi-spectral, multi-sensor

0103

EX-ANTE ASSESSMENT OF HERBICIDE REDUCTION BY IMPLEMENTING EARLY PRECISION WEED CONTROL IN SPRING CROPS

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Use of herbicides needs to be properly managed to balance benefit of reducing harvest loss due to weeds against potential environmental risks. Precision weed control is expected to reduce the quantity of applied herbicide by better targeting the spraying. This can involve several components of weed control, ranging from strategic to tactic decision-making, up to equipment management. To this end we tested the coupling of a weed emergence predictive model (AlertInf) for spring row crops with mapping of early weed distribution. Our aim was to achieve both timely herbicide application and precise spatial weed distribution to ensure the highest herbicide efficacy. Airborne images produced by Unmanned Aerial Vehicles provides the best trade-off for retrieving the spatial localization of the weed infested areas. Three series of images were acquired in early June 2019 over a maize field in the experimental farm of the University of Padova. Additional field surveys allowed to identify the presence of the target weed Sorghum halepense (L.) with an emergence percentage of 96%, of total final emergence, according to the AlertInf model, at the date of the flight. Weed spatial distribution was assessed by the exploratory comparison of two algorithms: Artificial Neural Networks (ANN) performed within the SAGA software, and Visible Atmospherically Resistant Index (VARI) within ArcGIS Pro. Classification performances were trained and evaluated against a dataset issued from visual on-screen labelling three classes, i.e. crop, bare soil, weed. ANN provided more precise weed classification in respect to VARI, therefore VARI missed a part of infested area compared to ANN. Based on the technical specifications of different models of sprayers, several maps were created splitting the field into cells of 3m2, 2m2 and 0.25m2 and with three different thresholds for treatment decision depending on each cell infestation (i.e., >1%, >5% and >10% of pixel labelled as weed). Prescription maps showed that potential sprayed area reduction, compared to traditional spraying of the entire field, can vary from 42% to 87% at >1% threshold and from 65% to 93% at >10% threshold by using ANN and VARI classification respectively . Altogether, the results suggest that site-specific mapping informed on emergence models can enable a substantial herbicide reduction through both timely and site-specific weed control with ordinary section control sprayers. Further research is required to evaluate the contribution of a weed emergence model, such as AlertInf, to herbicide usage reduction, performing additional tests in different fields and including more weed species.

Keywords: Precision agriculture, Herbicide reduction, UAV, Weed Science

0123

WHEAT NITROGEN AND SENESCENCE DYNAMICS IN FIELD ASSESSMENT THROUGH TWO PHENOTYPING APPROACHES LATE IN SEASON

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High-throughput field phenotyping methods have become an accurate method for nitrogen assessing in field early in season with vegetation indices but its application later in season remains more complicated. This study aims at developing a new method to estimate nitrogen content and senescence dynamics in field during the grain filling period through non-invasive phenotyping. Vegetation indices will be tested on two trials at two different scales; canopy and organs scale. The canopy data are taken through a UAV whereas the organs level data are taken by means of a ground-based mobile platform. They are both using an RGB camera and a multispectral camera. Mean reflectance of each micro plots from the UAV orthomosaics are used to compute vegetation indices. Since ground-based image acquisition allow finer spatial resolution, a segmentation between ears and vegetation can be compute with different methods such as machine learning algorithm, textural analysis or height information taken from stereovision. As a result, a list of vegetation indices is tested on the two classes of the images for nitrogen and senescence assessing. Data are also compared to reference measurements for leaves, stems and ears nitrogen content at different growth stages. Nitrogen and senescence dynamics are characterized in two trials; a fertilization trials and a fertilization with different fungicide application trials in order to evaluate their impacts on grain yield and grain nitrogen yield. The two acquisition scales approaches are also evaluated.

Keywords: *crop dynamics, nitrogen, senescence, in-*field phenotyping, wheat, grain yield

0136

DIGITAL AUGMENTATION FOR SUSTAINABLE INTENSIFICATION OF DRYLAND FARMING SYSTEMS

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Resilient agroecosystems that produces quality foods are become key pillars for sustainable development while also ensuring efficient resource-use and ecological functions under changing land use, climate, diet and demography. This calls for a paradigm shift towards producing food, fiber and forage in a sustainable manner with low inputs and integrated intensification. Such intensification system cannot be built on homogenous landscapes and monocropping and it require certain level of farming systems diversification with mixed crops, trees and livestock to preserve soil health, biodiversity, and overall ecosystem services. Crop rotation and intercropping of pulses in cereal-based production systems offer opportunities to achieve some of these goals. In dryland agriculture there is a tremendous potential to adopt these practices without increasing the water and land footprint of agriculture, by adding a short duration pulse crops in place of fallows between two cereals such as rice-fallows. This require multicriteria assessment of farming system dynamics along with resources that aid to upscale at country level sustainable intensification of pulses with sound ecological functions and management practices. The data driven digital augmentation to quantify farming systems and suitable areas in real-time basis (in-season) is made possible by recent advances in Earth Observation System (EOS), Open-Access Data (OAD), Deep Learning Intelligence (DLI), Cloud Computing Platforms (CCP) along with Smartphone enabled Citizen Science (SCS) making Big-Data Analytics (BDA) much smarter, interoperable and much more useful than ever before. Such Digital Augmentation Platform (DAP) helps to address the gaps at multiple levels (e.g., data, yield, ecology, economy, resilience) for demand-driven agroecological interventions across the scale (e.g., space, time and package). Here we are presenting ongoing efforts of digital augmentation for accelerating sustainable intensification through introduction of variety of food legumes and other crops in rice-fallows in south Asia aiming at quantifying functional domains (farming systems, farm typology, crop phenology), resources (soil moisture, nutrients, fallow dynamics) and drivers (climate, access, diet pattern, socio-economics) to target site specific interventions and management. It also aims to identify potential niche for scaling across agroecologies, regions and discuss foster development in the context of the DryArc interface for providing comprehensive and multi-actor analytical decision support to transform and enhance the resilient agroecosystems in the dry areas.

Keywords: Digital Augmentation, Sustainable Intensification, Agroecosystems, Pulses, Drylands

0205

CROPEBAL: A WINDOWS PROGRAM FOR CALCULATING THE INPUTS AND OUTPUTS OF ENERGY FROM CROP ROTATIONS

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The efficient use of energy in agricultural systems is a key condition for their sustainability because it allows financial savings, fossil resources preservation and air pollution decrease. Energy auditing is one of the common and reliable approaches to examine energy use efficiency and can serve as a first step towards identifying efficient production processes and cropping

ABSTRACTS OF POSTERS COMMUNICATIONS

systems or as building blocks for life cycle assessment of agricultural products. This work introduces CropEBal, a free and non-commercial Windows program to calculate the inputs and outputs of energy from cropping systems. On the one hand, the program evaluates the associated energy expenditure to tillage, planting, harvesting, fertilization, application of pesticides and irrigation. Further energy use in labor, transport of personnel and materials, drying of the harvested product or desalinizing water for irrigation can also be considered by the user. On the other, CropEBal provides an estimate of the energy outputs of the farm in the crop exports, hence evaluating the efficiency of the system from the ratio of outputs to inputs. The application can be applied to both monocultures and customizable crop rotations from a list of 149 species. Calculations are based on reports of the American Society of Agricultural and Biological Engineers and on chapters of the book 'Principles of Agronomy for Sustainable Agriculture' (Villalobos and Fereres, 2016, Springer). CropEBal is available (www.uco.es/fitotecnia) in three different languages so far (English, Spanish and Portuguese) and includes the manual and additional reading material. Video tutorials for first time users can be found in Youtube.

Keywords: crop management, environmental impact, sustainability

0206

A SIMPLE DECISION SUPPORT SYSTEM FOR FERTILIZER MANAGEMENT: FERTILICALC

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Rational fertilizer management is critical as it uses non-renewable resources and energy and may create environmental problems. We have developed a VB.net Windows program called FertiliCalc to calculate the seasonal requirements of N, P and K, and the most cost-effective combination of commercial fertilizers to meet them. It also provides estimates of the Ca, Mg and S balances in the field resulting from the fertilizer program chosen and the calculation of acidification and N losses. When available, the program considers the values of soil P and K concentrations in the calculations. In order to avoid blending of simple fertilizers at the farm, FertiliCalc includes the selection of the best complex fertilizer for pre-plant applications. The program was developed first as a tool for teaching/learning as it helps understanding the rationale behind fertilizer management, but it may be useful both for the fertilizer supply (dealers, manufacturers) and demand (extension agronomists, farmers) sectors. Thanks to the generous contribution of agronomists from many different countries, Fertilicalc is available in 75 languages (as of June 2020) and can be downloaded from www.uco.es/fitotecnia at no cost.

Keywords: decision support systems, fertilization, nutrient requirements

0264

TOWARDS STATISTICAL PATTERN RECOGNITION GRAPH MORPHOMETRY APPLIED IN AGRICULTURAL ROBOTIC VINEYARD PRUNING

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Computational systems employed in Precision Agriculture (AP) currently provide relative sampling, precision and level of data processing required by agricultural practices, which were not common to early conventional agriculture, raising production costs and research aimed at sensing remote, mapping and inspection of planting lines, assisting farmers' activities during all planting stages of a particular crop. Given this information and relating the level of investment and development of these technologies, this research aims to apply statistical-based image analysis referred to a graph morphometry agricultural scenario with robotic mobile manipulator assigned to vines' pruning. Such task is necessary so that the spur pruning process is carried out autonomously, verifying parameters and technical/real characteristics of pruning and also the vine itself. Within an initial potential pruning region detection, through a residual neural network R-CNN architecture, a merged statistical pattern recognition-based method with Naive-Bayes, KNN, and K-Means provided reliable results when identifying pruning points by a graph-based morphometry in each branch. This research is part of a multidisciplinary project namely VINUM.

Keywords: vine puning, mobile robot manipulator, graph morphometry.

3.4. New avenues for managing biotic and abiotic stresses

0071

WHICH NITROGEN FERTILIZATION TECHNIQUES AND CROP TRAITS PROMOTE WEED BIOLOGICAL REGULATION BY COMPETITION?

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Environmental concerns compel us to reduce agricultural chemical inputs such as herbicides and mineral fertilizers, particularly nitrogen. Reduced herbicide use may increase weeds and reduced mineral fertilization may limit nitrogen resources. Thus, crop-weed competition for nitrogen may increase.

Weeds with high nitrogen nutrition requirements are often hard to manage. They could be disadvantaged by driving crop-weed competition through an adequate choice of crop species/varieties (according to their nitrogen nutrition traits) and/or adaptation of nitrogen fertilization (rate, date, straw burial or export). This study aimed to identify which crop traits and nitrogen fertiliza

tion options can reduce weed harmfulness while maintaining crop production over the years.

A maize monoculture from Aquitaine (France) was simulated over 10 years and 5 weather repetitions using FlorSys[1]. This process-based model simulates crop growth and weed dynamics over the years with a daily time step from inputs describing cropping system and pedoclimate and from species traits. We simulated many combinations of nitrogen fertilization (dates and rates, straw burial vs export) and initial soil organic nitrogen content with three maize varieties (one actual V1 and two virtual named V2 and V3) differing by their trait values related to nitrogen nutrition. The effects of fertilization, initial soil organic nitrogen supply and maize variety on potential yield and weed (dis)service indicators were studied.

A sensitivity analysis revealed that maize variety, nitrogen rate and initial soil organic nitrogen content affected the indicators the most. Nitrogen date and straw burial vs export affected them the least. Compared to the V1 maize variety, in average, V2 improved potential yield, weed services (weed species richness, bee food offer) and decreased disservices (yield loss due to weeds, weed seed production). Variety V3 had the

opposite effect. Depending on their traits related to nitrogen nutrition, maize varieties reacted differently to fertilization techniques. For V1 and V2 to a lesser extent, increasing nitrogen rate increased potential yield, species richness, decreased weed seed production and bee food offer. It was the opposite for V3. Increasing nitrogen rate decreased yield loss for each variety, it was stronger for V1 and V2 than for V3. Interestingly, an increase of initial soil organic nitrogen of 50 kg/ha decreased potential yield by 0.5 to 1 q/ha depending on the variety.

Further simulations applying optimization algorithms will be carried out to identify nitrogen dates and rates that maximize yield, bee food offer and minimize yield loss.

1Colbach N, et al. (2014), Weed Research, 54: 541-555. https://doi.org/10.1111/wre.12112

Session 1: Crop functioning and crop quality

Session 1.1: Crop physiology

0008

A CODE AND DESCRIPTIVE SCALE FOR THE PHENOLOGICAL PHASES OF SUBTERRANEAN CLOVER (*TRIFOLIUM SUBTERRANEUM* L.)

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A visual and numerical scale for the subterranean clover plant is presented, with crop-specific descriptions and detailed assessment for vegetative and reproductive phenophases.

The phenological development process periods (main growth stages) and phases (secondary growth stages) are described using a code suitable for data processing in crop production which is assigned to each developmental step for subterranean clover. The stages were characterized visually in field and controlled environment conditions. The vegetative phenophases include the period from emergence (V1) to runner extension (VR). VR was when the secondary stem (runner) was formed and had grown more than 20 mm away from the centre of the plant. This phenological phase (VR) was used to represent the end of the vegetative phase and the first visible sign of reproduction on subterranean clover plants.

The sequential reproductive phenophases started with the first visible floral bud appearance (R1). The phenophase when the flower head peduncle bends towards the ground and positive geotropism is initiated was defined as R6. Burr formation and maturity were defined as R8 and R12, respectively. The developed visual scale presents the morphology of the inflorescences and specific individual floret/seed development to display the seed filling process. Each ontogenetical stage is identified with a picture and brief description, which can be used to track phenological development of any subterranean clover cultivar.

Keywords: *phenology, Trifolium subterraneum, growth-stages, vegetative, reproductive.*

0010

PHENOLOGY OF SUBTERRANEAN CLOVER AFFECTED BY SOWING DATE

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Phenological development of 6 subterranean clover cultivars was studied over a range of eight sowing dates in temperate New Zealand climate. The duration of vegetative development phases and reproductive phases were mostly influenced by environment (sowing date) than by genotypes.

The differences in total life cycle due to changes in physiological processes are reflected in each phenological phase in response to sowing date and genotype. The period from runner extension (VR) to appearance of first floral bud (R1) was the longest within the plant's life cycle. This period showed strong seasonality due to differences in temperature and photoperiod created by contrasting the sowing date regimes. It ranged from a minimum of 451± 159 ^{o}Cd when cultivars were sown in July, September and November sowing dates to a maximum of 1428 ± 163 ^{o}Cd when sown in February. The complete crop life cycle from sowing (V0) to maturity (R11) ranged from 1269 ± 31 ^{o}Cd (equivalent of 123 ± 6.3 days) for 'Antas' sown in July to 2799 ± 47 ^{o}Cd (300 ± 3.9 days) for 'Woogenellup'. For the sowing which occurred in and increasing photoperiod (June-November) the life cycle of all cultivars was 59% shorter than when sowing occurred in a decreasing photoperiod.

The quantification of phenological phases and thermal time requirements for specific development stages during the subterranean clover life cycle is vital to optimise management strategies (husbandry, grazing and seed harvest) and provides the basic parameters for inclusion in simulation models.

Keywords: *development, physiology, phenology, photoperiod, Trifolium subterraneum, genotype.*

0148

GENOTYPIC VARIATION IN SOYBEAN STOMATAL CONDUCTANCE, WATER STATUS AND ABA ACCUMULATION UPON SOIL DRYING

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Stomatal conductance is one of the most important physiological parameters to consider for breeding drought-tolerant genotypes, since stomatal closure could restrict photosynthesis thereby limiting soybean yields. In addition, prompt stomatal closure following exposure to drying soil early in vegetative development could conserve water, making more water available to the plant during the critical grain filling stages. Therefore it is necessary to understand the regulation of stomatal conductance. Different signals could cause stomatal closure, even though there are considerable interactions between signalling systems. Whereas loss of leaf turgor (a hydraulic signal) can stimulate a biochemical (ABA accumulation) signal, some studies have shown that a putatively root-sourced biochemical signal can mediate stomatal closure prior to any change in leaf water relations. Soybean (Glycine max (L.) Merr., genotypes Williams 82, Jindou 21, Union, Long Huang 1 and Long Huang 2) were grown under soil drying conditions to investigate relationships between leaf xylem sap and leaf tissue ABA concentrations, stomatal conductance and leaf water potential among different genotypes. Stomatal conductance was better explained by variation in leaf xylem sap ABA concentration than leaf tissue ABA concentration or leaf water potential in most of the genotypes studied, which is physiologically important as stomatal closure limits soybean yields. Thus, limited ABA accumulation may be useful as a marker for breeding plants under drought conditions, assuming plants can access sufficient soil moisture at depth. Whether there is genotypic variation in such stomatal regulation within a crop species, and soybean is particular, has attracted little attention.

Keywords: biochemical signal, genotypes, hydraulic signal, water stress

0291

HYDROSOS ALMONDS: IMPROVING THE FRUIT QUALITY BY MEANS OF DEFICIT IRRIGATION STRATEGIES

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Implementing deficit irrigation (DI) strategies in agricultural Mediterranean areas is not an option but also mandatory under the current climate change and water scarcity scenarios. This fact is even more compulsory in woody crops such as almond (*Prunus dulcis* Mill.), which traditionally had been cultivated under rainfed conditions although recently, it has been progressively introduced in irrigated areas. An important aspect to consider would be the capability of improving some fruit-quality parameters when DI strategies are imposed, which would allow a recovering in terms of final price, ensuring the sustainability and competitiveness of this crop when it is grown under water scarcity scenarios. This work examines the effects of water withholding in young almond trees (*cvs.* Guara, Marta and Lauranne) in the most determinant parameters related to the almond's marketability and consumer acceptance (almond size, color, kernel ratio, total phenolic content, organic acids, sugars and volatile compounds). Three irrigation treatments were defined: a full irrigated treatment, which received 100% of irrigation requirements (IR) and two sustained-deficit irrigation (SDI) treatments that received 75 (SDI_{75}) and 65% (SDI_{65}) of IR. Significant differences were obtained in all the studied parameters both in terms of irrigation doses and cultivar. On overall, SDI strategies allowed to improve physical parameters such as unit weight, kernel length, kernel thickness or color coordinates. Moreover, higher total phenolic compounds, organic acids or sugars were reached under SDI strategies. Even more, the highest concentrations of volatile compounds were reached under SDI treatments, these being a clear advantage in relation to almond flavor. These results allow concluding that SDI strategies offer relevant improvements in almond parameters related to marketability and consumer acceptance, improving the final added value of *HydroSOS* almonds in comparison to those obtained under FI conditions.

Keywords: Water stress, sustainability, marketability, fruit size, volatile compounds

Session 1.2: Crop interaction with biotic and abiotic factors

0011

EVALUATION OF NITROGEN, PHOSPHORUS AND SILICON APPLICATION FOR ENHANCING YIELD PRODUCTION , NUTRIENT STATUS AND PHYSIOLOGICAL PROPERTIES BY WHEAT PLANT GROWN UNDER VARYING PHOSPHORUS RATES

Silicon (Si) is a beneficial element for plant growth. It helps plant to overcome multiple stresses, alleviates metal toxicity and improve nutrient imbalance. A pot experimental was conducted in greenhouse of NRC, Dokki, Cairo Egypt to study the response of wheat plants to different levels of phosphorus at (60 kg P2O5 or 30 kg P2O5) with or without potassium or magnesium silicate and poultry manure on growth yield ,nutrients status and physiological compositions .

Results indicated that yield straw and grain, nutrients status and physiological composition by straw and grains of wheat plant increased significantly as affected by chicken compost and potassium or magnesium silicate addition under varying phosphorus rate in calcareous soils.

Data reveal that the addition either potassium or magnesium silicate (Si) with added to 60 kg P2O5 increased significantly affected all the growth and yield parameters as well as nutrient status and physiological compositions (Chlorophyll a and b, carotene and protein content) as compare to 30 P2O5 (low rate of P). Data also reveal that, application of poultry manure (PM) combined with Si significantly increased values of all mentioned parameters as compare to control (high and low rate of P). While the application of PM with added to 60KgP2O5 had positive effect on grain and straw yield and uptake of N P k and Si in straw and grain by wheat plant. Moreover, addition of poultry compost (PM) combined with potassium silicate had a positive effect of all yield components, nutrients status and physiological composition. Highly significant and positive correlation were observed when used of Si as potassium silicate combined with poultry manure with the high rate of P at (60 kg P2O5) produced the highest values of grain yield, weigh of 100g grain as well as straw yield plant and NPK uptake of wheat plant, also, this treatment suggested the optimum combination for higher values of physiological compositions (Chlorophyll a and b, carotene and protein).

Better level of P available as a result of Si fertilization and poultry manure may increase the production of yield and physiological compositions in wheat plant.

Keywords: Silica -wheat- P - PM - improve - production - physiological-nutrients -yield .

0017

EFFECTS OF ENVIRONMENTAL FACTORS ON HAY MEADOWS BIODIVERSITY IN ARAGÓN, SPAIN

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Soil and hydrological properties, as well as topographic and climatic features were analysed in 50 hay meadows from the Spanish Pyrenees in Aragón with the objective of studying the possible relationships among these factors and the biodiversity in the meadows. The vegetation survey consisted on a floristic inventory of the central 100 m^2 of each plot. The species cover was estimated by transforming the abundance-dominance phytosociological indexes to percentages and taking the data to 100%. From these values, the Shannon biodiversity index was calculated to quantify species richness and abundance. A representative soil sample was obtained at 0-20 cm depth of each plot and observable parameters such as compactness, altitude or slope were recorded on site. Soils showed a high content in organic matter and a low C/N relation, indicating a good mineralisation of organic matter. The effective cation exchange capacity was adequate and texture varied from sandy loam to loamy sand, with a mean clay content of 10.5%; pH oscillated from 6.5 (slightly acidic) to 7.1 (neutral), interval in which nutrients are at their highest availability. Contents of exchangeable Mg and K moved between high and excessive, with mean values of 2.58 and 1.4 $cmol_{(+)}\ kg^{-1}$ respectively. Chi-square automatic interaction detection (CHAID) was used to determine the key factors affecting the Shannon index. According to the decision tree, annual mean temperature (with an F-value of 12.676 and a corrected p-value of 0.001) and altitude (F-value=24.283 and corrected p-value=0.001) were the most important variables explaining the Shannon index in the area. Other factors, such as pH and K were not significant according to the CHAID decision tree, although they were correlated with the Shannon index by the Pearson coefficient and

the linear regression model. Management was also included in the analyses to check for any relation between different techniques, regarding fertilization (manure or chemical fertilizer) and mowing (with or without tractor). However, according to the different analyses applied, management techniques had no apparent influence on the Shannon index. These results show the importance of climatic and topographic factors on hay meadows biodiversity. This work is framed within the context of the European project Interrreg "SOS PRADERAS" SOE1/P5/E0376 and has benefited from cofinancing of FEDER funds 2014-2020.

Keywords: climatic variables, Huesca, Shannon index, soil analysis

0084

RESPONSES OF SOIL BACTERIAL AND FUNGAL COMMUNITIES TO ORGANIC AND CONVENTIONAL FARMING SYSTEM

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Organic farming is contributing towards sustainable agricultural management. More than 20% of Estonian agricultural land is managed following the organic standards. However, understanding of soil microbial diversity under long-term organic and conventional farming is still not well characterized. The aim of the study was to study the soil bacterial and fungal diversity and compositions in the long-term crop rotation experiment comparing organic farming and conventional farming using the Illumina MiSeq platform.

The field experiment was established on 2008 on the experimental fields of the Estonian University of Life Sciences (58o 22´ N, 26o40´E) and the soil samples was collected on 2013 and 2018 (beginning and end of the second rotation). Soil type was Stagnic Luvisol (sandy loam surface texture, C1,38% and N 0,13%, pHKCL 6,0). The experiment was set up in systematic block design with four replicates of each treatment. The field was divided by nitrogen treatments: three different treatment in organic plots (M0, MI with cover crops, and MII with cover crops and manure) and four different treatments in conventional plots (N0, Nlow, N100average, and Nhigh). The five-field crop rotation based on following order of the crops: barley with undersown red clover, red clover, winter wheat, pea, potato.

Fungal and bacterial alpha-diversity increased by the end of the rotation. However, the effect of the farming system was larger for bacteria. The Nhigh treatment had no effect for fungal or bacterial diversity.

Ascomycota, basidiomycota, mortierellomycota had the highest abundance among fungal phylum, and the abundance was not much changed after the full crop rotation. The biggest change was observed in N0, where glomeromycota was replaced by ascomycota and basidiomycota. Changes in bacterial abundance were clearly observable so that abundance of firmicutes as dominant phylum at the beginning of the experiment decreased and quantity of actinobacteria increased in all treatments by year 2018. By considering the most abundant bacterial classes, a reduction in bacilli and clostridia and an increase in thermoleophilia and actinobacteria were shown.

Farming system did not have significant effect on functional groups. The most abundant functional groups in fungal population were saprotrophs. Abundance of pathogenic functional groups decreased and mycorrhizal groups increased after 5 years crop rotation. Among bacterial population, aerobic chemoheterotrophy was the highest abundant group. Crop rotation significantly increased abundance of aerobic ammonia oxidation, nitrate reduction and aromatic compound degradation and decreased fermentation, aerobic compound degradation and aerobic chemoheterotrophy abundancy.

Keywords: organic, conventional, bacteria, fungi, diversity

0107

IMPACT OF ELEVATED TEMPERATURES ON THE BERRY QUALITY OF MONASTRELL VINES

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According to the climate projections for Europe and Spain for mid-century, temperature, aridity and water stress are expected to reduce yield. The increase of extreme temperatures would lead to a decrease in berry and wine quality, especially in the most continental and warmer areas from the center and south of the Iberian Peninsula. In this work it was evaluate the effect on Monastrell grape quality of an increase of temperature in the berry microclimate environment. A field experiment was carried out in Murcia (Spain) in a commercial vineyard cv. Monastrell. Control vines, at ambient temperature, were compared with heated vines using open-top chambers made with two different materials: transparent polycarbonate panels (TP) or thermal plastic sheets (TT). This structures were installed around the vines, from veraison to harvest and were placed from ground to cluster level, on both sides of the plant row. Berry and microclimate temperature were monitored and berry quality was evaluated at harvest time by determining their technological and phenolic quality. The temperature chambers induced a significant alteration of the berry microclimate, increasing temperatures above controls during 7-11 hours per day, with maximums of 5-7 ^{o}C above the control. Both materials produced similar variations in the microclimate of the berry with respect to the control, increasing 1.5 ^{o}C the mean daily temperature, decreasing 0.2 ^{o}C the mean daily night temperature, and increasing more than 1.5 ^{o}C the daily thermal amplitude (day-night). Similar behavior was also observed in the berry. Daytime temperatures compared to the control were slightly higher in both materials (around 1 ^{o}C). In contrast the night temperatures were lower in both materials (-0.55 ^{o}C in TT and -0.30 ^{o}C in TP) than in the control. In addition, both materials also presented significant differences in the daily thermal amplitude with respect to the control (1.64 ^{o}C in TT and 1.34 ^{o}C in TP). Both materials produced a significant effect on the grape quality. Due to the increase on the total anthocyanins produced in berries from TP treatment, phenolic quality was improved compared to the control. However, no improvement of berry quality was detected on berries from TT material. Considering the temperature results observed in both materials, the lower night temperature, with a moderate thermal amplitude with respect to the control could be the cause of this improvement. Our results seem to indicate the importance of the thermal amplitude experienced during the ripening period for berry maturation.

Keywords: Vitis vinifera, High temperatures, Monastrell, Berry quality

0130

PRODUCTIVE EVALUATION OF 33 BREAD WHEAT VARIETIES IN BALKH AGRO-CLIMATIC ZONE IN NORTH OF AFGHANISTAN

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Wheat is the primary staple food of most Afghanistan households. The use of improved wheat varieties has been demonstrated contributing to raise yields as much as 33% in Afghanistan. Thus, the more widespread use of improved seed has been identified as a major development imperative. This work was aimed to evaluate the productive performance of 33 improved wheat varieties (*Triticum aestivum*, L.) in Balkh agro-climatic zone, Afghanistan. A field trial was conducted during two consecutive cropping season, 2017/2018 and 2018/2019 at the Dahdadi Research Station. The experiment was laid out in a three replicated randomized complete block design having plot size of 2x0.8m (1.6 m2). Plots were maintained under well-watered conditions to avoid water stress. Varieties exhibited a general adaptation with a variable grain yield; Based on ANOVA and Tukey-HSD post hoc test ($p<0.05$) the varieties were classified in seven categories from higher yield class (A) toward to lower yield class (G). The highest yield was measured on variety Ghori-96 (4.6 t/ha) followed in decreasing order by Kabul-013 (4.5 t/ha), Lalmi-015 (4.4 t/ha), MH0303-09 (4.3 t/ha), Muqawim-09 (4.3 t/ha), Zarin-013 (4.1 t/ha), Dyema-96 (4.1 t/ha), Elham-015 (4.1 t/ha), Bakhtawar-013 (4.1 t/ha), Otan-09 (4 t/ha), Dahdadi-13 (4 t/ha) and Darulaman-07 (4). The lowest yield was measured on Solh-02 (2.3 t/ha) followed by Shamal-017 (2.5 t/ha), Afghan-015 (2.8 t/ha), and Chont#1-010 (3.1 t/ha). With respect to the yellow rust resistance, MH0303-09 was found being

resistant, Kabul-013, Lalmi-015 and Ghori-96 resulted medium resistant, while Zarin-013 resulted being medium susceptible. Grain yield in Lalmi-015 was positively correlated with growing degree days (GDDs) accumulated over the whole growing period. Grain yield in MH0303-09, Zarin-013 and Dyema-96 were found being negatively correlated with GDDs accumulated between sowing and heading to maturity, while being positively correlated with GDDs accumulated between heading and maturity. According to these results, the MH0303-09 could be highly recommended to be used in the Balkh province, north agro-climatic zone of Afghanistan.

Keywords: Wheat varieties performance, Varietal adaptation, Grain production, Afghanistan

0151

ACTIVITY OF SOIL ENZYMES DEPENDING ON SOIL CULTIVATION METHODS IN SPRING WHEAT CULTIVATION

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Adaptive soil cultivation methods for use on agricultural are crucial to improving crop productivity and water-use efficiency. Enzymes catalyse all biochemical reactions and are an integral part of nutrient cycling in the soil. Soil enzymes are believed to be primarily of microbial origin but also originate from plants and animals. Little information is available on the effect of using different soil cultivation methods on soil enzymes activity during vegetation of different species spring wheat. Hence, in this study, three methods of cultivation: 1. Plow, 2. Surface Plate, 3. Mulch Belt Sowing were used during vegetation three species of wheat: 1. Triticum persicum, 2. Triticum sphaerococcum, 3. Triticum aestivum. The study was based on a field experiment located in Poland, the kujawsko-pomorskie region (53˚130 ´ N, 17 ˚510´ E) near Bydgoszcz (Midwestern Poland). The soil was sampled from the Ap horizon 5-25 cm deep, in the 2nd year of the experiment, three following times: 12.04., 04.06. and 18.07.2019.

The reaction of soil enzymes activity dehydrogenase (DH), β-glucosidase (GL) and fluorescein diacetace hydrolyse (FDA) in vegetation of spring wheat depended on cultivation methods and they were differed during development stages wheat. The activity of dehydrogenase varied between 1.048 mg TPF $kg^{-1}\cdot 24\ h^{-1}$ and 35.292 mg TPF $kg^{-1}\cdot 24\ h^{-1}$ and depend on the date of sampling, methods of cultivation and species of spring wheat. Values for FDA activity was between 6.160 mg F $kg^{-1}\cdot h^{-1}$to 153 mg F $kg^{-1}\cdot 24^{-1}$ and was statistically insignificant between three sampling dates. The highest activity of dehydrogenase and FDA was in soils sampled from mulch belt sowing . The activities of this enzymes were decreased by 38% for DH and 33% for FDA for soil in plow system in comparison with mulch belt sowing. The activity of β-glucosidase varied between 0.190 mM pNP $g^{-1}\cdot h^{-1}$ and 1.283 mM pNP $g^{-1}\cdot h^{-1}$ and were depend on the date of sampling. β-glucosidase an enzyme involved in cellulose degradation, plays an important role in the soil organic carbon cycle. The activity of glucosidase was in July about 70% higher than its activity at the beginning of vegetation of wheat. While the higher activity of DH was shown for data collected in April than in June.

Since soil enzymes are very sensitive to different factors, determination of its activity might be helpful in soil quality monitoring.

Keywords: enzymes, cultivation, wheat, soil

0161

CREATING A NETWORK OF SEMIARID AGRO-ECOSYSTEMS FOR STUDYING CLIMATE CHANGE INFLUENCE ON CROP YIELDS

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Rainfed semiarid agro-ecosystems are known to be especially vulnerable to the effects of increasing temperatures and reduction of rainfall. Also, crop production might be the result of climatic conditions together with soil characteristics. Thus, our main objective was to create a network of experimental sites at different latitudes where we can evaluate the influence of climate change on crop yields and on soil quality. Our second objective was to set a greenhouse experiment under controlled conditions of temperature and water supply in order to elucidate to what extent differences in soil characteristics will influence crop development and yield.

We established in 2007 two experimental fields in two localities in Spain: Madrid and Sevilla with the same four-year crop rotation (wheat-pea-barley-rapeseed) under the same soil management practices (i.e. minimum tillage, 200 kg ha^{-1} 8/24/8 mineral fertilizer) and four field replications. The greenhouse experiment consisted on 32 pots corresponding to the two localities, four crops, and four repetitions. We analysed several soil properties from the field experiments and we followed crop development in the greenhouse.

Mean annual temperature and annual rainfall were both lower in Madrid (13.8ºC, 415mm) than in Sevilla (18ºC, 519mm). Soil from Madrid was classified as an Inceptisol *Typic Calcixerept* (Soil Taxonomy, 2014) with a sandy loam texture, whereas soil from Sevilla was classified as a Vertisol *Typic Haploxerert* with a clay loam texture. Both soils had high pH values (~8.3) and low values of organic C (~5.5g kg^{-1}) and organic N (~0.6g kg^{-1}), characteristic from Mediterranean areas. However, main soil nutrient contents (mineral N, available P and K) were much higher in Sevilla than in Madrid probably due to higher soil cation exchange capacity, together with differences in their previous management, which has been much more intensive and with higher mineral fertilizers inputs in Sevilla than in Madrid. On the other hand, potential enzymatic activity and potentially mineralizable nitrogen were much lower in Sevilla than in Madrid. We found that under the controlled temperature and irrigation conditions of the greenhouse, crops grown in Sevilla's pots developed better than under Madrid's pots: crops were higher, produced larger biomass and were better nurtured based on proximal chlorophyll, anthocyanins and flavonols sensors. We acknowledge that this kind of networks are skewed due to the bias induced by the soil, thus, based on experimental data, our next step will focus on the statistical approach to correct it.

Keywords: soil quality, climate change, greenhouse, DUALEX

0180

DEFICIT IRRIGATION IN OLIVE TREES: IMPACT ON VEGETATION INDICES

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In a global warming scenario, the use of water for irrigation in agriculture has increased. However, due to the water scarcity, it is necessary to develop efficient water management strategies, in order to maximize water use by crop and optimize water productivity. Thus, deficit irrigation, defined as the application of water below full crop water requirements (evapotranspiration, ET), appears as an important strategy to achieve the goal of reducing water use in agriculture. Nevertheless, this approach may change crops' spectral reflectance behaviour, which can be identified by determining vegetation indices (VIs). Therefore, the aim of this work is to assess the influence of this irrigation strategies on VIs estimated from multispectral imagery obtained in olive trees by Unmanned Aerial Vehicle (UAV). This study was conducted in an olive orchard with 2 ha located in Alfândega da Fé, Portugal, submitted under three irrigation strategies: Full irrigated (FI with 120 and 100% of estimated ET), sustained deficit irrigation (SDI 60 and 30% FI) and regulated deficit irrigation (RDI 100 and 60% of FI). Flights were performed before the beginning of the irrigation (end of May 2019) and early of September. The following VIs where computed: Normalized Difference Vegetation Index (NDVI), Green Normalized Difference Vegetation Index (GNDVI) and Normalized Difference Red Edge (NDRE). In general, the results for September indicated that SDI and RDI treatments have NDVI, GNDVI and NDRE values lower than FI treatment. Mean values of NDVI, GNDVI and NDRE were, respectively, 0.58, 0.56, and 0.16, for FI while SDI had 0.53, 0.53 and 0.13 and RDI 0.58, 0.55 and 0.15. Using Values of FI as reference, the NDRE showed higher decreases for SDI (15%) and RDI (5%), while NDVI decreased 8% and 0.2%, and GNDVI decreased 6% and 2% for SDI and RDI, respectively; whereas before the beginning of irrigation, the Vis values showed insignificant differences between irrigation treatments (variations of ~0.5%). Between May

and September, NDVI values increased 120, 130 and 140% for SDI, RDI and FI treatments, respectively, and, in the opposite way, decreases of 60, 56 and 53% in NDRE and 17, 15 and 12% GNDVI values were verified. Thereby, among the studied VIs, the NDRE was the most sensitive to the irrigation strategies and NDVI was most susceptible between temporal differences. Results appears as useful indicators to irrigation management from multispectral UAV imagery, with potential application for evapotranspiration studies in olive trees using VIs.

Keywords: Olea europaea L, multispectral imagery irrigation management, precision agriculture, unmanned aerial vehicles

This work was funded by the European Agricultural Fund for Rural Development (FEADER) and the Portuguese State under Action 1.1 «Operational Groups», as part of Standard 1, «Innovation» of the PDR 2020 - Continent Rural Development Program, as part of the GO Project - Olive Oil Operational Group - SustentOlive: Improvement of irrigation and fertilization practices at olive farms in Trás-os-Montes for its sustainability, supported by the European Regional Development Fund (FEDER) through the Competitiveness and Internationalization Operational Program - COMPETE 2020 under the PORTUGAL 2020 Partnership Agreement with Financial support provided by the FCT-Portuguese Foundation for Science and Technology (PD/BD/150260/2019) to Pedro Marques, under the Doctoral Programme “Agricultural Production Chains - from fork to farm” (PD/00122/2012) and to Luís Pádua (SFRH/BD/139702/2018).

Session 1.3: Modelling crop-environment interactions

0181

PREDICTING OF FLOWERING DATE AND HEAT REQUIREMNTS OF CV.“COBRANÇOSA” BY A MODEL FOR OLIVE

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De Melo-Abreu *et al.* (2004) have developed a sequential model to predict flowering dates for different cultivars. The model has two phases: firstly, it computes the chilling requirement to break endodormancy, and, secondly, computes the thermal accumulation above a base temperature to fulfill the thermal needs until flowering. The aim of this work is to contribute to the study of the phenology of cv. Cobrançosa and to use the model to predict flowering date. Visual observations were done from floral buds development to the beginning of fruits growth during three consecutive years in an traditional “Cobrançosa” olive orchard located at Vilariça Valley (Vilarelhos: 41.33º N, 7.04º W; 240 m altitude), a growing region of the Northeast of Portugal.

Preliminary results showed that the model generally overestimated the date of flowering in 5-6 days. In this region the mean date for flowering occurs in the day of the year (DOY) 134 with a mean duration of 10 days, depending on the year. Fruit set occurred around the DOY of 150 and pit hardening around DOY of 208, whit a mean duration of 65 days after full bloom. Nevertheless, these results are preliminary and the study needs to be extended for more years.

Keywords: Olea europaea L., base temperature, chilling requirements, phenology stage

This work was funded by the European Agricultural Fund for Rural Development (FEADER) and the Portuguese State under Action 1.1 «Operational Groups», as part of Standard 1, «Innovation» of the PDR 2020 - Continent Rural Development Program, as part of the GO Project - Olive Oil Operational Group - SustentOlive: Improvement of irrigation and fertilization practices at olive farms in Trás-os-Montes for its sustainability, supported by the European Regional Development Fund (FEDER) through the Competitiveness and Internationalization Operational Program - COMPETE 2020 under the PORTUGAL 2020 Partnership Agreement with Financial support provided by the FCT-Portuguese Foundation for Science and Technology (PD/BD/150260/2019) awarded to Pedro Marques, under the Doctoral Programme “Agricultural Production Chains - from fork to farm” (PD/00122/2012)

0204

SIMULATING THE IMPACTS OF COVER CROPS ON THE WATER USE AND YIELD OF OLIVE ORCHARDS

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Olive orchards represent one of the most emblematic agricultural systems in Spain, and especially in Andalusia, its southernmost region. The use of cover crops in the orchard alleys has long been proposed as an alternative soil management for ameliorating erosion rates while providing additional ecosystem services. However, its use might result in yield penalties due to competition for soil water with the olive trees if the cover crop is not removed early in the spring. This works proposes a modelling approach for simulating the impacts of cover crops on the water use and productivity of olive orchards that may help in the definition of optimal ‘kill dates’ for different environmental and management conditions. To do so, a new model component was developed within the framework of OliveCan, a complete process-based model of olive orchards. OliveCan solves the water balance independently for two soil compartments representing the fractions of the soil i) wetted by irrigation emitters and ii) only receiving water by rainfall. For the simulation of the cover crop we added a third independent soil compartment representing the soil strip occupied by the cover crop and where the water balance takes into account water uptake by the roots of the cover crop. Such uptake rate depends on the leaf area index of the cover crop and is constrained under soil water deficit. A simple thermal time approach is used to simulate the development of the cover crop, which modulates its growth along with soil water availability. To illustrate the potential applications of the improved version of OliveCan, the model was used to compare the effects of different killing dates on the water use and yield of olive orchards considering several locations in traditional growing areas in Andalusia. The results indicate that when the cover crop is removed early in early spring, this soil management can be viable in a large set of weather and agronomical conditions with olive annual transpiration and yield similar to that obtained in bare soil systems.

Keywords: modeling, sustainability, tree orchard management

0216

SENSITIVITY ANALYSIS OF FROST DAMAGE SIMULATION MODELS, FOR POTENTIAL APPLICATION TO COVER CROPS

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The extent of crop damage caused by frost is determined by the potential low temperature tolerance (set by crop genotype), by the temperatures at which the plants are exposed, by the length of the exposure, and by crop developmental stage at the time of the exposure itself. Crop frost damage can be simulated with mechanistic dynamic models which estimate the crop frost tolerance temperature, thus allowing its comparison with actual temperature at which the crop is exposed. The aim of our work is to fill a knowledge gap, by comparing via sensitivity analysis the existing crop frost damage models that can be potentially applied to cover crops.

FROSTOL (Bergjord et al., 2008) and Fowler et al. (2014) express frost tolerance as the “Lethal Temperature 50”, the temperature at which 50% of the plants are killed (Bergjord et al., 2008), while ALFACOLD estimates the subzero temperature that a crop can tolerate without being killed and similarly, Lecomte et al. (2003) simulate the temperature below which the first leaf damage can occur. FROSTOL and the models by Fowler et al. (2014) and by Lecomte et al. (2003) were developed for winter wheat, while ALFACOLD was designed for alfalfa. These models differ for the processes implemented, for their formalisation and for their total number of implicit and explicit parameters.

Model	Explicit parameters	Implicit parameters
FROSTOL	5	19
Fowler et al. (2014)	8	28
Lecomte et al. (2003)	6	7
ALFACOLD	1	49

We have carried out a one-at-time sensitivity analysis of these four models. Three of the four models share a common parameter which represents the cultivar-dependent genetic potential for low temperature tolerance, which is achieved at the end of the acclimation process. Sensitivity analysis showed that this is one of the most influential parameters on model outputs. For the winter wheat models, the determination coefficient of the linear regression between this parameter and the model output, at different dates after sowing, is equal to 0.99-1.00, while its positive slope confirms a direct proportionality between the parameter and the output. The formalisation of the common processes between these three models (acquisition and loss of frost tolerance) involves several parameters whose influence on the model outputs is variable: the determination coefficient values range from approximate zero to 0.99.

Keywords: frost damage, simulation model, sensitivity analysis, cover crops

Session 1.4: Sensory, nutritional and technological quality

0025

EFFECT OF CROP MANAGEMENT ON FATTY ACID PROFILE IN SUNFLOWER

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Fatty acid composition is the main determinant of oil quality. Genotype (G), environment (E) and interaction (G × E) determine oil fatty acid composition. Some environmental factors are climate, soil structure, and crop management (crop rotation, sowing date, crop density, etc.). This research was conducted to evaluate changes in the fatty acid composition in sunflower hybrids depending on genotype and different crop densities. Five confectionery hybrids (NS Goliat, NS Slatki, NS Gricko, Vranac, Cepko) and one for birds feeding (NS-H-6485) were sown in six crop densities from 20000-70000 plants per hectare (increasing step of 10000) in a randomized complete block design with four replications. Fatty acid composition was determined by gas chromatography using the Konik HRGC 4000 system. For most of the examined characters (palmitic, stearic, oleic and linoleic acid content) highly significant differences were stated for hybrids (H) and crop densities (CD), except for linolenic and arachidic acid, which showed only significant differences for hybrids. For all fatty acids interaction (H × CD) was not significant. Palmitic acid (C16:0) content varied from 4.40% (Cepko) to 4.98% (NS Slatki). The lowest palmitic acid content (4.62%) was in the lowest crop density (20000), and the highest (4.86%) in the highest density (70000). Cepko had significantly lowest stearic acid (C18:0) content (3.63%) and Vranac showed the highest value (5.22%). Crop density significantly influenced the content of stearic acid, showing highest value (4.56%) in the lowest density (20000). The stearic acid content (4.28%) decreased until highest density (70000). The significantly highest oleic acid (C18:1) content was found in Cepko (36.55%), and the significantly lowest in NS Goliat (30.56%). With the increase in density the oleic acid content decreased. The highest significant oleic acid content (35.72%) was found at the lowest density (20000) and the lowest (33.71%) at the highest density (70000). The content of linoleic acid (C18:2) ranged between 54.81% (NS Slatki) and 60.10% (NS Goliat). The lowest content (54.66%) was observed in the lowest density (20000) and the highest (56.73%) in the highest crop density (70000). Arachidic (C20:0) and linolenic acids (C18:3) were in traces. Our results indicate that fatty acid composition of sunflower oil show diversity depending on the genotype and the crop density. To achieve a better seed quality of confectionery hybrids, they should be grown in a lower stand density that will not much affect the yield decrease.

Keywords: crop density, hybrid, fatty acids, sunflower

Session 1.5: New products and services: functional food, chemicals, fibers, and energy

0059

VARIATION IN ROOT GROWTH AND NUTRITIONAL COMPONENTS IN AHIPA (*PACHYRHIZUS AHIPA*)

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Ahipa (*Pachyrhizus ahipa* (Wedd.) Parodi) is a tuberous-root legume native to Andean Valleys of Bolivia and N Argentina. It may be considered a neglected and underutilized species whose genetic diversity is threatened. It has a potential for the production of raw materials of industrial interest in sustainable systems and as a source of functional foods. When inoculated with specific rhizobia strains, it fixes significant amounts of N_2 and some accessions may reach up to 40 tonnes ha^{-1} root yield. As summer crop, it requires irrigation in our semiarid climates with very high evapotranspiration rates and it is quite tolerant to insects but very sensitive to nematodes.

We studied eight accessions to determine the variation in root growth and dry matter production and their contents in nutritional compounds with functional properties (proteins, minerals and carbohydrates).

Significant variation among genotypes was observed in root weight per plant and other yield-related morphological traits like specific leaf weight, shoot/root ratio or harvest index. Root fresh weight ranged from 78 to 417 g $plant^{-1}$ and dry matter contents from 16.7 to 22.5 %. Root protein (Kjeldahl N) showed some variation among the accessions, varying from 4.3 to 9.2% (dry matter basis). The carbohydrate contents were significant different among genotypes for starch, fructose and glucose contents but no significant variation in sucrose. Results demonstrate that ahipa should be an alternative for diet diversification as a source of energy in the diet and medicinal properties attributed by folk medicine.

The risks of loss of diversity might be diminished if its cultivation increases by means of improving knowledge on ahipa properties either for food diversification schemes or production of raw materials for industrial processes.

Keywords: Pachyrhizus ahipa, protein, minerals, starch, sugar, yield, food

0115

CEREAL VALORIZATION OPPORTUNITY

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Bioeconomy is economic activity that is fueled by research and innovation in the biological sciences. Production of value added products, such as food, feed, materials, fuels, chemicals, bio-based products and bioenergy using biological resources or bioprocesses. The general aim of our research is to evaluate the state and the potential of bioeconomy in Estonia, to take into account the best practices of the EU Member States and to present the conclusions and recommendations for the development of bioeconomy in Estonia. Our aims are to analyze the national potential of bioresources and their use and build bioeconomy scenarios until 2050; to propose smart, value-adding and sustainable business model prototypes to improve Estonian bioeconomy. Estonian cereals can be sold at higher prices, thus improving the sustainability of Estonian farmers. Bio-economy approach considering the entire value chain provides sustainability to farms, ecosystems, and rural areas.

Keywords: Bioeconomy, Valorisation, Wheat, Grain, Bran

Session 2: Farming systems and ecosystem services

0035

DEVELOP A PROTOTYPE OF WIRELESSLY AND REMOTELY INTEGRATED ELECTRONIC SENSORS WITH A BIG DATA SOLUTION FOR REAL-TIME SOIL ANALYSIS AND APPROPRIATE FERTILIZATION RECOMMENDATIONS FOR PEACH AND AVOCADO CROPS

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The agriculture sector plays an important role within the economic activities of Peru. Currently one of the obstacles to increasing agricultural production is the poor quality of Peru's soils and the high degree of dependence on fertilizers. In this context, soil analysis to optimize crop fertilization is a vitally important task for agricultural producers in Peru. At present there are various methods of soil analysis, more or less automated, that allow determining the nutrients in the soil to optimize the use of fertilizers and thus improve the production of agricultural crops, especially fruit trees. However, many of these methods are traditional and empirical, performed without the supervision of soil specialists. Based on the aforementioned, the idea of the innovation project was born, which aimed to develop a prototype of integrated wireless and remote electronic sensors with a big data solution for the analysis of soils in real time (Nitrogen, Phosphorus and Potassium) and the recommendations of adequate fertilization in peach and avocado crops. The use of electronic sensors to capture associated data to measure soil nutrients, together with a web solution that uses machine learning and Big Data techniques to analyze large volumes of data and that allows the introduction of new artificial intelligence algorithms for the prediction and recommendation of fertilization in crops. The purpose of the project was to contribute to the improvement of production through the recommendations of adequate fertilization in crops, to be used by rural farmers in the Ancash region and Peru.

Keywords: Fertilization, modeling, soil management, machine learning, big data

0272

EVALUATION OF USEFULNESS PARROT SEQUOIA+ UAV MULTISPECTRAL SENSOR FOR VEGETATION INDEX OF WINTER WHEAT

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The aim of the study was to evaluate usefulness of Parrot Sequoia+ multispectral sensor, in different times of the day, for evaluation of within-field variability of winter wheat crop in late autumn. The evaluation was performed on the basis of imagery acquired using a drone (UAV - unmanned aerial vehicle) on the 29 of November 2017. The images were collected at distance from ground 300 meters at ground resolution (GSD) about 30 centimeters. Three flight missions were conducted on the same day, i.e. about 8.30, 12.00 and 15.30 local time, to compare vegetation indices at different times of the day (insolation). The area of the study is located in north-western Poland (53°39'N 15°41') and covers field area of about 55 ha. Wheat plants were in the tillering stage, before the winter resting period. Based on of red and near-infrared spectral reflectance, NDVI was calculated for each dataset. Moreover, satellite-derived NDVI, as a reference, from the nearest dates (2017/11/07 and 2017/12/30) was calculated using Sentinel-2 data. For statistical analyses mean value of NDVI from two dates was used. Relationships between NDVI values from different sources were evaluated using Pearson's correlation coefficient and linear regression. The basic unit for the analyses was pixel of Sentinel-2 of size 10 x 10 meters (100 m^2). Values of UAV derived NDVI were averaged for such pixels. The relationships proved rather weak correlations between all variables, i.e. UAV acquired NDVI for different times of the day versus satellite derived NDVI. Correlation coefficient was in range from 0.26 to 0.40, the highest for the third flight. Relatively weak correlations were caused by low values of NDVI and low within-field variability of NDVI (mean satellite-derived NDVI 0.17 in range from 0.04 to 0.29). Means of UAV derived NDVI were higher but still quite low, i.e. 0.40, 0.37, and 0.27, respectively, for subsequent times of measurements. Correlations were weak not only with satellite-derived NDVI but also between UAV-derived NDVI evaluated at different times of the day. The correlations were in range from 0.32 to 0.44. One possible reason could be shadows of trees located in the field affecting reflectance.

Keywords: winter wheat, vegetation indices, UAV - unmanned aerial vehicle, multispectral imagery

Session 2.1: Farming system design for conventional and organic production

0050

ANCIENT WHEAT SPECIES (*TRITICUM SPHAEROCOCCUM* AND *T. PERSICUM*) IN ORGANIC FARMING: INFLUENCE OF SOWING DENSITY ON AGRONOMIC TRAITS, PEST AND DISEASE OCCURRENCE AND WEED INFESTATION

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Growing ancient wheat makes it possible to obtain consumable grains with a higher content of biologically active ingredients than in common wheat. The cultivation of primary cereals in the organic farming system can have a particularly beneficial effect on the grain quality. The aim of the study was to determine: *i.* the yield of ancient wheat species: Indian dwarf wheat and Persian wheat; *ii.* the optimal sowing density of these species; *iii.* the impact of sowing density on plant health, weed infestation and pest occurrence. A strict field experiment was established in 2019, in a split-plot design, with four replications, on three organic farms located in Poland. The experimental factors were: 1) spring ancient wheat species: Persian wheat (*Triticum persicum* Vav.) and Indian dwarf wheat (*Triticum sphaerococcum* Perc.), 2) sowing density (400, 500, and 600 grains per m^2). In our study, the yield of Indian dwarf wheat (2.83 t ha^{-1}) was significantly higher than the yield of Persian wheat (2.15 t ha^{-1}). The ear of Indian dwarf wheat was characterized by a greater number of spikelets and grains per ear. *Triticum sphaerococcum* had a higher yield at the sowing density of 600 than 400 no m^{-2}, while T. persicum had a similar yield at the density of 400, 500 and 600 no m^{-2}. The number of weeds per unit area in both wheat species was similar, but the dry weed mass was higher in Persian wheat, especially at the lowest sowing density. Powdery mildew was the greatest threat among leaf and ear diseases, the symptoms of which were observed on 26% of leaf area at stem elongation phase. Other leaf and ear diseases occurred in low intensity. The leaf area with tan spot symptoms did not exceed 11%. At fruit develop-

ment phase, the symptoms of this disease included a larger leaf area when sowing density was higher. The root rot symptoms were observed on 32% of plants. The eyespot symptoms occurred more frequently on Indian dwarf wheat than on Persian wheat. The number of pests feeding on the tested wheat species was very small (maximum 4 individuals of *Oulema* spp. and one aphid per 25 plants). The damaged plant surface caused by *Oulema* spp. was larger on *T. sphaerococcum* than on *T. persicum.* Indian dwarf wheat and Persian wheat are useful for organic farming. The highest grain yield is obtained at the sowing density 600 and 400 grains per 1 m^2, respectively. Increasing the sowing density suppresses the weeds, but can increase the severity of diseases.

Keywords: organic cereals, crop density, pathogen, pest insects, weed suppression

0098

IDENTIFICATION OF SUCCESSFUL TRAJECTORIES FOR THE REDUCTION OF PESTICIDE USE IN DEPHY FERME NETWORK

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The concept of "innovation tracking", described for the agricultural sector by *Salembier and Meynard* (*2013*), was implemented in the DEPHY FERME network which was set up in France as part of the Ecophyto plan to accomplish the objectives of the European directive 2009 / 128 / EC. Within the 1200 cropping systems monitored in the DEPHY groups in both arable and mixed cropping-livestock farms from 2010 to 2015, 112 agronomists, advisers and facilitators, were invited to identify cropping systems with efficient trajectories to reduce the use of pesticides and the associated technical and economic performances. A trajectory is considered successful for pesticide use when the Treatment Frequency Index is at least 30 % lower than the regional reference and remains low over the period or when its value is significantly decreasing. Ninety-two cropping systems and their trajectories were selected. The evolution of farmers' techniques and decision-making frameworks are described by surveys. These 92 monographs were then grouped into 16 strategy families with common traits, adapted to the production contexts across France and to farmers' individual choices. An agronomic analysis was used to determine the area of validity of each strategy.

Reducing the use of phytosanitary products is possible by mobilising levers of very different kinds: technical, organisational, commercial and learning. The excellence of the trajectories described is due to: (i) the appropriation and mastery of basic techniques (ii) the combination of these techniques (iii) the relevance of the choices made by farmers regarding both their work schedule and their investments (iv) the pre-existing or developed market opportunities for their products. Individual and collective supports and peer-to-peer exchanges enable these changes.

This work illustrates the gradual appropriation of technical knowledge by farmers and the gap between technical assessment and use assessment. It confirms, for example, the discrepancy between technical assessment of mixtures of species and cultivars and farmers use assessment, suggesting an evolution in structuring the advice to manage these mixtures. It identifies the lack of decision support tools for innovative pratices, for example mixed weeding.

The project helps determine the organisation of tracking, the interest of diversifying the profiles of "trackers", the importance of having a common description frame of the trajectories, the keys to group trajectories into families of trajectories, the great value of individual testimonies and the contribution of agronomical expertise.

Project supported by French government and the French Biodiversity Office

Keywords: innovation tracking; cropping systems; reducing pesticides; Ecophyto

0128

MANAGEMENT OF A PERMANENT COVER CROP IN AN ORGANIC FARMING SYSTEM

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The current societal, political and regulatory context is bringing farmers to search and develop low-input cropping systems, particularly in organic farming. Sowing a permanent cover crop is a practice of interest for those systems. Several functions can be highlighted: enhancing the symbiotic activity of the cover crop species to bring nitrogen into the system and limit the use of exogenous fertilizers, weed control through canopy competition, and erosion mitigation in sloping plots.

In organic agriculture, the non-chemical management of a permanent cover crop can be difficult and existing mowing solutions can only be done in the fallow period. Thanks to the collaboration between ARVALIS and an agricultural machinery manufacturer, an inter-row mower prototype was created to manage the cover crop into the main crop. This mowing is made possible by the tractor's self-guiding system, which is also used for sowing the permanent cover crop and the main crop. The principle of this practice is thus to separate the cover crop and the main crop in space to be able to manage them separately.

This technique has been tested for 4 years in the south of France, where a trial with alfalfa and wheat was carried out. The first results are very encouraging; in 2018, in the situation where alfalfa is mowed three times, wheat yields reach 26.6 q/ha and 13.9% of protein. Inter-row mowing limits competition from alfalfa and weeds on wheat, and provides nitrogen. It also acts as a mulch between rows which limits evaporation and erosion, and weed emergence. The amount of nitrogen (N) absorbed by the wheat has been calculated to understand the nitrogen dynamic into this cropping system; it seems to increase over years, with a cumulative effect. To confirm these initial results, a larger-scale experiment has been set up in spring 2019 to experiment the management of several permanent cover legumes species and different mowing methods using the innovative inter-row mower.

The cultural practice set up by ARVALIS has made possible to combine agricultural machinery, digital technology and agronomy to manage a permanent cover crop in organic farming. Its innovative nature offers multiple perspectives for the agro-ecological systems of tomorrow. References need to be created in the long run and under different production contexts to answer many issues: carbon soil storage, greenhouse gases emissions, erosion control, biodiversity, return on guidance system and inter-row mower investment, working time, profitability, effects on phosphorous nutrition, on soil life...

Keywords: organic agriculture, permanent cover crop, mowing

0139

HOW FARMERS CAN INTEGRATE IN THEIR FARMING SYSTEM NEW AGROECOLOGICAL PRACTICES?

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A large part of Northern France is impacted by water quality protection measures and in this context, several groups of farmers self-organized in order to find innovative and less environmental impact farming practices and systems. In an intensive arable farm area in Oise (France), a group of farmers has collaborated since 2012. Firstly, oriented to an increasing of the efficiency of their practices according to the ESR model, they asked to collaborate with a group of researchers since 2017 to create and share common knowledge and agronomical references for their territory. This study aims to give insights from the process of identification of a common agronomical object between farmers, the technical advisors and the researchers to the construction of local agronomical references.

The first step was to identify innovative practices and systems missing references and to detect references needed (efficiency, potential side effects, conditions of efficiency and feasibility). It was performed by co-designing new CS with each farmer with the support of the second step of the STEPHY guide adapted to other objectives such as reducing nitrates leaching or avoiding resistance development to herbicides. The second step was to choose the practice to focus on according to its interests and to the feasibility of references production in local farms. Then, methods and tools to test it were decided and a network of on-farm fields was surveyed from 2018 to 2020.

In the first step, results showed that for farmers the available technical references appear not to be relevant for local CS or even though already practiced, these techniques were considered not getting the highest potential benefits. The priority was given to create references on cover-crops management in order to maximize their ecosystem services (especially capacity to catch nitrogen, described by Ayerdi Gotor et al in this conference) and to optimize their cost. Once these references collected, a monitoring of the optimization of the cover-crops will be done. Further steps of the process will include a return on the results of the first step (a compilation of innovative practices and systems) and a discussion about their relevance after these three years, along with discussion on other innovations to implement for future.

Keywords: agroecosystem services, co-design, farm, cropping system, references needed

0174

EXPERIMENTAL CO-DESING FOR CROPPING SYSTEMS DIVERSIFICATION IN INTENSIVE ARABLE FARMS IN ITALY

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Specialized conventional farming systems relying on a few improved high-yielding species, miss the goals of sustainability and environmental quality due to an excess of external inputs. Therefore, the adoption of appropriate crop diversification strategies and alternative management practices in intensive agricultural systems might help to stabilize agroecosystem productivity and incomes, thus enhancing resilience to environmental stress and someway improving sustainability of food production systems. Despite the large technical and scientific consensus on the positive impact of diversification, there is still scarce awareness on the benefits of rotations, the costs of machinery or new labor organization and market uncertainty. Moreover, technical solutions are often not affordable as well as new crops out of market. In this context, the H2020-Diverfarming project (www.diverfarming.eu) aims to define sustainable, diversified cropping systems with low-input farming practices, adopting a multi-disciplinary approach across Europe. This study at first engaged stakeholders by public consultations to monitor their knowledge of current farmer practices for promoting suitable diversified cropping systems in the Po Valley in Italy, as alternative to intensive tomato-based systems. Thereafter, the agri-food value chain up-stream actors co-developed and tested the novel farming systems to increase the overall sustainability that pursues scientific, economic and environmental objectives. Solutions and practices proposed are oriented to farm resilience and ecosystems services, through 1) introduction of a leguminous crop in the rotation (pea); 2) introduction of the tomato as second crop after pea; 3) application of an organic fertilizer (digestate). The new crop rotation was planned to ensure technical and economic viability compared to the current management. A field experiment was set up in three farms of Po valley (provinces of Mantova, Piacenza, and Cremona), sharing similar geographical features and farming systems. In all farms, cropping systems are set to supply raw material (T) to agroindustry (Consorzio Casalasco del Pomodoro-CCP, a farmers' cooperative), which in turn, sets the quality requirements for acceptance and provides farmers with technical advisory. The goal was to make the whole rotation cost-effective to farmers and the agro-environment. In each farm, the values of Gross Margin (i.e. GSP - Variable Costs) per hectare were compared between diversified (tomato-pea/tomato-durum wheat) and current management (tomato-tomato-durum wheat) plots in 2018-2019. On average, the values were 1% and 9% higher in two out of three farms, respectively. Similar trend was observed for crop productivity. These results can be improved over the entire three-year crop rotation period.

Keywords: diversification; crop production; gross margin

0192

CONSERVATION AGRICULTURE: HOW FARMERS MANAGE WEEDS

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Conservation agriculture is characterized by the continuous and simultaneous application of three principles: minimum soil disturbance (no-tillage), residue cover on the soil surface (dead mulch or cover crop) and diverse crop successions and cover crop mixes. Adopted in France by farmers since the 1990s, this farming system still faces some challenges to its adoption, particularly for weed management. To highlight this problem, 425 French farmers practicing conservation agriculture were surveyed by an online survey. Cultural practices used to manage weeds during the first years of conservation agriculture were requested. The use of each cultural practices was first studied independently. Then, a multiple correspondence analysis followed by a hierarchical ascendant classification resulted in groups of farmers with different combinations of practices.

During first years of conservation agriculture, chemical weeding during the crop cycle was divided between a post-emergence application only (49%), a pre-emergence application only (13%) or the use of both applications (38%). Spot management on weed patches (51%) and on field border (30%) was also part of weed management. Cover crops and intercropping period weeding represented the main points of weed management for 80% of the farmers. Another practice to compete weeds by adding such as cover crops was the use of combined/companion crops by 37% of farmers. To manage weeds, many farmers also used practices to avoid emergence of weed cohorts, such as sowing date optimization (39%), crop rotation optimization (48%) and alternating sowing periods (61%). Increasing crop competitiveness was not part of the weed management strategy. Only 8% of farmers optimized row widths and used a variety to compete with weeds. Seeding rate optimization was used by 24% of the farmers . When regarding to the combinations of these cropping practices, six groups of farmers were identified. Main contributing practices for partitioning the groups were chemical weeding (crop weeding and intercropping period weeding), increasing competition by adding species (cover crops, combined/companion crops) and crop competition (sowing rate optimization).

Thanks to the active participation of farmers' networks during the broadcast, the use of an online survey resulted in effective responses to our questions.

Keywords: weed management, farming system, crop management

0208

COMPARATIVE STUDY OF CONVENTIONAL AND ORGANIC FARMING SYSTEMS OF SIX COMMON VETCH (*VICIA SATIVA* L.) VARIETIES

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Legume crops are widely grown for food and feed, as well as having the agronomic advantage that they can fix nitrogen from the air. Many *Vicia* species are native in the Mediterranean areas and some of them, such as common vetch, are suitable for organic or low input farming systems with little application of non-renewable resources. Common vetch (*Vicia sativa* L.) grows in Greece and is characterized by adaptability to varying conditions and high productivity. The objective of this experiment was to evaluate the performance of six common vetch varieties in order to determine their suitability to local environmental conditions, in both conventional and organic farming systems.

The experimental work conducted at the farm of Western Macedonia University of Applied Sciences in Florina, Greece, under organic and conventional production. Six varieties of common vetch (*Vicia sativa* L.) (cv. FILIPPOS, OMIROS, ALEXANDROS, TEMPI, ZEFYROS, PIGASOS) were compared in a strip-plot design, with four replications and the six varieties randomized within each plot (the farming systems was one factor and variety the second factor). Individual plots consisted of seven rows, 5 m long, spaced 0.25 m apart and plot size was 8.75 m^2.

In plots under conventional cultivation, nitrogen and phosphate nutrients were applied as a mixed fertilizer (ammonium phosphate, 20-10-0, 300 kg per hectare, corresponding to 60 kg ha^{-1} N and 30 kg ha^{-1} P_2O_5), during the seedbed preparation operations, followed by tillage, as is common practice in the region. In plots under organic cultivation, fertilizers and pesticides were applied.

Significant differences in seed yield were found among the common vetch varieties included in the study. Moreover, common vetch yielded better in organic than conventional farming, possibly due to the fact that common vetch, being a legume does not need nitrogen fertilizers because of its nitrogen fixing ability, while other nutrients were present in the soil in sufficient quantities.

Keywords: legumes, varieties, organic farming, conventional farming, yield

0221

DISSEMINATION OF VERMICOMPOSTING TECHNOLOGY ADDRESSED TO FARMERS AND YOUNG PEOPLE

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The use of organic fertilizers or organic amendments can decrease the use of agrochemicals and favour carbon sequestration in soils. Vermicomposting of both organic and plant residues has the advantage of achieving objectives such as minimization of gas emissions, reduction of the use of fertilizers, favouring the fixation of organic carbon and improving soil properties. Vermicomposting is a simple technique, easy to apply, which results in a large amount of vermicompost production,

and has the advantage of being used as self-sufficiency by small and large farmers. One of our goals is the disseminations of knowledge about vermicomposting, and our targets are farmers and young people. Our final aim with farmers is to increase the use, development and application of vermicompost in agricultural crops. Nowadays, many young people has high environmental awareness, especially in the field of the recycling. Our objective with young people is to increase the awareness about the use of organic waste to obtain through vermicomposting a product that can improve various soil properties. In order to develop this dissemination project two actions will be undertaken. The first one will consist in workshops addressed to farmers interested in learning the tecnique of vermicomposting and, the second one oriented to make young people aware of the adventages of this tecnique through for instance humoristic comics, a teaching unit and videos. Both actions can favour and redirect efforts to enhance vermicomposting destination; and thus, convert waste into resources by contributing to zero waste, and further progress towards the circular economy.

Keywords: vermicomposting, organic waste, earthworms, learning activities.

0274

COMPARING YIELDS AND NUTRITIVE QUALITY OF PRODUCTS FROM A MIXED ORGANIC AND STOCKLESS ORGANIC ROTATION

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Crop rotations have the potential to have a greater impact on the future sustainability of food production than any other agricultural management technique. However, not all rotations are equally beneficial for crops and soils, thus it is necessary to investigate the consequences of a range of different rotational management strategies before making blanket recommendations regarding their usage. Rotations are an integral part of organic farming systems, which typically mix arable production with livestock to provide fertility building manure and graze during ley periods. Assessing the ability of stockless organic crop rotations to deliver consistent yields of adequate nutritional quality compared to mixed counterparts may provide evidence for their utilization among arable land managers. This study utilises a farm-gate approach to compare annual offtakes from two organic rotation systems in a long-term field trial in Scotland. The mixed rotation includes a 3 year grass/white clover ley and 3 years of arable cropping. The ley is grazed by sheep and the rotation receives organic cattle manure additions. The stockless rotation includes 5 years of arable cropping and a 1 year grass/red clover ley period which is cut and mulched. Yields and crude protein are compared across all crops in both rotations. Micronutrient concentrations of the spring oats and spring barley can be used to compare the two management systems as they are cultivated in both rotations. In terms of overall rotational offtake, no significant differences in yields and crude protein content were found between the mixed and stockless rotations for any of the 12 years assessed, although the mixed rotations generally appeared to have more consistent yields through time. It was thought that inputs of cattle manure on the mixed rotation would lead to higher crop micronutrient availability, however, this was not consistently found to be the case. Although there were variations between the years sampled and rotation management, the micronutrient concentrations of the crops in both rotations have declined over the period 2007- 2019. The work conducted so far provides some evidence that stockless organic rotation systems are capable of sustaining crop yields and quality that is comparable to stocked systems.

Keywords: crop rotation, protein, micronutrients

0289

SHADE EFFECTS IN SILVOARABLE AGROFORESTRY SYSTEMS IN SWITZERLAND

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With climate change and an increasing world population, the concept of growing trees and crops on the same land is gaining economic and environmental interest. The practice of agroforestry is, however, mainly applied in tropical and subtropical climate. This research project aims to address the role of light competition in temperate agroforestry systems at three different levels, i.e. environment, species, and cultivar. On the environment-level, a field experiment was conducted in a full factorial design in three agroforestry systems in Central Switzerland. At each site, barley (*Hordeum vulgare* L.) was grown as understorey crop under 90%, 40% and 0% shade, respectively, with and without irrigation and/or fertilization. On the species-level, in a second field experiment suitable crop species for cultivation in temperate agroforestry systems are being tested in a full factorial design with one sun-loving, two intermediate and one shade-tolerant crop species grown in an agroforestry system, again with combined treatments of 90%, 40% and 0% shade as well as irrigation and/or fertilization. On the cultivar-level, the performance of a composite cross population of barley along cardinal transects around trees is investigated. Findings of the first field experiment show that shade reduced barley yield significantly. However, for the 40% shade treatment, yield reduction was not severe (-14%). In the experiments to come, findings about optimal understorey crop species choice and adaptive cultivar lines in barley can be expected.

Keywords: agroforestry, farming systems, low-input agriculture, organic farming

Session 2.2: Crop diversification

0067

COMPARISON OF ENERGY OUTPUT PRODUCED IN DIFFERENT CROP ROTATIONS

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Benefit of crop diversification in rotation can be evaluated as energy output from harvested yield. Aboveground biomass of each crop contains specific energetic value (MJ kg^{-1}). Field crop diversification in crop rotation often leads to yield increase and in its turn - to gained energy increase. A research described in this paper was conducted to compare the effects of three different crop rotations (repeated wheat (*Triticum aestivum*) sowings (W-W), oilseed rape (*Brassica napus* ssp. *oleifera*)-wheat-wheat (OR-W-W), and field bean (*Vicia faba*)-wheat-oilseed rape-barley (*Hordeum vulgare*) (FB-W-OR-B)) and two soil tillage systems (traditional and reduced) on average per year energy output from rotation during three growing seasons (2016/2017 - 2018/2019) in field trial in Latvia. The influence of crop rotation scheme ($p=0.002$) and year ($p<0.001$) on average energy output from rotation during three years was found; soil tillage system did not affect this parameter. The highest average per year energy output was obtained from rotation OR-W-W (199.05 GJ ha^{-1}), but the lowest ($p=0.009$) from rotation FB-W-OR-B - 168.25 GJ ha^{-1}. Energy output from rotation with repeated wheat sowings (179.73 GJ ha^{-1}) did no differ significantly from both others. The most energy is concentrated in oilseed rape seeds (28.7 MJ kg^{-1}), field beans' seeds contained on average 18.4 MJ kg^{-1}; values of cereals' grain were very close - 17.5 MJ kg^{-1} for barley and 17.6 MJ kg^{-1} for wheat. Average energetic values of straw differed minimally between crops: from 17.7 MJ kg^{-1} (field beans) to 18.4 MJ kg^{-1} (wheat). Strong positive correlation was found between grain/seed yield and energy output ($r=0.82 > r_{0.05}=0.17$, $n=140$), and between straw yield and total energy output ($r=0.97 > r_{0.05}=0.17$, $n=140$). The highest average energy output was obtained when wheat was grown (208.0 GJ ha^{-1} $year^{-1}$), and it was significantly higher ($p<0.001$) if compared with all other crops included in the research. Winter wheat energy yield was significantly higher in rotations (OR-W-W) and (FB-W-OR-B), if compared to rotation W-W ($p<0.001$). Explanation: positive fore-crop effect in more diversified rotations. Average energy output from oilseed rape during researched period was low - 165 GJ ha^{-1}, due to comparatively low yields caused

by low field germination in clay soil; low yields were observed also for spring crops in 2018 and 2019 due to extremely dry spring/summer period. Research will be continued.

Research was financed by Ministry of Agriculture of Latvia project „Influence of minimal soil tillage on its fertility maintenance, development and distribution of pests as well as crops' yield and quality in resowings".

Keywords: crop rotation, crop diversification, energy output

0079

EFFECT ON MAIZE YIELD OF THE INTRODUCTION OF DOUBLE CROPPING SYSTEM WITH LEGUME AND THE REDUCTION OF TILLAGE AND N FERTILIZATION RATE

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The **double cropping systems** are increasingly common in the Mediterranean irrigated areas due to the greater economic benefits they could provide. The aim of this work was to evaluate the combined impact of crop diversification, tillage systems and mineral N fertilization rates on crops yields (grain yield and grain N yield), and water and nitrogen use efficiencies (WUE and NUE) under Mediterranean irrigated conditions. The study is being carried out in Agramunt (NE Spain). A long-term tillage and N rate fertilization field experiment established in 1996 under rainfed conditions was transformed into irrigation with maize (Zea mays L.) monocrop as cropping system in 2015, and into a diversification experiment in 2018. Maize monocrop (MC) against a winter pea-maize double cropping (DC) with three tillage systems (conventional tillage, CT; reduced tillage, RT; no-tillage, NT) and three mineral N fertilization rates (0; medium, 200 kg ha^{-1} in MC and 150 kg ha^{-1} in DC; high, 400 kg ha^{-1} in MC and 300 kg ha^{-1} in DC) were compared. DC in combination with the medium and high nitrogen rates showed the highest yields. No differences were found between the medium and high nitrogen rate or between the tillage systems for yields in DC. In MC, the treatment with the highest yields was NT for medium and high nitrogen rate. The combination of DC with medium and high nitrogen rate obtained the highest WUE_B (for biomass) and WUE_Y (for yield). The effect of tillage treatments on WUE was only significant for MC with higher WUE_Y in NT. NUE was higher in DC. Due to the large amount of residual N that existed in the treatments with N fertilization, NUE was significantly higher in the treatments without N fertilization. Accordingly, high N rate was the treatment with the lower NUE. Our preliminary study shows that in Mediterranean irrigation agroecosystems the use of legumes in DC could be a good strategy to improve crops yields, NUE and WUE.

Keywords: Corn, Double cropping, N fertilization, Legumes, Tillage system

0099

VARIATIONS OF CROP AREAS IN FRANCE: REGIONAL DESPECIALISATION AND RE-SPECIALISATION

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Part of the challenges for agro-ecological transition are longer rotations and crop diversification. This study aims to identify variations in the area of each crop and associated risks. It uses Agreste data from the Annual Agricultural Statistics provided by the French government from 2000 to 2018 at the national level and at the level of the former administrative regions. This paper defines arable land as any land that is used to grow annual crops and temporary grassland.

From 2000 to 2018, arable land slightly varied from 17.3 to 17.8 million hectares. This figure has remained within this range since 1960. Twelve annual crops covered 75 % of the arable land. Wheat is the main crop in France and represents 26% of the arable land which is followed by maize and rapeseed. Minor crops are considered to be highly relevant to crop diversification crops. They increased by 22 % over the past decade and reached 1320 000 hectares by the end of the period. These represent 7.4 % of total arable land, 9 % of the only areas under annual crops. This is one crop in eleven. In regards to redesigning cropping systems with long rotations of six years or more, this contribution is no longer marginal.

At the level of French regions, larger variations are observed: regions are "despecialising". In the south-west where maize reached 46% of arable land in 2000, its area decreased by 100 000 hectares i.e. 30%. Similarly, the areas under wheat and rapeseed have decreased in their traditional regions while gaining in others. These variations in area are greater than those concerning minor crops. This means that major crops, when turning out to be regional diversifying crops, are likely to have significant agronomic impact on cropping systems.

However, under the effect of technical and economic factors at both the farm level and the marketing chain level, new concentrations of major crops and diversifying crops appear which could locally raise new agronomic and economic challenges: potatoes in northern France, lentils in various regions, etc. Considering agricultural sustainability, it will be useful to integrate new parameters for designing developing sectors such as: (i) the preservation of a low level of pests and diseases allowing low-input management for all crops in the rotation (ii) diversification of technical and economic risks for farms under climate deregulation context (iii) and relocation of part of the production to reduce logistical hazards.

Keywords: crop areas; diversification ; cropping system design; France

0108

IMPACT OF SHIFTED SOWING DATES ON PHENOLOGY, GROWTH AND YIELD OF NARROW-LEAVED LUPIN (*LUPINUS ANGUSTIFOLIUS* L.)

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Increasing the share of leguminous crops in European crop rotations offers numerous advantages from agro-ecological point of view. Hence legumes are promoted through the European Protein Strategy to increase the supply by local protein crops, strengthen regional supply chains and improve ecosystem services and resource protection. One promising legume with intensified breeding and research efforts in recent years is narrow-leaved lupin (*Lupinus angustifolius* L.). However, for its wider integration in temperate European cropping systems its low yield levels and high yield variability need to be overcome. To make optimal use of available growth resources, site-specific cultivar selection and sowing dates are crucial factors to realizing increased and stabilized yields.

Therefore, we conducted a field experiment with three cultivars and four shifted sowing dates at the JKI experimental field in Berlin-Dahlem during 2017, 2018 and 2019. The experimental design was a split plot design with six replications with sowing date as the whole-block factor and cultivar as the sub-plot factor. Sowing dates were shifted by seven to ten days starting with the first sowing date at the earliest possible time after winter.

We assessed phenological development stage, canopy height and leaf area index using the SunScan Canopy Analyser (Delta-T Devices) on a weekly basis. Additionally we conducted destructive assessments of dry matter of different plant compartments at pre-determined phenological stages specifically for each sowing date x cultivar combination. The stages were namely five-six leaf stage (BBCH 31-33), beginning of flowering (BBCH 59-61) and first brown pods (BBCH 83) during 2017 and 2018 season. At harvest maturity we assessed yield and various yield components, including harvest index, pods per plant, seeds per pod, thousand kernel mass, as well as raw fat and raw protein content during 2018 and 2019 season. Due to severe *Fusarium* spp. infestation in the late 2017 season no yield could be determined in the first experiment year. We found that earlier sowing dates led to higher maximum leaf areas and to highest grain yields. Higher grain yields were not related to higher thousand kernel mass, but were mainly driven by higher number of pods per plant and seeds per pod. The cultivar Mirabor showed the most stable performance also under delayed sowing.

Keywords: Legumes, crop quality, sustainability

0129

PEAS (PISUM SATIVUM) OR OAT (AVENA SATIVA) - WHAT FITS BETTER WITH LENTIL (LENS CULINARIS) IN MIXED CROPPING?

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Due to lodging, pure lentils (*Lens culinaris* Medik.) often are difficult to harvest with a combine. The pods are near the soil surface and as a consequence either pods remain on the field which reduces the already low yield level and soil and stones are accidentally collected which makes additional cleaning processes necessary. Therefore in practice lentils often are cultivated with companion crops, which prevent lentils from lodging and help to suppress weeds. Up to now lentils are mainly grown together with cereals in practice because of its good weed suppressing ability.

Mixed cropping of lentil with pea (*Pisum sativum* L.) or oat (*Avena sativa* L.) was compared with monocropping of all three crops in Zurich (Switzerland) from 2016 to 2018. Besides the sole cropping, three mixing ratios (1:3, 1:1 and 3:1) were investigated. The objective of the study was to find out, which of the two companion crops and which mixing ratio are the most suited for the cultivation of lentils in terms of different parameters like lodging, yield, protein content or protein yield.

Lodging of lentils was highest in sole crop and decreased in the mixtures with decreasing proportion. However, the effect of the companion crop was not consistent: lentils lodged more with oat as companion crop in 2017 while in 2018 lodging of lentils was more pronounced when grown together with peas. Although the land equivalent ratio (LER) of the yield increased in the mixed cropping (> 1.04), the differences were not significant - neither between the different ratios nor between the companion crops investigated. The thousand kernel weight (TKW) of oat was neither influenced by the year nor the mixing ratio, unlike to the legumes.

Independent of the proportion of lentils in the lentil-pea-mixture, the protein content of the peas remained the same and the lentil-oat-mixture always had a significantly lower protein yield (6.3 dt/ha) compared to the lentil-pea-mixture (10.7 dt/ha) except of the lentil-pea-mixtures with the ratios 1:1 and 3:1 in 2018. Additionally, with increasing proportion of peas in the mixture, the protein yield increased significantly and achieved 12.0 dt/ha in pure peas. As lodging of lentils in lentil-pea-mixture was not worse compared to a lentil-oat-mixture but protein yield was increased, this cropping system could be an interesting option to increase the production of regional proteins - either for humans or animals.

Keywords: lentil, oat, pea, mixed cropping, Switzerland

0227

COVER CROP SPECIES AND PLANTING METHOD EFFECT ON WEEDS AT A MAIZE MONOCULTURE FIELD

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The use of legume cover crops to replace fallow during the winter intercrop period of maize monoculture allows to reduce nitrogen fertilizer without yield penalties. Cover crops can also affect the weed flora because of its competitive effect and/or allelopathic effects. We studied the effect of the species and seed rate of legume cover crops (CC) and the planting method on the weed density of the subsequent maize crop. Three CC crop species (winter peas, common vetch and hairy vetch) at two seeding rates (normal and reduced by 25%) and a control (without cover crop) were tested using two planting methods (conventional with tillage and no tillage). The experiment was started in October 2018 after a maize crop. Maize was grown during the experiment with conventional practices (tillage and herbicides). Weed density was measured on September of 2019, before the harvest of maize. Weed density was also measured after the following CC season on May 2020 in early stages of the maize crop in a part of the field where no pre-emergence herbicide was applied. Main weeds at maize harvest were *Diplotaxis erucoides*, *Poa annua*, *Sonchus oleraceus* and *Stellaria media*. Common vetch increased the density of *S. oleraceus*. No tillage planting of CC decreased the density of *D. erucoides and P. annua* to a third compared to conventional planting, and *S. media* was almost suppressed, but duplicated the density of *Cynodon dactylon*. Main weeds at the early stage of the following maize crop season were *Abutilon teophrasti*, *Chenopodium album*, *C. dactilon*, *Cyperus rotundus*, *S. oleraceus* and *Xanthium strumarium*. No effect of the CC species on weed density was found. Compared to conventional planting of CC, no tillage planting suppressed *A. teophrasti*, decreased to a third the density of, *C. album* and *C. rotundus*, and to 17% the density of *X. strumarium,* but increased the density of *C. dactylon* six times. In both measurement dates, the total density of dicot and monocot weeds was reduced when the CC were planted without tillage. The effect of the CC species and seeding rate on weed density was minor but the experiment just started and will continue during two more years.

Keywords: intercrop period, no tillage,corn, leguminous

0252

PRODUCTION POTENTIAL OF SOYBEAN, CHICKPEAS AND LENTILS IN THE NORDIC CONDITIONS

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Current climate conditions have provided new opportunities for the Nordic regions, thus providing novel choices for local farmers. Changed water regime and risen daily degree days have made it possible to grow greater variety of different legume crops, which in turn helps to diversify local protein production. Plants like lentil, chickpea and soybean are widely known protein crops in warmer climate conditions. The aim of the research was to study the growing potential of these crops in Estonia, in Nordic part of Europe. More specifically the aim was to have overview of the best farming practices, and to better understand optimum harvest time and measure yield gaps.

Data about soybean, chickpeas and lentil production trials was collected from years 2016-2019. Throughout these years there have been four regions where soybean has been grown and also two regions for lentil plant and chickpea. Data collected includes weather conditions (rain per mm, number of sunny days, temperature) and growing conditions (sowing time and method, inputs, harvested yield). Not all studied year gave a measurable yield, but on better years the soybean yield varied from 1,3 t/h to 1,8 t/ha. The results indicate that it is possible to grow soybean, chickpeas and lentils in Estonia. The biggest challenge is the selection of the varieties for the short vegetation period.

Keywords: legumes, diversity, climate change, yield, production

Session 2.3: Crop-Livestock integration

0056

CATCH CROPS GRAZED BY SHEEP: FORAGE, ANIMAL AND SOIL NITROGEN MONITORING

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The Nitrates Directive and its mandatory catch crops may become an opportunity to produce forage. Making hay or silage can be difficult in Belgium in fall due to the climate but grazing is an attractive alternative. By far lighter than cattle, sheep can cope with cold and wet weather while grazing catch crops. Farmers observed multiple benefits for this practice: cover crops natural destruction, cheap forage, transformation of N present in plants to N available for the next crop, lower damage from slugs and rodents, fewer weeds, etc. However, the initial goal of intercrops catching nitrates could be mitigated by animal N excretions.

To assess this risk, six field trial sites were set up in August 2019 across Wallonia, Belgium. A forage mixture was sown at 62 kg/ha composed of spring oats (61%), vetch (20%), Egyptian clover (12%), radish (5%) and phacelia (2%). All sites included three treatments (no grazing, extensive grazing and intensive grazing) of 48x30m each, repeated three times. On each site, 22 to 37 ewes grazed successively subplots in November and December, spending totally 10 to 31 days on each site according to available biomass.

Forage production ranged from 960 to 3205 kg DM/ha, with on average 52% radish, 20% cereals, 15% phacelia, 10% Egyptian clover and 3% vetch on a DM basis. Forage nutritive value was high (1,02 UFL, 142 g PDIN and 107 g PDIE/kg DM). The animals' mean daily gain was 78 g/day (significantly positive; $P < 0.001$). More than 70% of the herd gained weight and 50% improved their body condition. Only 21% lost weight and 13% lost body condition. At the end of the grazing period, all treatments made it possible to reduce the mineral N content in the soil (- 75% in the 0-30cm horizon and -60% in the 0-90cm horizon; $P < 0.05$). The ungrazed plot showed lower N than the grazed ones (8 kg N/ha

for no grazing vs 16 and 13 kg N/ha in the 0-30cm horizon for extensive and intensive grazing respectively; P < 0.05) but grazing intensity had no significant effect on this parameter.

Catch crops seemed effective at reducing N losses, whether it was grazed or not. Grazing, at both intensities, increased mineral N in soil. However, in 5 out of 6 sites, mineral N levels stayed in the permitted range. These results are preliminary and more soil analysis results will come.

Keywords: catch crops, nitrogen losses, grazing.

Session 2.4: Mitigating climate change: modelling, prediction, and strategies

0133

VULNERABILITY OF CASSAVA YIELD TO CLIMATE CHANGE IN THE BRAZILIAN SEMI-ARID REGION

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Cassava is one of the most important crops for tropical countries. Due to its tolerance to adverse weather and soil conditions, it has been cultivated as a strategic crop in semi-arid regions. Within the predictions of climate change (CC), it is crucial to understand in which ways cassava production might be affected in these regions, since any change in its yield might be critical for food security. In this context, crop simulation models are effective tools to quantify the future climate effect on crop yields. Thus, this study aimed to apply the DSSAT CSM-CROPSIM-Cassava model to elaborate a CC vulnerability index for cassava at Brazilian Semi-arid (BS).

The CSM-CROPSIM, previously calibrated (r^2 = 0.85, d = 0.93) and evaluated (r^2 = 0.82, d = 0.94), estimated cassava cultivar BRS Formosa attainable yield (AY) for 50 locations in BS. Soil profile data was obtained from soil analyzes. Weather data from 1980 to 2010 composed the current historical series (CHS). The weather series under future projections were created from the CHS through the delta method, based on projections of global climate models (GCMs), from CMIP5/IPCC/AR5. Projections were considered under scenarios of intermediate (RCP4.5) and high (RCP8.5) greenhouse gases emission, for medium (2040-2070) and long (2070-2100) terms, using seven GCMs. The GCMs simulations were presented as mean values of their ensemble. With the average AY for 29 cycles performed for the sites, for current and future scenarios, a vulnerability index (VI) was created to identify the most vulnerable areas for cassava AY reduction due to CC. For the VI mapmaking, the locations were divided into 35 sites, for the development of linear regression model (for VI spatialization) and 15 sites, for map evaluation; and statistical analysis were applied.

VIs estimation by the linear equations was efficient (MAE from 5.0 to 8.4%) and consistent (d from 0.86 to 0.93) compared to the calculated IVs. CC is likely to increase BS's vulnerability to cassava production, with predominating reductions in AY. Areas already vulnerable will become more critical, while most non-vulnerable areas will show some degree of vulnerability.

The cassava production vulnerability to CC in BS was greatest in the long term (2070-2100), in RCP4.5 and RCP8.5. The most vulnerable region was at SW of the BS and the less vulnerable, at N and NE. Thus, studies of adaptation measures are essential to minimize the vulnerability of such important crop to food security in BS.

Keywords: Manihot esculenta; Crantz; DSSAT/CSM-CROPSIM-Cassava; Crop model; Global warming

0169

NEW CROPPING SYSTEM WITH FOOD AND VEGETABLE CROPS FOR CONVERTED PADDY FIELDS

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Rice production in South Korea exceeds the local demand on rice in Korea, so government encourages farmers to grow alternative upland crops in paddy fields. Therefore, a two-years field study was conducted at a paddy field located in Pyeongchang, Korea to develop new cropping system consisting of various upland crops such as food and vegetable crops suitable to paddy fields converted into upland condition. Six cropping systems consisting of food crops including corn and potato and vegetable crops including cabbage and broccoli were tested in comparison with soybean and rice monoculture in 2018 and 2019. For economic analysis, all cost-related input data such as fertilizer, pesticide, seeds, labor etc. were recorded during cropping season and all output data including crop yield and crop price were measured after harvest. Among the tested cropping systems, the cropping system (CS3) consisting of potato and perilla in the first year and corn and cabbage in the second year required the greatest input cost, about 3.2 time greater than rice or soybean monoculture. In terms of gross output, the CS3 produced the greatest gross output, about 7.3 time greater than rice monoculture and 2.7 times greater than soybean monoculture. Considering both input and output data, our field study revealed that the cropping system based on corn in the first year and potato in the following year with other vegetable crops provides regional farmers with the greatest economic return. We are currently evaluating environmental impact of new cropping system, so our study may advise not only economically but also environmentally sounding cropping system in the region.

Keywords: Economic analysis, New cropping system, Converted pPaddy field, Upland crops

0177

INFLUENCE OF WEATHER ON ESTONIAN GRAIN PRODUCTION

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Agriculture is more dependent on climate than any other sector. And the fate of agricultural productions is determined by year-to-year climatic variability as weather has a significant impact on crop growth and development (Hoogenboom, 2000). Estonian weather conditions are challenging and fluctuating. To avoid loss in production, farmers need precise weather prediction methods to successfully plan their crop rotation and ensure sustainable food production.

This paper presents an in-depth analysis of the weather impact on various crops from 2008 to 2018. The influence of temperature, precipitation and snow coverage was determined by correlation analysis. The correlation was performed for each 10-day period of the month on four different levels- test field, producer, county and national level. The difference in the yield was from 38% up to 73% depending on the year and the data clearly shows that years with optimal weather conditions had higher yield. According to the correlation analysis winter wheat is the most stable crop in terms of yield stability and field pea is the most weather dependent crop. For winter crops the most influential factor was temperature in January and May. Temperature in January is of paramount importance in terms of survival of the crops. Warmer temperature in the winter increased the yield of winter crops. For spring crops, the most influential factor was precipitation and temperature in May and also temperature in July. Higher than average precipitation in May and lower than average temperature in May increased the yield of all the crops studied.

Despite the negative impact of the weather, most of the yield loss can be prevented or the damage can be eased by careful planning and detailed knowledge about the influence of different weather factors. Further investigation is required to determine the change

in growing season length, sowing dates and harvesting to provide farmers more detailed tools to predict and plan their actions.

Keywords: crop-environment interactions: climate; climate change; agroclimatology; cereals

0182

COULD CONSERVATION AGRICULTURE LAND PRACTICES ENHANCE SOIL RESILIENCE AGAINST DROUGHT EVENTS?

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How climate change will affect soil functioning is a major concern, especially in Mediterranean agrosystems, where, according to climate change projections, the occurrence of extreme temperatures and drought events will be increased. The main objective of our experiment was to evaluate de effect of land management (tillage system) on soil resilience against a simulated dry-rewetting cycle. Soil samples were collected from an in-situ field experiment established in 2008 in the Guadalquivir Valley, where conservation agriculture practices have been tested. Three different land management practices under a typical Mediterranean wheat-legume rotation system were compared: 1) traditional tillage (TT), 2) minimum tillage (MT) and 3) no-tillage (NT). Following our hypothesis, conservation agriculture practices (reduced tillage and no-tillage) may allow a more mature soil microbial community by reducing soil perturbation, and this would result in a higher resistance of soil functioning against drought periods. Soil enzyme activities (β-glucosidase, phosphatase, acetylglucosaminidase, aminopeptidase and dehydrogenase activities), microbial functional diversity (Microresp method), and soil DNA concentration (as an index of microbial biomass) were analyzed in a base-line sampling. Afterwards, a dry-rewetting cycle was simulated under controlled conditions. 8 subsamples of 50g from each soil sample were hydrated to reach the 70% of each soil water holding capacity (WHC) and kept in those conditions for a pre-incubation period of 15 days. After this period, half of the replicates were let dry for 12 days (drought), while the others were maintained at 70% WFC (controls). Finally, all replicates were rehydrated again to the initial water content during a 14 days rewetting period. During this cycle, soil respiration rates were periodically measured to study the evolution of soil microbial activity. Our results showed that initial respiration rates were slightly higher in MT compared to NT ($p<0.1$), likely due to higher organic C and N content in the MT soils. Drought extremely reduced respiration rates in the three treatments, but the results did not show a clear pattern among treatments. During the rewetting period, respiration rates were significantly higher in drought samples in comparison with the controls, while no significant differences were found for the land management treatments. Besides, land management practices did not have a significant effect on soil DNA concentration, functional diversity of the microbial community or enzyme activities.

Keywords: land management, tillage, soil biodiversity, soil respiration rate, enzyme activity.

0219

PERSPECTIVES FOR IMPROVING THE FUTURE SUSTAINABILITY OF OLIVE GROWING IN THE MEDITERRANEAN AREA: EXPLORING THE EFFECTS OF INTENSIFICATION AND DEFICIT IRRIGATION

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Olive orchard represents a key agricultural system with huge economic and environmental relevance. Future climate is expected to show tendencies to warmer and drier conditions with large regional variability over the Mediterranean. This could threaten the sustainability of such strategic tree crop. This study evaluates the productive and environmental performance of olive orchards under different climate change scenarios and management strategies across the main olive-farming regions over southern Europe using the process-based model OliveCan. Meteorological data over olive tree cultivated area were clustered into 22 sub-climates over baseline period (1980-2010). Future climate data (2041-2070 and 2071-2100 horizons) of GUF-CCLM4 Regional Circulation Model for RCP4.5 and RCP8.5 scenarios were used. Simulations were performed for low density LD (100 trees ha^{-1}), high density HD (400 trees ha^{-1}) and super high density SHD (1650 trees ha^{-1}) olive orchards. Climate change impacts on the the sustainability of olive orchards regarding productivity and capacity for carbon capture were assessed. Implication of new planting systems namely intensification and irrigation were also evaluated. Results showed that drier and warmer conditions are expected all over the study area, with the most negative impacts over the driest areas and under RCP8.5. Rainfed low density orchards will be most vulnerable to these expected changes. In particular, over the Iberian Peninsula, a decrease in yield up to 28% is expected under rainfed conditions with an increase in its interannual variability of 20%. Meanwhile over the centre of the Mediterranean, yield increased up to 26%. Irrigation requirement for the maximum productivity are expected to increase by 5-27%. Olive orchards responses in terms of yield and Net Ecosystem Productivity (NEP) were highly influenced by deficit irrigation and intensification. Yield and NEP responses to future scenarios in the wettest clusters were more positive than those in the driest ones. Our analysis showed that productivity depends on the balance of water supply, evaporative demand and atmospheric CO_2. In general, the increase in CO_2 considered in the future scenarios may compensate the negative effects of higher evaporative demand and diminished water supply resulting in an enhancement of water use efficiency and carbon capture potential in olive orchards. Even though findings of this research showed that olive orchards may benefit from future conditions, assessment of management alternatives at local scale will be a must for a better adaptability of olive orchards.

Keywords: Olea europaea L.; Climate change; Agricultural management; Productivity; Carbon sequestration; Sustainability

0271

EMISSION OF NITROUS OXIDE AND METHANE FROM RAINFED WHEAT AND PEA CROPFIELDS IN TWO LOCATIONS IN SPAIN

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A set of agronomic experiments was launched in 2017 in different locations in the Iberian Peninsula, networked to monitor the effects of climate change on crop performance and soil properties in rainfed systems. Among other variables, fluxes of GHG between soil and atmosphere were monitored in fields in Madrid (La Canaleja; 40°30'48.8"N 3°18'51.5"W; 600 m a.s.l.) and Seville (El Majano; 37°14'48.5"N 6°03'01.6"W; 3 m a.s.l.) where a four year rotation (wheat, pea, barley, rape) was cropped under minimum tillage conditions. Fluxes of nitrous oxide and methane were estimated by the closed chamber technique (Parkin&Venterea, 2010) and GC (ECD and FID detectors) on plots sawn with wheat or pea (three replicates/crop in a random block design). Sampling was performed at two phenological stages of wheat (first node of stem elongation-BBCH31- and anthesis-BBCH61).

Crop management was the same at both sites, but soil and climatic differences were substantial (mean annual temperature, annual rainfall and soil type were 18.0 ºC, 519 mm and *Vertisol Typic Haploxerert* for Seville, vs. 13.8ºC, 415 mm and *Inceptisol Typic Calcixerept* for Madrid*;* Lammerding et al., 2020*)*. The effects of site, crop or sampling time on the estimated fluxes of GHG was tested by GLM procedure with R.

Mean net fluxes of N_2O from soil to atmosphere (g N_2O-$N*ha^{-1}*d^{-1}$; s.e.= ± 1.18); Soil Tª (ºC) and yields.

	MADRID						
	2017-18				2018-19		
Phenology	Pea	Wheat	Tª		Pea	Wheat	Tª
Elongation	-1.29	-3.02	5.4		0.92	-0.32	9.3
Anthesis	-2.72	-1.66	17.1		-0.18	-0.43	17.3
Yield (Mt/ha)							

	SEVILLE						
	2017-18				2018-19		
Phenology	Pea	Wheat	Tª		Pea	Wheat	Tª
Elongation	0.02	-0.41	20.7		-0.63	2.12	13.6
Anthesis	2.55	3.63	16.5		4.87	4.48	15.4
Yield (Mt/ha)							

***: significant location effect; $p<0.01$

Mean net fluxes of Methane from soil to atmosphere (g CH_4-C*ha^{-1}*d^{-1} ; s.e.= ±1.40).

	MADRID *				
	2017-18			2018-19	
Phenology	Pea	Wheat		Pea	Wheat
Elongation	0.52	-1.83		-3.96	0.52
Anthesis	-1.34	-0.95		-5.29	-4.17

	SEVILLE				
	2017-18			2018-19	
Phenology	Pea	Wheat		Pea	Wheat
Elongation	-3.51	0.51		-1.23	-1.31
Anthesis	-1.71	1.23		-1.02	-0.39

*: significant location effect; p<0.1

In the two locations, soil acted as a sink for methane, but only in Madrid N_2O was consistently taken up by soil. No significant differences can be attributed to crop or phenological stage. For both GHG analyzed, fluxes were significantly higher in Seville, most probably due to differences in soil texture and composition, although other conditions (i. e. climatic variables) could also be involved.

Keywords: Green house gases; Rainfed crops; Minimum tillage.

Session 2.5: Protecting natural resources and the human environment

0031

PLACE OF ANIMAL FEED IN THE REGION OF CHLEF IN ALGERIA

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The nerve problem for ruminant farming in Algeria has always been that of food, its development is conditioned by the improvement of fodder resources. The Chlef region is located in the north of Algeria, it occupies a total area of 454,800 ha and the land allocated to agriculture represents 53% or 227,500 ha. The methodology adopted was based on the use of statistics from the National Statistics Office (ONS), those of the FAO and agricultural statistics of Algeria, series A and B.

In fact, 39% of the region's land is devoted to animal feed compared to the national figure which is around 48%. Barley, oats and fodder crops occupy 37% compared to 43% for all of Algeria. However, fallow areas represent 2% of the total compared to the national figure which is around 6%.

Guaranteed producer prices for wheat increased much more than free market prices for meat. Also; it seems that the price reports for cereal meats have remained almost the same, going from 23 in 2009/2010 to 24.5 in 2014/2015. Indeed, the value of animal production went from 78.3% in 2010/2011 to 77.2% in 2014/2015 against 21.7% for plant production in 2010/2011 and 22.8% in 2014/2015.

Analysis of the forage balance of herbivores in the wilaya. first shows that the quantity of barley distributed by it decreases from year to year and is no more than 200 tonnes. there is a fodder surplus which is around 30 million FU (fodder unit) .

Overall, we can consider that in Chlef as well as in Algeria 2/3 of the land in the SAU is intended for animal feed. The price ratios for meat and cereals remained almost the same, around 23. Thus, the guaranteed producer prices for wheat increased much more than the prices of meat on the free market. The value of animal productions represents 2/3 against 1/3 for vegetable productions.

Keywords: fodder ressources, ruminants, animal production, semi-arid

0061

WATER PROTECTION IN SENSITIVE KARST AQUIFERS - IMPACT OF N-FERTILISER REDUCTION ON AGRONOMIC PARAMETERS AND NITRATE LOADS IN NORTHWEST-GERMANY

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The demand by the European Water Framework Directive of a good ecological and chemical water quality was not reached all over Germany. Specifically, the groundwater bodies in the north western part with high livestock densities suffer from nitrate leaching. Since nitrate concentrations >50 mg l^{-1} cause problems for drinking water supply, some production areas are protected by special regulations for reduced N-fertilisation strategies. Within the drinking water production area Belm-Nettetal (Lower Saxony, Germany) farmers must reduce the nitrogen (N-)fertilisation by 10/20% in cereals/maize in protection zone II since 2017. A project was launched to observe the effects of reduced N-fertilisation on leaching water quality and agronomic effects with an installation of suction cups below a field trial with 3 crops (winter wheat, winter barley, silage maize) and six N-treatments (0, 50 kg ha^{-1} N mineral, fertiliser ordinance (FO) N-need estimation mineral and combined organic+mineral, reduced FO N-need estimation mineral and combined organic+mineral), with 3 replications in a randomised block design. During the winter season the percolating water was continuously collected below the root zone and analysed every second week for chemical parameters.

After 3 years, reduced N-fertilisation led to a mean decrease of nitrate loads, largest effects were observed in the beginning of leaching water season in early winter. With reduced N-fertilisation nitrate loads were on average in 2017 and 2018 11 kg ha^{-1} lower following barley, 30 kg ha^{-1} lower following wheat and 21 kg ha^{-1} lower following maize which equals a mean load improvement of 14 % for mineral and 35 % for organic+mineral treatment. Despite low nitrogen balance surpluses and increasing dilution effects over the winter period only 44 % of all measured samples reached the NO_3-limit (mean concentration >100 mg l^{-1}). Yields for all three crops were not significantly affected by reduced N-application. Whilst protein contents were not affected in 2017, slightly reduced grain quality was observed in 2018 and 2019 for winter wheat. Overall, the regulations for reduced N-fertilisation took effect for water protection aims with greater potential for organic+mineral fertilisation compared to only mineral N-applications without significant yield losses.

Keywords: nitrate leaching, fertiliser ordinance (Düngeverordnung), water protection, nitrate directive

0127

HOW TO OPTIMIZE ECOSYSTEM SERVICES OF COVER CROPS WHILE REDUCING THEIR COST? A CASE STUDY IN NORTHERN FRANCE

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Cover-crops have become mandatory in several vulnerable agricultural areas in Europe to reduce nitrogen leaching and limit soil erosion. Nevertheless, they represent a cost for farmers who would like to optimize their use. This study aims to assess what are the technical actions to be optimized in order to maximize the nitrogen leaching limitation and other ecosystem services and minimize cover-crop cost.

The study was conducted between 2018 and 2020 in 100 fields from 15 arable farmers in the Oise region (Northern France) differing for soil types, cropping systems and mixtures of cover-crops. Each field was managed according to the farmers' cropping system, leaving an uncropped part as control. Farmers were interviewed to survey its practices on each cover-crop field. The cover-crop growth was followed both by collecting biomass and by taking photos at several stages from September to December. Weeds were identified and analyzed. N analyses were made both in the biomass (weeds and cover crops) and on the soil (beginning and end of the winter). STICS simulation were performed in parallel to identify the best sowing and destroying dates and model the impact of the N delivered by the cover crop to the following spring crop in terms of N economy.

Results showed that, in both years, potential cover crops biomass was generally not reached (maximum 2.5T DM/ha). To reach this threshold it was required at least 1200°C.day from sowing and 50 plants.m-2 density. We also observed that to reach this density it was preferable to have more than 3 species in the mixture. From soil N availability, we showed that nitrogen avail-

ability was not the limiting factor to cover crop growth. And we confirm that the highest the cover crop biomass the highest the nitrogen recovering and providing to the next spring crop. Moreover, the highest was the cover-crop biomass and the soonest was obtained the lowest was the infestation by weeds.

From the economic point of view, the use of variable cover-crop mixture and sowing techniques induced a large variable costs range, from 40€ /ha up to 174€/ ha. And cover crops biomass was not significantly different between techniques showing that maximization of ecosystem services such as nitrogen retrieving, soil C enrichment or again weeds limitation from cover-crop is not a single economic question but more certainly an agronomic question, being solved by considering cover-crop as a real crop and giving it all the necessary attention.

Keywords: cover crops, biomass, agroecosystem services

0200

THE ROLE OF AGRICULTURE IN TIMES OF HEALTH CRISIS IN SPAIN

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The role of agriculture has always been important in our country, however, in recent years, the economy has been based on other economic sectors such as tourism, services, construction, etc., moreover, the subsides have been directed to these or other similar destinations rather far from agriculture. Despite that, agriculture remains an important pillar of our economy. Agricultural crops have often been abandoned. They are now being grown by big landowners and large companies. Agriculture plays an important role in a country's development, although its basic role tends to decline as the economy improves and the economy shifts to industrial development. In times of development, the role of the agriculture increases, as it has happened in times of war, and in health crisis as at present. The role of agriculture has been well demonstrated in the current health crisis caused by COVID-19, holding itself as a key pillar when almost all other activities had disappeared. In a delicate and complex global situation like the current one the agricultural sector has not stopped since the health crisis caused by the COVID-19 began. During the present situation, agriculture has been supported, "agriculture of proximity" has been favored and probably also the organic farming. Therefore, it is necessary to increase and maintain aid to agriculture, not only in difficult times, but also on a continuous basis and at the same time to value the role of the agriculture sector which has often played a significant role in these times of crisis.

Keywords: agriculture sector, health crisis, agriculture of proximity.

Session 3:
Efficient use of resources in agriculture

Session 3.1:
Sustainable intensification in farming systems

0030

STEPS IN INTENSIFICATION OF LOWLAND RICE PRODUCTION IN UGANDA: INSIGHT FROM ON-FARM EXPERIMENTS

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The importance of rice (*Oryza sativa* L.) as a staple food and cash crop for smallholder farmers in Africa, including Uganda, is rising. However, yields are very low and in many countries domestic rice production has not been able to meet the growing demand. Indications are that both macro and micronutrients limit productivity in East Africa. Diagnostic on-farm trials were conducted in Doho rice scheme and Bugiri district, Uganda, in 2016 and 2017 to identify ways through which smallholder farmers can increase lowland rice productivity. Experiments in Doho and Bugiri 2016 were conducted under good water management. In Bugiri 2017, trials were placed under rain-fed condition where farmers have poor control of water. All treatments included good agricultural practices (GAP) combined with each of the following fertilisation treatments: a zero fertilisation as a control, NPK fertilisation with and without micronutrients (B, Mn, Zn, S), and three treatments in which B, Mn and Zn were omitted one at a time from the NPK + micronutrient treatment. GAP included proper land tillage, bunding and levelling, line transplanting of 21 day old seedlings, and timely weeding. In the Doho irrigation scheme, GAP without fertilisation increased rice yields by 70 and 40% in 2016/2017 and 2017/2018, respectively, compared to the 3.3 t ha^{-1} average yield across farmers' fields from the scheme during the same seasons. Under well-watered conditions, similar yield was recorded in Bugiri during 2016/2017 as in Doho. However, under rain-fed conditions in 2017/2018, very low yields were recorded due to erratic drought that set in from maximum tillering to grain-filling stage. GAP + NPK fertilisation significantly ($P<0.05$) increased grain yields by 24 and 103% compared to the 5.5 and 4.6 t ha^{-1} recorded without fertilisation during 2016/2017 and 2017/2018, respectively, in Doho. Similarly, yields increased by 44 and 82% in Bugiri due to NPK application under GAP compared to the 4.8 and 0.8 t ha^{-1} obtained without fertilisation during 2016/2017 and 2017/2018, respectively. Adding micronutrients to NPK did not increase grain yields ($P>0.05$) at either location and season. GAP and NPK fertilisation were found cost-effective in both locations across the growing seasons. These findings show GAP as the first step through which smallholder farmers can sustainably increase lowland rice productivity, and further yield gains can be realised with NPK fertilisation under good crop management practices. Micronutrients were not co-limiting grain yield and therefore not yet to be considered in these areas.

Key words: Good agricultural practices, NPK fertilisation, Micronutrients, Lowland rice, grain yield

0058

OPTIMUM PRODUCTION AND AGRONOMIC USE OF COMPOST FROM ORGANIC AND GREEN WASTE IN ORGANIC FARMING

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The aim of the project "Optimum production and agronomic use of compost from organic and green waste in organic farming" is to provide scientific evidence and a process framework in order to increase the use of certified quality compost (organic and green waste) in organic farming and to support sustainable farming practices. The potential for using compost from organic and green waste is not currently being realized, despite the high demand for macro- and micronutrients in organic farming. In particular, the project will help to optimize compost production in fermentation and composting plants so that the high compost qualities required in organic farming are produced. Agronomic and environmental effects of different composts will be evaluated under differing site and cultivation conditions in organic

farming. Application recommendations will be developed based on scientific research. Comprehensive investigations in field trials and in composting plants will be supplemented with surveys of farmers about composting. Another project goal is the establishment of a nationwide compost expert group. Knowledge transfer will take place in cooperation with all regional compost quality assurance organizations, soil and humus organizations, the Federal Compost Quality Assurance Organization of Germany, the Organic Food Production Alliance, as well as the organic farmers associations Bioland and Naturland.

The project aims to promote the use of compost, which contributes to closing regional nutrient cycles and optimizing soil nutrient supply, thereby increasing yields and product quality. Through the linking of sub-projects and the expertise of the project partners, this project is particularly suited to strengthening the circular economy in the agricultural sector, improving the performance and resource efficiency of organic farming, and enhancing environmental and consumer protection.

Keywords: fertilization, nutrients, nutrient cycle, process quality, soil

0091

SPATIAL AND TEMPORAL DIVERSITY OF SERVICE CROP MANAGEMENT STRATEGIES ACROSS VINEYARDS IN THE SOUTH OF FRANCE. ANALYSIS THROUGH THE COVERAGE INDEX

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Service crops represent a great alternative to herbicides and soil tillage providing a wide range of ecosystem services in vineyards. Service crops may target specific services depending on the management strategy implemented by the winegrowers, including the plant species, the surface covered, the plants growth control and the date of destruction. Understanding the management strategies linked to their associated target services at the regional scale is necessary to better help winegrowers and their advisers regarding an adapted use of service crops. To do so, we conducted a survey in 2016 among winegrowers (n=334) in Languedoc-Roussillon region (south of France), enquiring about their service crop management practices during the season 2014-2015. Given the diversity of the strategies of service crop management, we proposed a typology analyzing their spatial and temporal dimensions. In addition, we present a Coverage Index (CI), which combines both temporal and spatial dimensions of the different service crop management strategies. Only 23% of the interviewed winegrowers presented a bare soil strategy during the whole year, meaning that 3 interviewed winegrowers out of 4 inserted or maintained service crops in their vineyards; 41% used a winter service crop strategy; 8,4% a semi-permanent and 27,3% a permanent service crop strategy. Although the preferred surface coverage strategy was full surface during grapevine dormancy and its reduction to half of the inter-rows after grapevine budburst, the diversity of surface coverage strategies during grapevine vegetative period is remarkable. The use of the CI helped us to compare the strategies according to farm structure, vineyard pedoclimatic conditions and of the correlation with the main targeted services and disservices. Surprisingly, lower water resources and specific soil characteristics were not linked to the specific service crop strategies. In contrast, higher CI was correlated with vineyards presenting quality labels (PDO and Organic), independent winemaking and lower target yields, showing that the added value of wine can play an important role when implementing service crops in vineyards. Overall, our study showed: i) the importance of spontaneous service crop strategies; ii) the spatial and temporal diversity of service crops management strategies and iii) the utility of the CI to study the implementation of service crops in a large population and to understand the motivations and constraints to their use. In the future, encouraging and monitoring service crops will help to improve sustainability in vineyards.

Keywords: survey; cover crop; intercropping; viticulture; spontaneous vegetation.

0120

POTENTIAL FOR SUSTAINABLE WHEAT PRODUCTION WITH NOVEL GENOTYPES FOR ENHANCED ROOT GROWTH IN TYPICAL GERMAN CROPPING SEQUENCES

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As one of the most important crops for human nutrition, ensuring the production of wheat (*Triticum aestivum* L.) under conditions of climate change in central Europe is of high importance. Dry springs and summers with little precipitation limit the capability of plants to take up water and nutrients, especially during the important phase of grain filling. Besides that, leaching of nitrate into groundwater aquifers on several locations with high precipitation has been a common problem for years. To cope with these challenges of future wheat production the objectives of our study are: Testing of novel genotypes with pronounced growth of the root system to (I) reach subsoil water in dry seasons and to (II) avoid nitrate losses in wet seasons as well as to (III) reveal agronomic effects of different previous crops and nitrogen (N) fertilisation strategies. A complex field trial for testing novel genotypes under three different fertilisation strategies following two different pre-crops (winter oil seed rape/ silage maize) with two different N levels (ΔN 100kg) was installed at the experimental station of Martin Luther University Halle-Wittenberg in Merbitz, located in the central German dry area around 150 km southwest of Berlin. We investigated the effects of root system parameters and the nitrogen uptake as well as grain quality traits of one winter wheat wild type originating from the Chinese wheat gene pool, where the proliferation of a pronounced root system was detected, and three wildtype x European winter wheat-cultivar crossing lines. After one experimental year, precrop yields were not significantly different between N-levels. First results showed little impact of precrops and precrop-N-management on wheat development. Compared to the crossings, the Chinese wild type plant development was earlier since end of tillering/beginning stem elongation. As roots are the plant organ responsible for water and nutrient uptake, they play an important role to withstand phases of drought, to ensure stable yields and to avoid leaching of nitrate. Furthermore, the yield quality (protein content) must be considered to provide e.g. good baking quality. Overall, the availability of water due to a powerful root system is a key process for increased nitrogen use efficiency as a contribution to sustainable intensification of wheat production.

Keywords: drought, climate change, nitrogen use efficiency, sustainable

0193

LONG-TERM EFFECT OF DIFFERENT TILLAGES ON AVAILABLE PHOSPHORUS AND CROP YIELD

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Soil degradation is one of the main concerns in Mediterranean agricultural lands. Agricultural practices aimed at improving soil protection and functioning are required for enhancing agricultural sustainability. Conservation agriculture is a strategy which usually involves the reduction in the intensity of tillage, avoiding moldboard plowing and promoting the incorporation of crop residues to soil, and the increase in the number of crops in rotations. Beneficial effects in the medium-long term involves an increase the size and activity of the microbial biomass closely related to an increased soil organic matter, and also an increased availability of nutrients to crops. Our objective was to assess the effect of different tillage practices on crop performance and available phosphorous (P) in soil. To this end, three tillage treatments were compared in a long- term field experiment: Conventional tillage involving moldboard plow (CT), minimum tillage (MT) and non-tillage (NT) with a randomized complete block design with four replications. The 3-year crop rotation involved durum wheat, sunflower, and peas.

CT led to the highest yield in sunflower, 56% and 32 % higher than NT and MT, respectively in the 2017-18 growing seasons. However, in the following crop (pea) the crop yields were not significantly different between tillage treatments. Differences in sunflower performance may be ascribed to the particular rainfall distribution, a dry season with most of the rainfall in March, which led to poor nascence of seeds; in addition, CT may led to better water infiltration and potential saving in soil water with NT did not lead to any advantage. The Olsen P content measured at a depth of 60 cm did not show significant differences between tillage treatments. However, in the surface horizon, this P availability index was higher in NT relative to CT (by 44 %) as a result of the increased stratification of applied P fertilizer. The microbial activity of the soil estimated as the β-glucosidase activity in the surface horizon was 44% greater in NT relative to CT. However, the phosphatase activity did not show significant differences between treatments. Soil management affects other chemical properties such as soil organic C. It can be concluded that NT did not perform worse than CT in years of nor-

mal rainfall and lead to improved soil quality indicators.

Keywords: tillage, enzymatic activity, phosphorous

0195

20 YEARS OF DIGITAL TECHNOLOGY FOR NITROGEN FERTILIZATION IN CORN: ADVANCES, ADOPTION AND GAPS IN KNOWLEDGE

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Numerous digital technologies have been developed for the decision making process in nitrogen fertilization during the last 20 years, where great advances have been made, but a poor massification of the use by farmers due to factors such as high cost and low practicality in the tuning and calibration and low scalability. We are going through a satellite revolution with exponential growth in development and it is expected that this trend i will be even greater in the next 10 years taking into account the emergence of Startup companies, launches of new satellites and their technological advances, presenting itself as an opportunity to overcome the previous difficulties. Nevertheless, and despite the research carried out by INTA, there are still knowledge gaps in the development of methodologies and algorithms to obtain a reliable and rapid product, fundamental factors for the mass use that will require a strong interdisciplinary intervention for the development of technologies such as Machine Learning, which are solutions that form part of a worldwide trend. For all this is that it is necessary to establish a new starting point for future research on the application of N with VRT, generating new algorithms of absolute indexes that can be calculated from information from multiple satellites to benefit from the flow of data that together will allow Real-time monitoring of crops and with high spatial resolution, text of the abstract, text of the abstract Text of the abstract (limit 400 words),

Keywords: satellite; fertilization; nitrogen; machine learning; precision farming.

0197

A REVIEW OF INNOVATIONS FOR SUSTAINABLE INTENSIFICATION OF IRRIGATED RICE-BASED SYSTEMS IN WEST AFRICA

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After a period with decreasing support to irrigation development, there is a renewed interest for water management in agriculture in West Africa, as reflected by the Sahel Irrigation Initiative launched during the High Level Forum on Irrigation (Dakar 2013). There are a number of possible pathways for improving irrigated agriculture but any improvement action must fit the local environment, meet the needs of smallholder farmers, and be environmentally sustainable (Montpellier Panel Report, 2018).

Sustainable intensification (SI) of irrigated agricultural systems has been proposed as a promising pathway leading to more resilient and food-secure farming communities while complying with these premises. SI is a wide concept encompassing very diverse initiatives. This paper reviews the scientific literature to obtain a comprehensive overview of technical and governance potential solutions leading to sustainable intensification of irrigated systems in West Africa and trying to answer the questions: Which options are effective and under what conditions? Which ones are more appropriate for smallholders?

We have followed the framework developed by Koutsous et al. (2019) for conducting a systematic literature review in agricultural sciences, extending the basic steps provided by the widely used PRISMA Flowchart (Moher et al., 2010). The procedure includes a review protocol for the systematic literature searches and for the selection of inclusion and exclusion criteria. The review focuses on sustainable intensification practices aimed at enhancing the productivity and resilience of irrigated rice-based agricultural systems, with focus on West Africa.

We have distinguished options aiming at improving water, soil and crop managements, at the plot, farm and irrigation scheme levels. We will provide insights on the most promising options, including the key elements that could facilitate their adaptation to local conditions.

Keywords: sustainability, water management, cereals

0207

SUSTAINABLE INTENSIFICATION OF SMALLHOLDER WATER-MANAGED AGRICULTURAL SYSTEMS IN WEST AFRICA - ACTIONS UNDER THE WAGRINNOVA PROJECT

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Development and positive impact of irrigated perimeters and improved lowland valley systems in West Africa have been limited in spite of their potential for economic and social growth. Understanding why the expected benefits are not observed for smallholders, and setting the basis for a direction change, are necessary to successfully address the agricultural challenges in the region. The LEAP-AGRI WAGRINNOVA project suggests that sustainable intensification (SI) of agricultural systems is the pathway to a new, dynamic, inclusive, market-oriented and technology-based agriculture. The project focuses on the two most common water-managed agro-ecological systems for smallholders in West Africa: community-managed irrigation schemes, and regulated or rainfed lowland valleys. It offers a methodology that leads to SI through a systemic multi-scale approach (plot, farm, scheme/watershed) for the characterization of current conditions and the evaluation of options to foster sustainable agricultural systems. The objective is to co-design adequate technical and governance solutions, and to advise policymakers, developers, and farmers, in particular in a context of climate change and food insecurity. The project uses a participatory action research approach in five innovation hubs localized in Senegal, Burkina Faso and Ghana.

This paper presents the results of the initial assessment of current conditions, in particular, the major constraints faced by smallholders at different scales, proposed innovations to address these constraints, and the pathways to the sustainable intensification of these systems.

Keywords: sustainability, water management, farming systems.

0217

IMPLEMENTATION ELECTRONIC SERVICES SYSTEM IN SUSTAINABLE HORTICULTURE

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Lithuanian Agricultural Advisory Service (LAAS), together with LRCAF Institute of Horticulture and other institutions, developed and implemented electronic services' system IKMIS (www.ikmis.lt.), which presents electronic services for farmers which intend to sustain their horticulture system. The service has been developed accordingly to European agriculture issue relevant today while implementing the EU strategy for sustainable pesticide use and other legal acts. In the course of this project and in collaboration with farmers, the growth abundance of sugar beet weevil *Bothynoderes punctiventris*, Germ. was observed in different places of Lithuania. Sugar beet weevil - a pest of beet - was described in 1974 as very rare in Lithuania. As the climate warms, the harmfulness of this pest species increases. The larvae of sugar beet weevil were found inside of red beets' roots in 2018. The imagoes of this pest in South East part of Lithuania appear in end of March, in Northern part - in middle of April in 2020. The IKMIS provides access to use electronic catalogues of pests, how they look like, what time the pest can appear and what plant protection measures can be applied, what actives ingredients are allowed to be used. In Lithuania, in sustainable horticulture system, the usage of pesticides is very restricted. Due to the small

number of available active ingredients for sugar beet weevil control this pest can become the most harmful pest of all beets.

Keywords: abundance, Bothynoderes punctiventris. electronic catalogues

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0222

ROLE OF SOILS IN THE CONTEXT OF THE REGULATION OF THE HUERTA DE VALÈNCIA

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In the Valencian Community, the Valencian Generalitat has exclusive jurisdiction over territorial and coastal planning, urban planning and housing. Article 16 of the Law 5/2014, of July 25, of the Generalitat, of Planning, Urbanism and Landscape in the Community Valenciana, sets out the provisions that regulate the uses and activities in the Huerta de València as a space of great productive, environmental and cultural value, and regulates the developing of a supra-municipal territorial planning instrument. From the point of view of agrarian activity, the productive development of the Huerta de València is justified in the article 49.3.3ª of the Statute of Autonomy. The agricultural activity and the natural, cultural and landscape heritage of the Huerta de València plays a relevant social role by promoting the development of the agricultural sector, food sovereignty, the well-being of people and the sustainable use of the territory. Law 5/2018, of March 6, of the Huerta de València regulates the basic elements that define and characterize the Huerta de València, among which is soil, in this case of high agrological capacity. The publication of Law 5/2018, which includes soil protection to keep it in its original use, far from speculation and buildings, has been invaluable. These soils are included in all classifications within group I and have high agricultural potential for all their attributes such as high thickness, low stonyness, adequate physical properties, stability, high infiltration and flat topography, among other parameters. For all this and also by tradition it is worth maintaining and protecting the soils of the Huerta de València, which is possible thanks to the publication of the aforementioned law.

Keywords: agriculture, soil protection, agrological capacity, Huerta de València.

0249

THE USE OF ORGANIC MATTER AS AN ACCELERATOR IN THE DEGRADATION OF THE BIODEGRADABLE MULCHING

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The current intensification in the use of plastic material in agriculture, even though it has significantly increased the productivity, is causing as well increasing harmful effects over the environment of the agro-ecosystem. At the end of their useful life, the plastic material used to cover the soil, such as the soil mulching, turns into a source of pollution when they are not properly removed, when they are left in the soil or when they are burnt. The use of biodegradable mulch might be a solution, but there is a problem that, in the Region of Murcia and southeastern Spain areas, they are not completely decomposed mainly due to the weather conditions and the sort of crops found there. Furthermore, the lack of soil moisture after the end of the crops, causes the decrease, deceleration or detaining in the activity of the soil microorganisms due to their survival difficulties, being these microorganisms essential in the process of degradation. The objective of this work was to hasten the degradation process of the bioplastics by means of the use of organic matter originating from cows, sheep and goats. Plastic films were used in broccoli crops, after their use in these crops, they were sliced, classified according to their exposure to the sun in their internal or external part and buried along with agricultural soil and organic matter (cow, sheep and goat). Afterwards, this mixture was irrigated simulating a crop. A gravimetric and visual (photographs) monitoring of the buried films was carried out, thereby offering that the mixtures which contained sheep organic matter decomposed faster than the rest. In the coming 90 days, the external part was a 92% decomposed, and the internal one an 85%. Nonetheless, the necessary days for the decomposing process in the rest of the mixtures were higher. In the case of the mixture composed of goat organic matter, 139 days were needed, resulting in a loss of the 95% and 85% of the external and internal part accordingly. Regarding the treatment containing cow organic matter, the necessary days for the decomposing process were even superior, resulting in a loss of 65% and 54% of the external and internal part respectively after 187 days.

Keywords: Biodegradability, Eco-friendly, Soil, Organic farming

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0013

ALTERNATIVE METHODS TO AEROBIC INCUBATION FOR THE DETERMINATION OF POTENTIALLY MINERALIZABLE NITROGEN

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The estimation of soil nitrogen (N) release for plant nutrition, N potentially mineralizable (NPM), is an important tool for the design of a fertilization strategy useful for the farmers. The knowledge of NPM avoids the application of inadequate rates of N fertilizer. These rates should be adjusted based on the ability of the soil to supply N through mineralization. When organic residues from agri-food industries or farms are used as fertilizers, part of the N is in organic form. The estimation of the mineralization rate improves the prediction about the availability of N for the crop. The aerobic incubation method (N_o) described by Stanford and Smith (1972) is considered a standard method to measure the soil’s potential to mineralize N. The difficulties in implementing this method are related to the control of soil moisture, high incubation time and the need of an incubator. These reasons make this method unsuitable for routine soil analysis. Consequently, studies have been conducted to identify methods based on biological or chemical procedures that can accurately estimate NPM to solve these difficulties. The aim of this study was to evaluate alternative methods to aerobic incubation (14-days, 25ºC, 60% water holding capacity of the soil, N_o), such as biological method (anaerobic incubation, 7- and 14-days, 40ºC waterlogging, N_{an_7}; N_{an_14}) and chemical extraction (hot KCl, 400ºC, 4h, N_q). Organic residues from substrate spent mushrooms and anaerobic digestates from different origins (C:N range 4 to 45) were applied to a silty clay loam soil. A mineral treatment and a control, without application, were included. The N_{an} was not adequate to predict NPM (N_o) in mineral treatment and the values were discarded. The determination coefficient was significant in N_o vs. N_{an_7}, N_o vs. N_{an_14} and N_o vs. N_q (0.84, 0.94 and 0.95, respectively). However, the paired sample test indicated that only the N_q did not showed differences with N_o method. In conclusion, N_q is a reliable alternative to N_o method. Its implementation in routine soil laboratories

is easy, consumes little time and does not require special equipment.

Keywords: aerobic incubation, anaerobic incubation, KCl hot, organic fertilizer.

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0016

BIOLOGICAL INDICATORS OF SOIL HEALTH IN MEADOWS AND FODDER CROPS

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Cropland and grassland systems must be managed using more environmentally, economically and socially sustainable methods in order provide ecosystem services and to help resolve problems affecting productivity. Soil microorganisms have significant roles that contribute to the sustainability of agricultural systems. The objective of this work was to compare the long-term effects of two types of agricultural systems: grassland (meadow) and cropland (double cropping of annual ryegrass and forage maize) on four farms in the central coast area of Asturias (northern Spain) on the diversity and composition of soil microorganisms. Soil samples were obtained after the harvest of the forage maize (October 2018) from each of the eight plots to analyze the following soil biological indicators: 1) bacterial functional diversity with EcoBiolog™ plates, 2) genetic diversity of bacteria and fungi, by automated ribosomal intergeneric spacer analysis, 3) basal microbial respiration was determined by titration in a statitc system (ISO 16072:2002), and 4) microbial biomass carbon with the chloroform-fumigation extraction method. ANOVA, post hoc Tukey's test and Non-metric multidimensional scaling were used in order to establish any differences between the biological indicators in the soils under the two agricultural systems. Microbial respiration (1.91 mg C-CO_2 kg^{-1} h^{-1}, SD=0.20) and microbial biomass carbon (926.52 mg C-CO_2 kg^{-1} h^{-1}, SD=219.16) were statistically significant ($p<0.05$) higher in meadow than the forage crop rotation (microbial respiration = 1.25 mg C-CO_2 kg^{-1} h^{-1}, SD=0.48 and microbial biomass carbon = 558.81 mg C-CO_2 kg^{-1} h^{-1}) plots. Greater microbial biomass carbon is expected in grasslands because croplands are reported to have less microbial activity associated with physical (tillage) and chemical (misuse or overuse of pesticides, fertilizers and manures) soil disturbances in maize cultivation. Although the bacterial functional diversity and genetic diversity of bacteria and fungi were higher in the meadow than in the forage crop rotation soils, the differences were not statistically significant. The spatial distribution of the samples in relation to the bacterial genetic diversity overlapped for both types of agricultural systems, and the variability was higher in the forage crop rotation. By contrast, the fungal genetic profiles were spatially separated between grassland and cropland. It should be noted that the results obtained might vary according to the type of soil. While there is no standard threshold that indicates high soil health, an increase in the values of the biological indicators especially microbial biomass and basal microbial respiration over time would indicate improving of soil health.

Keywords: cropland, grassland, microbial abundance, microbial activity, microbial diversity

0049

CLIMATE CHANGE IMPACT ON MAIZE IN SOUTH EAST OF FRANCE

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Climate change is a reality lived by French farmers for many years now. Since 1850, temperature in Europe increased by 2°C (Copernicus Climate Change Service). Projections show temperature increase and rain stagnation for next years (Boé and al., 2008; Terray and Boé, 2013 ; Vidal and al., 2012). These estimations will increase crop water needs but to what extent? Maize in France represents 3 million hectares to produce grain, seeds and biomass (Agreste, 2017). Due to its summer seasonality, it is sensitive to water scarcity and heat. It is the main irrigated crop with 0.93 Mha irrigated(Agreste, 2017). Rhone-Alpes Auvergne region is a big maize producer with 0.16 Mha. In this study, the objective is to estimate maize water needs evolution in the east of France due to climate change.

To estimate maize water needs, we use a French water balance called Irre-LIS®. It is a tool available online for farmers and technicians on grain maize, corn seed, straw cereals, soybean (in partnership with Terres Inovia) and tobacco. The model is coupled with a simple decisional model. We irrigate when three conditions are gathered :

- We are in the irrigation period
- We did not irrigate during a fixed number of days (water turn)
- We irrigate if water deficit is under the amount of easily available water

We worked on climatic data for Montelimar (26, France) on a past set (from 1950 to nowadays) and on a future set (from 1950 to 2068). GIEC scenarios are used for the future set. 2 scenarios are selected : RCP 4.5 which is the realistic scenario if states have a real politic in favor of environment, RCP 8.5 if we do nothing.

We simulate two sowing dates (04/15 and 05/10), one precocity (late variety) and two total available water levels (135 mm and 70 mm).

For real climate, flowering date happens one week earlier on average between 1960-1990 period and 1991-2019 period whatever the sowing date be. For irrigation amount, there is a slight increase (from 10 mm to 20 mm in average depending sowing date). Cycle shortening paired with water amount increase lead to more important daily needs.

For future climate, we see a phenomenal aggravation with a new cycle shortening and a slight irrigation increase. One of the issues will be farmer irrigation equipment and daily flow they can deliver.

Keywords: climate change, water needs, maize

0063

TILLAGE SYSTEM EFFECTS ON MAIZE GRAIN YIELD IN CENTRAL SERBIA

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Maize production is prevalent in Serbia. Soil tillage system can significantly influence yield and its components through the effects on soil moisture, nutrient availability, temperature and aeration. Under variable climatic conditions and frequent occurrences of dry years, soil tillage and fertilisation level adjusted to the soil type, agro-ecological conditions and the crop, can contribute to the achievement of maximum yield potential. The effects of no-tillage, reduced and conventional tillage, and three levels of fertilizer application, on the maize yield and its components, were analyzed in 2017-2018.

Investigation was initiated in 1978 at the Maize Research Institute, Belgrade, Serbia (44°52'N 20°20'E) and still running. The soil was a slightly calcareous chernozem and winter wheat was the preceding crop. In the no-tillage treatment, sowing was performed by direct maize planter, reduced tillage was performed with a rotovator while conventional tillage consisted shallow plowing immediately after wheat harvest, plowing in the autumn and seedbed preparation in the spring. Within each tillage treatment as the main plot, the maize was grown with three levels of fertilizer application as subplots: F1 - without fertilisation; F2 - 180 kg N ha^{-1} and F3 - 240 kg N ha^{-1}. Fertilisers in the amount of 50 kg P ha^{-1} and 50 kg K ha^{-1} were applied in the autumn, while N fertiliser was incorporated in the spring, prior to sowing. The maize hybrid 'ZPSC 606' (FAO 600) was sown on 26 and 27 April in 2017 and 2018, respectively. The maize grain yield at 14 % moisture was measured, as well as, 1000-kernel weight, ear length, ear diameter, number of kernel rows per ear and number of kernels per row.

Meteorological conditions of the year made noticeble influence on maize yield parameters. In average, grain yield was nearly three times higher in 2018 - 8.60 t ha^{-1} than in very dry 2017 - 3.47 t ha^{-1}. The higher rate of N (F3) resulted in increasing of all maize parameters within each tillage system, but esspecially conventional tillage. Maize grain yield, 1000-kernel weight, ear length, ear diameter, number of kernel rows per ear and number of kernels per row, had by 89.9%, 61.1%, 30.6%, 33.2%, 19.1% and 37.3% higher values in conventional tillage, F3 and 2018, than in no-tillage, F2 and 2017.

Conventional tillage together with N supply, is optimal for achievement of high maize grain yield and its components under agro-ecological conditions of central Serbia.

Keywords: conventional tillage, nitrogen, yield components, maize

0066

USE OF PLANT BIOSTIMULANTS AS NEW TECHNOLOGIE FOR SMART AND SUSTAINABLE AGRICULTURE

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The excessive use of chemical fertilization in the crop production causes contamination on surface and ground waters, as well as the toxicity of soils. The excess of nitrates, urea and phosphatesprovokes toxic accumulations that is very harmful to the environment and affected people's health. Such pollution can also release harmful gases into the atmosphere and cause critical environmental pollution. Furthermore, environmental pollution may increase in the future because climate change is expected to decrease precipitation and increase evapotranspiration in many regions of the world. In this context, the use of natural biostimulants to improve soil characteristics and nutrient availability for crops can reduce the use and damage caused by the chemical fertilizers. Moreover, the soil fertility is not only based on the application of macronutrients and micronutrients through fertilization, the natural metabolism of soil bacteria and fungi can provide soil fertility and consummation of CO_2. Therefore, plants within its physiological growing cycle can assimilate in a more effective way the nutrients available in the soil, as well as the use of synergies to synthesize together with soil microbial flora the essential nutrients for its development. The main objective of this study is to evaluate the effect of biostimulants on the chemical composition, fertility and enzyme activity in two types of soils (sandy and sandy loam soil), both soils were cultivated with grasses. Two different types of biostimulants were examined; natural substance and microorganisms composed the first one, while the second one was obtained from algae substances. Field experimentation were conducted at two different sites, the Golf Course (Encín Golf) and the Madrid Institute for Rural Research and Agrarian Development and Food (IMIDRA), both situated at Madrid. Soil samples from plots with and without the application of biostimulants were analyzed for the evaluation of chemical composition, the content of organic matter and both microbial and enzymes activities.The results of this study showed significant differences in the characteristics of soil samples with the application of both biostimulants and with some difference between the two types of biostimulant applied. Biostimulants application has improved the microbial and enzymatic activities of the soil, as well as the availability of nutrients, allowing thus adequate growing conditions to the crops, the reduction in the excessive use of fertilizers and a better preservation of the environment.

Keywords: Biostimulants, microbial activity, enzyme activity, soil nutrients, sustainable agriculture.

0073

NATURAL ZEOLITE IMPROVES FERTILIZER EFFICIENCY AND INCREASES OLIVE TREE PHYSIOLOGY, YIELD AND SOIL MYCORRHIZAL ACTIVITY

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The long-term excessive use of agricultural chemicals has resulted in a decline of soil health and fertility, as well as environmental degradation. Improving soil fertility and reducing the environmental impact of chemical fertilization is a challenge for a sustainable agriculture. In this concern, zeolites, a natural aluminosilicate, have been studied as soil amendments to improve the fertility of soil, due to its properties of porosity, high surface area and cation exchange capacity. The inclusion of zeolites to fertilizers seems to increase the nutrient retention, allowing its slowly release along the time, which will help to reduce leaching of nutrients from the soil, contributing for a reduction of fertilizer use. The objective of this study was to investigate the effects of application of a compound N:P(P_2O_5):K(K_2O) (15:15:15) fertilizer and the combination of zeolites with fertilizer on physiological and biochemical responses, yield and the concentration of glomalin-related soil proteins (GRSP), of commercial olive trees (*Olea europaea* cv. Cobrançosa), grown under rainfed conditions in Trás-os-Montes region, Northeast of Portugal, during the year of 2018. Results showed higher net photosynthetic rate, stomatal conductance and transpiration rate in zeolites + fertilizer plants in the majority of summer days, in comparison with fertilizer and control. A protective effect of zeolites + fertilizer was demonstrated by an increase of total antioxidant capacity in leaves, compared with fertilizer treatment. In addition, leaves from plants treated with zeolites + fertilizer showed lower concentration of starch and soluble sugars than fertilizer and control treatments, which may indicate a higher investment of photoassimilates in plant growth and production, once this treatment registered higher crop yield. On the other hand, the concentration of GRSP, a glycoprotein produced by arbuscular mycorrhizal fungi, was significantly higher in zeolites + fertilizer at two different depths, indicating higher mycorrhizal activity.

These results give evidence that zeolites are able to increase the fertilizer efficiency and plant nutrient use. Therefore, the incorporation of zeolites combined with fertilizer, seems to be a suitable strategy to improve the physiological performance and yield of olive trees, as well as the microbiological properties of soil.

Keywords: Zeolites; Fertilizer efficiency; Olea europaea; Soil fertility.

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0088

TOTAL LEAF AREA AND MAIN ROOT LENGTH ARE CORRELATED WITH NUTRIENT ACCUMULATION AND GROWTH IN JUVENILE SPRING WHEAT

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The aim was to explore candidate traits for spring wheat breeding to improve nutrient accumulation and rapid growth in early season at high latitudes. A greenhouse experiment was conducted with nine contrasting spring wheat genotypes grown for 20 days and assessed in an automated phenotyping system. Functional growth analysis was performed to identify the mechanistic links between growth traits, and we found leaf area productivity and nitrogen (N) productivity to be good predictors of variation in relative growth rate (RGR). Potassium (K), sulfur (S), calcium (Ca) and magnesium (Mg) were accumulated proportional to N, but not phosphorus (P) and micronutrients. Suboptimal N-to-P and N-to-Mg ratios were observed in some genotypes. Our results suggest total leaf area after 20 days of growth to be an appropriate candidate trait in spring wheat breeding, because it was linearly related with the pools of six macronutrients and RGR, and it can be easily measured in large breeding populations. Main root length was important for the uptake of P and Mg. Thus, our study suggests that attention should be paid to roots, because prioritizing leaf growth over root growth put some genotypes (e.g., 'Happy') in the risk of suboptimal P content.

Keywords: growth analysis, high latitude, nutrients, phenotyping, wheat breeding

0118

FERTILIZATION WITH ORGANIC RESIDUES: EFFECT ON SOIL ENZYMES AND NITROGEN MINERALIZATION.

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Soil enzymes are often used as an index of soil fertility since they are very sensitive and respond to changes in soil management faster than other soil variables. The fertilization with organic residues from agri-food industries or farms are used as nitrogen (N) source after their mineralization. During soil N mineralization, soil N-degrading enzymes are involved in different stages of organic N degradation. The organics residues added to the soil could have a response in enzymatic activities involved in sulfur, carbon (C) and N cycle (arylsulfatase (ARYL), ß-galactosidasae (GAL), urease (URE)). The purpose of the study was to analyze the mineral N forms (ammonium and nitrate) and enzymes (ARYL, GAL, and URE), in a soil fertilized with liquid anaerobic digestate (LIQ; C/N:4), and substrate spent mushroom (SMS; C/N: 45), in comparison to mineral N fertilizer (MIN) and a control soil (CO, without N source addition). Samples were taken after residues application (0 days) and at the end of the incubation (14 days, aerobic conditions, 25ºC, 60% soil humidity). The mineralization was different for each organic residue after 14-days incubation. The mineral content in SMS showed lower values than CO which indicated the predominance of the N immobilization process. Otherwise, LIQ treatment increased significantly the nitrate content with respect to CO, although was lower than that obtained after MIN application, in relation to its organic-N content (80 vs. 114 mg mineral-N kg^{-1} dry soil, LIQ and MIN respectively). The enzymatic activities response was not affected by incubation time. The organic residues had different effect on each enzyme. The ARYL activity showed higher value in SMS treatment but the

differences were not statistically significant. However, URE activity showed a significant higher response in SMS, (14-16 vs. 2-4 nmol PNP min^{-1} g^{-1} dry soil respectively). The GAL activity increased significantly in SMS and LIQ, around 1.7 and 4.2 times greater respectively, respect to CO and MIN treatments (66, 27, and 15-16 nmol PNP min^{-1} g^{-1} dry soil respectively). In the assay conditions, the organic residues enhanced soil enzymatic activities compared to MIN treatment. The LIQ treatment behaved as a relevant N source for crop.

Keywords: aerobic incubation, N mineralization, urease, arylsulfatase, galactosidase.

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0132

WHEAT PRODUCTION UNDER A CHANGING CLIMATE: STRATEGIES TO MITIGATE WATER STRESS WITH OPTIMAL NITROGEN FERTILIZER USE

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Wheat is the most cultivated crop in Europe and it demands high levels of nitrogen (N) for high productivity and baking quality. Excessive N fertilization can not only result in N losses, but also boost wheat vegetative growth and water consumption, with not necessarily a proportional increase in grain yield. Despite improvements in policies and management, the N use efficiency (NUE) of wheat production remains one of the lowest among major crops. The fate and plant uptake of N is highly influenced by water availability, which is expected to decrease in the future in certain European regions. Drought substantially affects wheat yield and, for this reason, the association between wheat varieties with stable yield potential and adapted management practices to ensure production in water-limited conditions are indispensable. The aim of this study is to quantify the effect of management practices on wheat grain and protein yields, and on NUE (defined as the grain yield-N supply ratio).

Field experiments are being conducted in the Swiss midlands under low (0 kg N ha^{-1}) and high (180 kg N ha^{-1}) N supply with four winter wheat (*Triticum aestivum* L.) genotypes (Apache, Allez-y, Cellule, and CH-Nara) that were sown after three preceding crops (oilseed rape, barley and winter peas). The amount of rainfall during grain filling is manipulated with rain-out shelters that intercept approximately 40% of the incoming rain.

A preliminary analysis of the results of the season 2018-19 have shown that independently of the preceding crop and the water and N availabilities, the genotype Cellule had the highest grain yields. The grain yield of Cellule was on average 18% higher than Allez-y, the second genotype in the ranking. The water limitation imposed during grain filling did not significantly affect grain yield. This is explained by the high precipitation registered during the spring and summer of 2019; the 40% reduction in precipitation did not result in water limiting conditions. Furthermore, the increase in grain yield that resulted from a higher N supply was modified by preceding crop, with the highest increase being after winter peas and the lowest, after oilseed rape. Results of two growing seasons will be presented at the congress, after the harvest of the second growing season during the summer of 2020.

Keywords: Triticum aestivum; climate risk; plant nutrition; adaptation

0145

PHYSIOLOGICAL AND BIOCHEMICAL RESPONSES OF OLIVE TREE TO N REGIMES UNDER RAINFED CONDITIONS

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Nitrogen (N) is a major essential plant nutrient and the most applied in fertilization programs of horticultural crops such as olive trees. But, on a great number of orchards, large quantities of nitrogenous fertilizers are applied for sustained productivity over time. This practice results in N over-fertilization, where the fraction of N not directly absorbed by plants becomes increasingly vulnerable to a variety of loss mechanisms, including leaching and denitrification, as well significant costs for the farmers. Thus, becomes important to implement a good fertilization recommendation. The study was carried out in north-eastern Portugal in a rainfed olive (cv. 'Cobrançosa') orchard with three N fertilizer rates: 0N, 40N, and 120N (kg N ha^{-1}). In general, the application of N benefits the plant performance along the three years of the experiment, with a significant positive impact in crop yield. Plants with N40 and N120 showed higher net photosynthesis (A), stomatal conductance, intrinsic water use efficiency, and maximum quantum efficiency of PSII. However, when the summer stress was more intense (August 2018), N40 presented superior A than 120N plants. In general, N0 leaves had lower water content at saturation, but higher RWC during the peaks of summer stress. In addition, N0 plants showed higher concentration of phenolic compounds (2018 and 2019) and flavonoids (2017), strategies to counteract summer stress effects. Moreover, the increase of ascorbate in N0 and N40 trees suggest a rearrange of metabolic pathways to maintain a better balance between repair damage, activation of plant defences, and stimulation of plant growth processes.

In summary, nitrogen application benefits the plant's physiology and biochemistry of olive trees. However, N40 seems to be the better dose under rainfed conditions. These plants showed a good physiological and biochemical performance, and maintain crop yield very close to N120 level. The lower quantity of N applied could be easily absorbed by the trees, reducing the losses and, consequently, the negative impacts on ecosystems, as well as the costs for the farmers.

Keywords: olive tree, nitrogen, gas exchange, leaf biochemistry

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0154

EFFECT OF IRRIGATION FREQUENCY ON WATER USE, YIELD AND FRUIT QUALITY OF STRAWBERRIES

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[1] Agroscope, 1964 Conthey.

Climate change represents a challenge and will impact both the demand and the availability of water for agriculture. Better irrigation systems are needed to improve water use efficiency. During 4 years, an automatic irrigation system of Watermark® was tested in strawberries under plastic tunnels at Agroscope in Switzerland. This automatic irrigation system was compared to the traditional irrigation system using tensiometers.

Fresh plants of strawberries (cv. Clery) were planted (4 plants per m^2) every year beginning of August on a sandy loam. Two irrigation systems were compared, both with a threshold for drip-irrigation at a soil water potential (Ψsoil) of –0.02 MPa. This value was measured at 0.25 m soil depth, an intensively rooted zone. For the automatic irrigation system (based on Watermark® sensors and managed by WEM (Watermark® Electronic Module)) soil moisture was measured four times a day and irrigation was applied nearly every day (0.75 l/m^2 per application). With the traditional irrigation system soil moisture was measured two times a week and irrigation was applied every third to fifth day (3.0 to 5.0 l/m^2 per application according to the season). Fertilizer was applied by fertigation and applied once a week for both irrigation systems.

Automatic irrigation resulted in an average yield increase of about 10% over the four trial years, with no significant impact on fruit size and fruit quality (firmness, sugar and acidity content). Automatic irrigation managed by WEM significantly reduced water applications by 35 to 55% depending on the year compared to traditional manual irrigation.

Ψsoil with the traditional manual irrigation system oscillated between 0 and –0.025 MPa at 0.25 m as well as at 0.35 m soil depth. This suggests that water percolation to lower soil depth occurred. With automatic irrigation Ψsoil at a soil depth of 0.25 m also fluctuated between 0 and –0.02 MPa. However, at 0.35 m Ψsoil continuously decreased from –0.005 to –0.090 MPa indicating that there was no percolation and all the applied water was used by the plants.

In conclusion, the automatic irrigation system with frequent drip-irrigation significantly increased the water use efficiency and allowed a reduction in the use of irrigation water of around 45 % as well as a slight in-

crease of the yield of about 10 % without any significant differences in fruits quality parameters compared to traditional drip-irrigation system.

Keywords: fruits, irrigation frequency, soil moisture, strawberries, water use

0155

EFFECTS OF REGULATED DEFICIT IRRIGATION ON PRODUCTIVITY AND FRUIT QUALITY OF SUBSURFACE DRIP-IRRIGATED APPLE TREES

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[1] Agroscope, 1964 Conthey.

Climate change represents a challenge and will impact both the demand and the availability of water for agriculture. In this context, increasing water-use efficiency is a vital issue for socio-economic development in many regions. More efficient water use is possible with improvements in plant breeding and irrigation systems such as subsurface drip irrigation. This system delivers water directly to the root zone and minimizes soil surface evaporation, runoff and deep percolation. Another promising approach is irrigation management, such as the regulated deficit irrigation (RDI), which aims at reducing irrigation during specific phenological stages without risking yield and fruit quality loss.

The aim of this work was to assess the effects of regulated deficit irrigation (RDI) during fruit cell growing period in apple orchards on fruit yield, fruit weight and fruit quality parameters under high frequency subsurface drip irrigation in a region with a continental climate in Switzerland.

Four irrigation treatments were applied during two years to apple trees cv. 'Gala': T1, no irrigation; T2, optimal irrigation except during summer; T3, optimal irrigation except during summer when RDI (from the beginning of July to the beginning of August, threshold for irrigation at a soil water potential (Ψsoil) of –0.15 MPa was used; T4, optimal irrigation (threshold Ψsoil at –0.03 MPa, measured at a soil depth of 0.3 m),. The soil water status and plant water status were followed over two growing seasons. during fruit cell growing period.

The irrigation treatments had no significant impact on fruit yield. However, compared to optimal irrigation (T4) and RDI (T3), the absence of irrigation in summer (T1, T2) induced low Ψsoil (< –0.15 MPa), decreased fruit size and slightly increased the soluble solid, vitamin C and polyphenol contents in the fruits. The RDI (T3) during summer allowed a water-use reduction of 47% without loss in fruit yield, fruit weight and fruit quality compared to the optimal irrigation (T4).

In conclusion, the RDI treatment saved 47% water compared to optimal subsurface drip-irrigation without negative impacts on yield and fruit quality.

Keywords: irrigation scheduling, Malus domestica, regulated deficit irrigation, phenolics, vitamin C, water stress

0172

BIOMASS PRODUCTION AND N UPTAKE OF CATCH CROPS AFFECTING SOIL N_{MIN} OVER WINTER

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Agricultural crop production is increasingly focusing on topics such as climate protection and protection of groundwater from nitrate contamination. Catch crops potentially reduce nitrate leaching to lower soil layers. Different types of catch crops can absorb different amounts of N, which can subsequently mineralize and influence the N supply, root growth and yield formation of following crops. Currently, such effects are difficult to evaluate. Our study aimed to quantify and optimize the positive effects of catch crops in agricultural crop production.

Field experiments were carried out in 2018/19 and 2019/20 with 4 catch crops (fodder radish, bristle oat, spring vetch, winter rye) in comparison with a fallow.

Biomass production and N-uptake from soil was different among catch crops. They were able to prevent nitrate from leaching, but effects differed according to the catch crop species and the year. For instance, in 2018/19 winter rye had an N uptake of about 120 kg/ha and maintained a low soil N_{min} content of 25-60 kg N/ha over winter. In contrast, N_{min} increased soon after freezing of non-hardy catch crops such as vetch and oat. Under fallow, N_{min} decreased from 272 kg N/ha in November to 159 kg N/ha in March, indicating leaching of more than 100 kg N/ha. The data of 2019/20 supported the findings of the first year.

Keywords: Crop management, Environmental impact, Crop-environment interactions, Soil, Fertilization, Legumes.

0176

COVER CROPS AND MULCH IMPACTS ON SOIL MOISTURE AND GRAIN MAIZE IRRIGATION MANAGEMENT

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Whether for regulatory (EU/national), environmental or agronomic reasons, cover crops are widely implemented by European farmers. Technical improvements now allow direct seeding mulch-based cropping systems. Many references have been published concerning the soil nitrogen flows, but few information is available about soil moisture impacts. Compared to bare ground, cover crops extract water from the soil (crop transpiration) but reduce soil evaporation when the canopy is alive. Then when destroyed, the mulch left on the ground is supposed to reduce soil evaporation. A three-year experiment was conducted by ARVALIS in order to measure the benefits of this technique on soil moisture after sowing grain maize. This trial also aimed to determine if it is possible to reduce the maize crop water needs thanks to a lower ground evaporation, and thus, to limit the irrigation rates.

The treatments were :

- A reference (T1) with a small cover crop destroyed during winter. The ground is bare during a long period before sowing maize ;
- A treatment without cover crop where a wheat straw layer is brought before sowing maize (T2). The goal here consists in reducing soil evaporation with a passive cover but without plant transpiration during intercropping;
- A treatment where a selected cover crop is grown and mechanically crushed just before sowing corn (T3) ;
- A fourth treatment has been added after the first-year findings, with a cover crop mechanically destroyed 3 weeks before sowing the cash crop (T4). It was observed that it was difficult to implement the T3 plot with a high developed green cover.

All those terms have been conducted under two different irrigation programs:

- A rain-fed system (not irrigated) ;
- An irrigated one, but limited to a 125 mm water irrigation total rate. This quota represents about 2/3 of the normal water irrigation total rate.

The experimental system was carried out using a 2 factors split-splot model (cover crop and irrigation, irrigation is positioned as a sub-block) with 3 replications.

Soil water flows were observed with tensiometric measurements and confirmed that a living cover crop catches soil water at the beginning of the maize crop cycle, whereas a wheat straw layer allows more moisture to the cash crop roots. Those differences tended to disappear quickly when the corn crop reached 10 leaves. Nevertheless, the experimental set up did not highlight potential consequences on irrigation management and water savings. However, the 10 days-lag between the main stages persisted until the harvest, this explaining a most important grain moisture level for the plots conducted with a cover crop (grain moisture +1% to +4% depending in the delay between the cover crop destruction and maize sowing). Concerning grain yields, results obtained with the T3 plot were systematically penalized (-13%), whereas those measured with the T4 one (cover crop destroyed earlier) were 8% better than the reference.

Keywords: mulch, soil water content, grain maize, irrigation, water savings, cover crop

0179

ENHANCING P USE EFFICIENCY IN THE WHEAT/OLEAGINOUS-LEGUMINOUS CROP ROTATION IN SPANISH VERTISOLS: FREQUENCY OF APPLICATION AND RATE

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Calcareous soils accounts for more than two thirds of total agricultural land in the Mediterranean basin. Restricted availability of some nutrients is expectable since their content in of calcite (calcium carbonate, $CaCO_3$) lead to basic pH (7.5-8.5). In many soils in the Mediterranean region, mineralogy is dominated by carbonates and iron oxides that act as sorbents for phosphorus (P) or contribute to the precipitation of insoluble phosphates, thus reducing the availability of this nutrient. Because P is a non-renewable resource and a fundamental nutrient for agriculture, fertilisation

strategies should be as sustainable as possible. The main objective of this study was to compare different P fertilization strategies (P rates and frequency of application) in the long-term, assessing their efficiency in maintaining and enhancing available P content in soil and their effects on crop yield. We established a randomised block design experiment within a long-term field experiment conducted at two locations with calcareous soils (ENC and PRA) in the province of Córdoba (southern Spain), with wheat-oleaginous/leguminous crop rotations. Each experimental unit was a 9 m × 3 m size plot and four replications per treatment were used in each field. The experimental area was ploughed to 20-25 cm every year and fertilized with nitrogen (N) following local practices. The five different P strategies were (T1) non-P fertilization, (T2) addition of 88 kg P ha^{-1} every four years, (T3) addition of 22, (T4) 44 and (T5) 66 kg P ha^{-1}, every two years. Although soil properties in both locations were similar, a higher former available P content was found in PRA (Olsen P = 27 mg kg^{-1}) than in ENC (Olsen P = 24 mg kg^{-1}). The application of 44 and 66 kg P ha^{-1} every two years were the strategies (T4 and T5) that produced the highest yields in ENC and the recommended strategies to maintain former available P content in soil in ENC and PRA after 4 and 8 years since the beginning of the field experiments. Reducing the frequency of P fertilization at the same time as increasing the P rate (T5) was not useful to enhance yields (especially in ENC) or available soil P content (ENC and PRA) in comparison with the other strategies (T3, T4 and T5). The most efficient P fertilization strategies based on yields and soil fertility include increasing the frequency of P fertilization at the same time as reducing the P rate applied to these Mediterranean soils; however, it depends on the initial available P content in soil and farmers' budget.

Keywords: calcareous soils; soil phosphorus; phosphorus use efficiency; vertisol

0183

USE OF FERTILIZERS AND HYBRIDS IN REDUCING THE ENVIRNOMENTAL COST OF MAIZE CROP

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Climate change is an important issue for the 21rst century and agriculture contributes to the release of 10% of greenhouse gas emissions and 95% of ammonia emissions. One of the most important factors that contribute to greenhouse gas emissions is the use of inputs and especially N fertilizers. Also excessive use of fertilizers can lead to pollution of surface and ground water. Moreover, there is significant cost due to the pollution from nitrogen fertilizers that are used in modern agriculture and can reach up to 320 billion euros. Therefore, it is important to reduce the use of fertilizers and at the same time to use the inputs more sustainable. The objective of the present study was to use of precision agriculture and smart farming in order to reduce the negative impacts of the excessive fertilization and to reduce the greenhouse gas emission from agriculture. The experiment was conducted at the American Farm School during the growing season 2018-2019. Two different maize hybrids were used and five fertilization treatments control, green manure, cattle manure, slow release fertilizer and conventional fertilizer. It was found that fertilization influenced the morphological, agronomic and physiological characteristics of maize compared with the control and green manure that showed the lowest values. Also, there was interaction between the two hybrids that were tested. Leaf area index and plant height were lower compared with the fertilization treatments. In addition, chlorophyll content and assimilation rate was also lower at the control treatments. Therefore, it is necessary to maintain the productivity of the crop and also affects the environmental cost and footprint in the production of animal feeds by applying the appropriate amounts of fertilizers and also by using the appropriate hybrid.

Keywords: precision agriculture, smart farming, climate change, environmental footprint

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0186

NITRATE LEACHING WITH OR WITHOUT NITRIFICATION INHIBITOR UNDER IRRIGATED CROPPING SYSTEMS WITH OR WITHOUT INTERCROPPING

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Nitrate leaching and water eutrophication are major concerns for the EU. It has been shown under irrigated conditions, that the use of cover crops and intercrops have potential to reduce nitrogen (N) leaching and increase the N use efficiency (NUE) of the cropping system. However, these practices add complexity to the management and even the yield can be compromised without proper management. The use of nitrification inhibitors (NI), as DMPSA, could be a useful tool to reduce nitrate leaching without reducing crop yield or quality. The NI could complement, or even replace, the practice of growing cover crops or intercrops.

The objective was to evaluate the potential of the DMPSA to reduce nitrate leaching in a maize/wheat rotation. Moreover, the effect of intercropping was studied by comparing sole cropped maize, with a legume - maize intercrop, were the legume (vetch, *Vicia sativa* L.) was sown between maize rows. The effect of the treatments on the NUE of the complete crop rotation was analysed under field conditions.

The experiment was carried out under field conditions with a total of 22 plots (8 x 16 m^2). There were four treatments (4 times replicated), including (1) ammonium sulphate nitrate (ASN, 26%) and (2) ASN plus DMPSA nitrification inhibitor, applied in two side dresses, and multiplied by the presence or not of vetch intercrop. In the intercrop treatment the vetch was sown when the maize had 4-6 leaves and was terminated before the wheat sowing in February. The control treatments consisted of unfertilized plots with or without vetch intercrop.

Based on the total mineralization rates, no effect was determined using DMPSA on the microbiological activity. The application of DMPSA nitrification inhibitor coupled with the conventional ammonium sulphate nitrate (ASN) reduced nitrate leaching during the maize growing period. However, the delay of the fertilization with DMPSA affected the N coupling between the crop demand and the mineral nitrogen availability, delaying the N availability for the maize crop. Then, the fertilization with DMPSA seems to be more appropriate at earlier maize vegetation stages. The intercrop reduced the risk of nitrate leaching under the fallow period, retaining the residual N and recirculating it for the next wheat. The DMPSA showed limited residual effect in the soil (based on the soil N available at the beginning of wheat season), but slightly higher N concentrations were found in the topsoil (0-30 cm) after the wheat, suggesting that the N available during the wheat crop period could have been higher as well.

Keywords: Fertilization, Environmental impact, Sustainability, Crop management

0194

USE OF COMPOSTED AGRICULTURAL AND AGRO-INDUSTRIAL RESIDUES AS PHOSPHORUS FERTILIZERS

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Phosphorus (P) is a non-renewable, limited and strategic natural resource, inefficiently used in agriculture. Organic amendments using agricultural and agro-industrial residues can be an alternative P source in agriculture. In addition, these resources, which imply recycling, may provide additional benefits to soil and crop quality by the improvement of the uptake of other critical nutrients. Composting produces a stabilized organic matter which allows longer persistence of the organic carbon and increased availability of nutrient from these materials in the soil. This work aimed at studying the effects of different organic sources of P relative to mineral P fertilizer on the P use efficiency by wheat. A completely randomized experiment in field condition was performed in south Spain. Treatments involved: composted olive oil mill, vermicomposted from horse manure, vermicompost from vegetable waste from crops production, mineral fertilizer and control without fertilizer. All the P sources were applied at 30 kg P ha^{-1}. Extra mineral NK was applied if necessary, for equal NPK supply to crops.

The results showed that the different organic materials were efficient P sources for crop Dry matter in shoots and grain yield was significantly higher with composted olive oil mill than with mineral P (16%, and 24 %, respectively) P uptake at the beginning of the growing season was higher with mineral fertilization. However,

at harvest, P uptake was the highest with the composted olive oil mill. Vermicompost from crop residues was more efficient in increasing Olsen P in soil than mineral fertilizer during the growing season. Olsen P index decreased throughout the crop cycle, and no significant differences were found between treatments at harvest. It can be concluded that the different organic P sources tested in this study can be used as an alternative P sources for a more sustainable agriculture involving a decreased P outflow in agricultural systems thus contributing to reduce the use of mineral P.

Keywords: phosphorous, wheat, organic amendment

0196

SCREENING FOR PHOSPHORUS EFFICIENCY IN POTATO GENETIC RESOURCES

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Potato (*Solanum tuberosum* L.) is one of the most important food crops worldwide. Due to the relatively small and shallow root system, the plants can only explore a small soil volume, making potato prone to drought stress and nutrient deficiency. The phosphorus (P) supply is of particular importance, because P is rather immobile in the soil and needs to be acquired by active root growth. In order to unravel the natural variation which may exist in potato germplasm, the P uptake and the root architecture of 179 cultivated and four wild potato accessions of the Gross Luesewitz Potato Collections were studied in pot and rhizotron experiments. The genebank set was compared to 17 modern starch potato cultivars. In the pot experiments, *in vitro* plantlets were cultivated for five weeks in a soil:sand mixture treated with a P source of high (KH_2PO_4) or low plant availability (Ca-Phytate). On average, total plant biomass was reduced under low P conditions, with the extent being genotype dependent. The total P uptake correlated strongly with the total plant biomass ($r= 0.954$, $p \leq 0.001$) and was, on average, lower under low P conditions.

In the rhizotron experiments, *in vitro* plantlets were cultivated for three weeks under high P conditions (KH_2PO_4) or without any additional P. The shoot and root biomass were determined and root architecture traits were studied on root scans using the software GiaRoots. We found in general smaller root systems under low P conditions and differences in the root-system structure between high and low P conditions in most genotypes.

In conclusion, we observed clear variation among the potato genotypes in terms of shoot and root biomass development and P uptake at an early stage of plant growth, which is important for plant breeding in order to improve nutrient efficiency in potato. Currently the results are validated by additional pot and rhizotron experiments using sand-hydroculture. Interesting genotypes will be studied in more detail in pot and field trials.

Keywords: Solanum tuberosum, nutrient efficiency, root-system, rhizotron

0212

CHANGE OF PHOSPHORUS EXTRACTABILITY DURING HUMANURE COMPOSTING AS AFFECTED BY BIOCHAR

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Phosphorus (P) is a critical macronutrient required for the optimum growth of crops. Phosphate rock deposits, from which P fertilizers are produced, is predicted to last for the next 50 to 300 years. Hence there is a rising need for alternative sources of P for the sustenance of crop production. Human excreta is an abundant but ignored source of nutrients and could be an alternative source of P through the concept of ecological sanitation and thermophilic composting. To examine the suitability of compost from human excreta (humanure) and other organic waste materials as a fertilizer, two experiments were performed; and the change of P extractability in the course of composting humanure was studied by the Hedley fractionation procedure. Biochar was added to one treatment (3-4% of total compost mass) to investigate its impact on the composting process and P availability. An increase in the concentration of total P was observed from the initial to the mature stage of the compost for all treatments. The highest increase was observed in the treatment with biochar (65.22%) and a lesser increase in the treatment without biochar (24.06%). However, this increase was only significant in Experiment 1. For the initial compost, resin extractable P was with 40.37 ± 15.63% to 48.37 ± 12.67% the largest fraction of total Hedley P (P_{tot}), while the mature compost contained 32.31 ± 0.73% to 33.39 ± 3.31% of acid extractable P in Experiment 1 and 35.85 ± 1.78% to 35.83 ± 1.89% in Experiment 2. This suggests that the composting process transformed water-soluble P (Resin P) at the beginning of the composting to moderately recalcitrant fraction of P (Acid P) at the end of the composting. The significant effect of biochar was only seen in the Residual P fraction in Experiment 1 and Bicarbonate P fraction in Experiment 2 while it was negligible in the other five fractions of P_{tot} in both experiments. Due to mass loss in the course of composting, the mature compost comprised increased concentrations of total P. The transformation of Resin P to Acid P suggests that lesser amounts of easily extractable P may be directly available for plants when applying the compost as a fertilizer. The addition of 3-4% biochar to the composting substrates showed a pronounced and significant effect on the increase of P_{tot} contents, but no significant effect on P extractability and availability to plants.

Keywords: Phosphorus, Humanure, Biochar, Compost, Ecological sanitation.

0214

ANAEROBIC CODIGESTION OF SEWAGE SLUDGE AND WINE VINASSE TO OBTAIN AN ORGANIC FERTILISER

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A sustainable alternative to conventional fertilisers to enrich plantations is sewage sludge (SS). For its correct land application, this sewage sludge must be treated to achieve stabilization and satisfy legal requirements. Regarding the pathogenic microorganisms, American Environmental Protection Agency (US EPA) for the biosolids Class A quality report a density lower than 1000 fecal coliforms/g total solids. On the other hand, the current European legislation (Regulation (EU) 2019/1009 of the European Parliament and of the council of 5 June 2019) inform that *Escherichia coli* (*E. coli*) density must not exceed the limits of 1000 colony forming units (CFU)/g total solids in an organic fertiliser.

On the other hand, Sherry brandy is a spirit produced in southern Spain, specifically in the area of Jerez-Cadiz. This brandy is produced by distilling wine. On the bottom of the distillery unit is obtained a high amount of wastewater called wine vinasse (WV). Due to the characteristics of WV (acid pH and high biochemical oxygen demand (BOD) and chemical oxygen demand (COD)), this wastewater can cause serious environmental problems if it is discharged into the environment without the proper treatment. The wine vinasse treatment supposes a high cost for the wineries. Therefore, anaerobic codigestion (AcoD) with sewage sludge is a good option for its purification.

With the aim of obtaining a digestate from anaerobic codigestion of sewage sludge and wine vinasse, which can be used as an organic fertiliser, two AcoD process have been studied. The two process were: a) AcoD in a single stage under mesophilic conditions at HRT of 5 days (M5) and b) Temperature Phased Anaerobic coDigestion (TPAcoD) which consisted in thermophilic (HRT 1 day) and mesophilic (HRT 4 days) digesters in series (T1/M4). *E. coli* and total coliforms have been studied both in the effluent of M5 digester and in the effluent of T1/M4 system. The removal percentage of total coliforms were 93 and 91%, with a density of 1014 and 1263 total coliforms/g total solids for T1/M4 system and M5 digester respectively. Regarding *E. coli*, the density was 271 and 794 CFU/g total solids to M5 digester and T1/M4 system, respectively. Therefore, both digestates were in accordance with the specifications imposed by the European legislation and by US EPA for the biosolids Class A quality.

Keywords: Fertilization, Environmental impact, Low-imput agriculture

0237

EFFECT OF CROP INTENSIFICATION ON WATER AND NITROGEN USE EFFICIENCY UNDER IRRIGATED CONDITIONS

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Intensification of irrigated agriculture is a need to provide enough food to a growing world population. However, the agrosystems must be able to decrease their environmental impact on air, soil and water resources through an efficient use of water and nitrogen. Thus, four rotations with different degree of crop intensification were compared during two seasons (2018 and 2019) in terms of productivity, water use efficiency, and nitrogen use efficiency in a drainage lysimetric installation and for two soils with different soil water holding capacity (Deep: 125-cm depth, and Shallow: 50-cm depth). The treatments were: a long season maize in monoculture (LSM), a long season maize with a leguminous cover

crop (common vetch or peas) during the winter period (CC+LSM), and a double cropping of a short-season maize preceded with winter barley (B+SSM) or with peas (P+SSM). A completely randomized experiment with three replicates (lysimeters) was used for each soil type. Nitrogen rates and irrigation water were managed according to expected crop necessities. Total aerial biomass (TAB), grain yield (GY), water use efficiency (kg TAB or GY mm^{-1} evapotranspirated water), nitrogen use efficiency (kg N uptake in TAB kg^{-1} N applied), and N losses by drainage (kg N leached ha^{-1}) were evaluated for each rotation. The soil type did not influence the WUE of the different treatments. In both seasons, the B+SSM presented higher WUE in terms of TAB (between 17 to 60%) and in terms of GY (between 17 to 38%) than the other treatments. The Shallow soil presented much lower NUE than the Deep soil, although the difference was smaller for the double cropping systems. Depending on the rotation treatment, N leaching in the Shallow soil was 2 to 8.5 times higher than in the Deep soil. The P+SSM presented higher NUE compared to the other treatments irrespective of season and soil type. The double cropping B+SSM had lower N leached than the other treatments but the double cropping P+SSM presented similar or higher N leached than the LSM rotations. Intensification of crops in the rotations can improve WUE and NUE but the N inputs (in amounts and time) associated to N fixation by leguminous crops included in the rotation has to be properly considered to avoid unwanted environmental impacts.

Keywords: double cropping, cover crops, nitrogen use efficiency, water use efficiency

0238

OLIVE MILL WASTEWATER CONTAMINATED SOIL BIORESTORING INTO FERTILE SOIL BY LANDFARMING AND PHYTORREMEDIATION

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Olive mill wastewater (OMW) is a polluting liquid residue resulting from the olive oil extraction. The most widely used method for OMW management has been its accumulation in large evaporation ponds. There the water evaporates and the sediment/sludge concentrates increasing antimicrobial and phytotoxic compounds such as polyphenols. As a consequence, they cause serious environmental impact on the soils and groundwater nearby the evaporation ponds. It is necessary to find sustainable and eco-friendly techniques to in situ restoring the polluted soil and sludge in evaporation ponds. In this work, we propose applying a cascade of treatments to restore these matrices, including landfarming followed by phytoremediation techniques. Additionally, we analyze the effect of bioaugmentation with a mix of specialized fungal species in the efficacy of the solution proposed. The aim is to recover the space occupied by the polluting sludge in the evaporation ponds as a safe and healthy substrate that could be later covered with plants.

For this cascade, the OMW sediment accumulated in an evaporation pond (2400 m^2) were added with a mix of organic residues available near the pond such as spent-mushroom compost (SM), rabbit manure (RM), and chicken manure (CM) at the following w/w ratios 0.5:0.12:0.33:0.05 (OMW:SM:RM:CM). This area was landfarmed during 266 days (mechanical plough and irrigation every 15 days) and six plots (2 m^2 were used to monitor the effect associated to the use or not of the organic amendment. Additionally, each plot was divided into two sub-plot in order to inoculate one of them by spreading on the surface with a mix of two fungi Asperigllus ochraceus H2 and Scedosporium apiospermum H16, previously isolated and characterized by its potential in OMW bioremediation. After landfarming, 16 different species were applied to the area (6g/m^2) to promote phytoremediation during 266 days. Samples were taken every two months since the beginning of the experiment until the ninth month in which the electrical conductivity, phytotoxicity, the polyphenols and NPK content were analyzed. The cascade of landfarming following of phytoremediation treatments reduced the OMW toxicity since a great decrease of the polyphenolic content and phytotoxicity was observed. The biostimulation with organic matter favored the electrical conductivity decrease and the NPK macronutrients increase promoting OMW soil restoration and a fertile soil generation. The inoculation improved the efficacy of the techniques in OMW biodecontamination. Landfarming following of phytoremediation treatments have demonstrated to be a sustainable cascade of techniques for OMW sediment bioremediating, resulting in a restored soil with optimal characteristics for vegetation growing.

This research was financially supported by the project LIFE+REGROW (LIFE16 ENV/ES/000331) “Reclamation of olive oil waste abandoned lagoons using biorecovering strategies in a circular economy”.

Keywords: Landfarming, phytoremediation, biostimulation, fungal consortium, revalue.

0242

NEW BIOINDICATORS TO EVALUATE COMPOST QUALITY: BIODIVERSITY, STABILITY AND MATURATION

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Regarding the management of organic waste, composting is currently positioned as one of the closest alternatives to the concept of sustainable economy, which was revealed in the comprehensive package of European circular economy published in December 2015. During composting, microorganisms carry out the biological decomposition of organic matter, resulting in a stable and humidified product called compost. Throughout the process, microbial diversity varies according to the succession of different thermal phases. This phenomenon is directly influenced by a wide variety of physicochemical factors, such as humidity, pH, electrical conductivity, nutrient availability, or oxygen consumption. Furthermore, the raw materials and conditioners used for the initial constitution of the composting piles also significantly influence the evolution of biodiversity throughout the process. Currently, the study of the microbiome associated with the composting process allows a greater understanding of the microbial diversity in composting piles than traditional techniques. As a result of this, there are numerous works in which microbial diversity is correlated with the degradation of organic matter and different physical-chemical parameters. However, there are few studies that show the possible relationship between microbial biodiversity with agronomic quality of compost. The main objective of this study was to determine the influence of raw materials on the stability, maturity and biodiversity of composting on an industrial scale, as well as the relationship between all these aspects. In this work, 45 compost samples from 15 companies dedicated to composting Vegetable Waste (VW), Urban Solid Waste (USW), Sewage Sludge (SS), Agrifoodwaste (AW) and “Alpeorujo” (ALP) were analyzed. The studies carried out were based on the characterization of toxicity, respirometric parameters, metagenomic profiles and biodiversity indices from the final products obtained in each case. The results showed the influence of the raw materials used in the different processes. Despite this, it was possible to verify the correlation between certain parameters related to maturity and stability, such as oxygen consumption (AT4) or germination index, with Chao1 or Shannon biodiversity indices.

Keywords: Sustainability, Fertilization, Organic farming

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0245

INDUSTRIAL COMPOSTING OF AGRI-FOOD WASTE: THE EFFECT OF RAW MATERIALS COMPOSITION ON THE QUALITY OF COMPOST

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The generation of agri-food by-products or waste at different stages of production processes currently contributes to a global environmental impact. Around 90 million tons of food waste is produced annually in the European Union, most (72%) coming from household and food processing sectors. Agri-food wastes are residues of a high organic load produced during raw materials processing to foodstuff. Inadequate disposal disturbs the ecosystem, since its high biodegradability, moisture, and microbial load suffer a rapid and uncontrolled degradation that directly leads to environmental pollution, including greenhouse gas emissions. Composting is one of the main treatments recommended for agri-food waste, because of its economic and environmental benefits. This process allows the biological stabilization of the material under aerobic conditions and leads to a product, named compost, which has properties as fertilizer. The main objective of this work was to evaluate to what extent the composition of agri-food waste-based mixtures determines the quality of the final compost produced at the industrial scale. Samples were collected from six industrial composting plants located in Southern Spain (Almeria, Jaen, and Alicante) that process agri-food waste as the main input, particularly, cull tomato, olive mill waste, and citric sludge,

from the tomato processing, olive oil extraction, and citric juice production industries, respectively. Samplings were performed at three different phases of the composting process: at the beginning, i.e., to the mixture that constitutes the windrows, in the cooling phase, and at the end of the process. Parameters related to the stabilization and humification of organic matter were analyzed, for example, germination, humification, and respirometry index, NH_4^+/NO_3^- ratio or lignocellulosic fractions, as well as basic control parameters in composting processes, such as conductivity, pH, bulk density, soluble organic carbon, organic matter, and C-N ratio. The results showed that the compost produced from the same type of agri-food residue did not necessarily share evolution and characteristics. Despite the low suitability of some unfavorable initial mixtures for composting, especially due to raw materials with a low carbon-nitrogen ratio, all the final compost reached sufficient quality. This could be due to the corrections caused by management operations during composting.

Keywords: sustainability; environmental impact, organic farming; fertilization.

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0247

EFFECTS OF HYDROMULCH ON PLANT GROWTH, PHYSIOLOGY, AND SOIL QUALITY IN AN ARTICHOKE CROP

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The soil physical-chemical properties are very important in the crops growth. The Mediterranean agroecosystem soils present generally low levels of organic matter content (OMC) and total organic carbon (TOC), due to the lack of soil moisture. It has been shown that higher levels of carbon in soil produce an increase in moisture retention with the consequent increase in crop production. The use of plastic mulches is a very common practice in the vegetables cultivation in the Mediterranean area due to its effects on the crop: it increases its yield, improves fruit quality, and acts as a physical barrier against evaporation, increasing soil moisture. However, its continued use generates large amounts of plastic waste, leading to environmental pollution problems. This study aims to evaluate the influence of the use of organic hydromulches on the plant growth, its physiology and the soil quality parameters in an artichoke crop. The application of an organic mulch, such as hydromulch, is expected to produce an increase in soil carbon levels, benefiting the growth of plants in the crop. Three blocks of culture were established at random with 5 treatments: three different mixtures of organic hydromuch (CHY, PY and AY), white bi-color low density polyethylene (FAB) and uncovered control (H). The vegetative growth parameters measured were plant height and plant width, number of leaves, fresh weight and dry weight of the aerial part. Apart from this, Gas exchange (photosynthesis, stomatal conductance and leaf transpiration) as well as chlorophyll content (SPAD) in fully developed leaves were measured. The soil chemical parameters analyzed have been the electrical conductivity (CE), OMC, TOC, N and the C/N ratio. The results show an increase in the growth of the plants subjected to mulching treatments, observing significant differences in all the evaluated variables. Regarding photosynthetic parameters, there are significant differences in transpiration, being inferior in plants that were developed with mulching. All the soil parameters analyzed are positively affected by treatments with organic hydromulch. The amount of TOC, OMC and the C/N ratio show significant differences compared to the uncover treatment. The use of hydromulch increases the vegetative development of the crop as well as the amount of carbon in the soil, making its use an interesting option as a practice in conservation agriculture to improve soil quality in Mediterranean agroecosystems.

Keywords: Cynara scolymus, Sustainable agriculture, soil health, soil carbon content.

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0256

BIORECOVERING OF OLIVE MILL WASTEWATER SLUDGE IN EVAPORATION PONDS BY MEANS OF COMPOSTING FOLLOWED BY VERMICOMPOSTING

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One of the main residues generated from the olive oil agroindustry is the olive mill wastewater (OMW) which has phytotoxic and antimicrobial effects. This pollutant character is due to the presence of high amounts of polyphenolic compounds. The most common method for OMW disposal is its storage in evaporation ponds where the water evaporates while solids settle resulting in highly toxic sludge. Although many of these ponds are currently in disuse, they still contaminate the soil and groundwater nearby. It is necessary to implement feasible and environmentally friendly techniques to solve this issue while simultaneously recovering OMW sludge as a bioresource for agricultural applications. In this work, we study the efficiency of a cascade of *in situ* treatments for OMW sludge in evaporation ponds involving composting followed by vermicomposting. The effect of inoculation with a polyphenol-degrading fungal consortium on these treatments was also tested. The study was carried out in an OMW evaporation pond (4540 m^2) where the OMW sludge was thoroughly mixed *in situ* with locally generated beef manure. The mixture was accumulated into two trapezoidal piles of around 500 m^3 that were built up in the pond. One of the piles was inoculated with the fungal consortium. During the bio-oxidative phase, the piles were periodically turned and the moisture was maintained around 50-60%. At the end of the bio-oxidative phase earthworms (*Eisenia fetida* and *Eisenia Andrei*) were added with a density of 2.500 individuals/m^3 into each pile for vermicomposting post-treatment. Samples were taken at the beginning and every two months for a total period of 204 days, in which total polyphenols, humic substances, water-soluble carbon, microbial biomass carbon, and phytotoxicity were analyzed. A significant reduction of polyphenols was obtained after composting (95% depletion) that was further improved by vermicomposting up to 98%. The phytotoxicity of the OMW sludge was eliminated after the treatments obtaining materials that were phytostimulant. Earthworms decreased the water soluble carbon content and increased the microbial abundance in comparison to compost. The inoculum improved the efficiency of both techniques. *In situ* composting and vermicomposting are eco-sustainable and efficient biostrategies to recover OMW sludge as mature and stable product for agricultural applications while solving the problems posed by the evaporation ponds.

This research was financially supported by the project LIFE+REGROW (LIFE16 ENV/ES/000331).

Keywords: Environmental impact, Sustainability, Organic farming, Fertilization.

0257

LONG-TERM EFFECT OF FARMING SYSTEMS ON THE YIELD OF CROP ROTATION AND SOIL NUTRIENT CONTENT

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The effects of organic (manure, cover crop) and mineral fertilisers on total yield, soil phosphorus (P) and potassium (K) dynamics and soil pH changes were studied over 10 years. Five field crops were grown organically and conventionally in rotation. The total yield of five course crop rotation was 24-25% higher in conventionally fertilised treatments than in organic treatments. The higher yielding conventionally fertilised treatments (annual total yield 29.0-29.8 t ha^{-1}) removed 12-18 kg ha^{-1} P and 45-73 kg ha^{-1} K per year, which was respectively 28-35% and 28-40% higher than organic treatments. The soil became more acidic in the conventional system due to the long-term use of mineral fertilisers (pH 5.4-5.9 versus 5.9-6.3). The highest annual uptake of P and K from the soil was by the potato crop, followed by winter wheat. The use of winter cover crops and well composted cattle manure in the organic system did not maintain the levels of P and K in the soil at baseline.

Keywords: total yield, farming system, organic, conventional, manure, cover crop

0261

PHENOTYPING FOR NITROGEN AND PHOSPHORUS EFFICIENCY IN POTATO

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As resources are scarce and the world focuses upon ecological awareness, the demand for organically grown produce is increasing. While organic farming focuses on reducing the use of plant protection products and fertilisers to a sensible minimum, it is aiming to maintain high quality standards and satisfactory yields. The application of fertiliser in organic farming can also be restricted by government regulations, such as the Fertiliser Ordinance in Germany. However, as adequate nutrient supply is essential to growing field crops such as potatoes, organic farming can be challenging. Therefore, not only the improvement of fertilising strategies, but also the selection of nutrient efficient potato varieties plays a major role in tackling the challenges organic farmers are facing today.

In cooperation with the Julius Kuehn Institute - Federal Research Centre for Cultivated Plants (JKI) as well as the Bavarian State Research Center for Agriculture (LfL), the Leibniz Institute for Plant Genetics and Crop Plant Research (IPK) is phenotyping potato genotypes regarding their nutrient use efficiency.

In our project, we will be testing a broad range of potato genotypes and gene bank accessions, preserved in the Gross Luesewitz Potato Collections, for their efficiency of taking up and utilising low amounts of nitrogen (N) and phosphorus (P). Each genotype will be tested with different levels of N and P fertilisation and compared to standard varieties with known efficiencies or inefficiencies in N and P use. On the poster we present first results from different cultivation methods: in addition to traditional pot experiments using sand as substrate, experiments in a greenhouse-based hydroponic system, as well as jar trials conducted in climatic chambers will be compared for their potential to assess N and P use efficiency in potato. Impacts of the different cultivation systems and N and P supply levels on shoot and root development, N and P uptake, as well as leaf flavonoid, polyphenol and chlorophyll contents will be measured.

In subsequent years, all genotypes will be tested via genome-wide association studies to identify reoccurring genetic markers for N and P efficiency. Using the resulting genetic markers, the breeding process could be streamlined and accelerated, enabling potato breeders to supply farmers, and organic farmers in particular, with a wider spectrum of nutrient-efficient potato varieties.

Keywords: Solanum tuberosum, nutrient efficiency, GWAS, hydroponics

0262

EFFECTS OF REGULATED DEFICIT IRRIGATION AND KAOLIN APPLICATION ON NUT AND KERNEL MORPHOLOGY OF TWO ALMOND (PRUNUS DULCIS (MILL.)) VARIETIES.

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The cultivation of almond trees has undergone a great increase in recent years in Mediterranean countries. This is due to the increase in the consumption of almonds and the good profitability of this crop compared to others. On the other hand, climatic changes in Mediterranean systems are already a reality, as evidenced by different scientific studies. The projections are not favorable and provide for a decrease in rainfall and an increase in temperatures, which causes a higher level of water stress in the plants during the crop development. To mitigate the harmful effects caused by water stress, different strategies are being studied in all Mediterranean areas. The aim of this work was to study simultaneously the effect of deficit irrigation and the kaolin application on morphological parameters in nut and kernel of almond (Prunus dulcis (Mill.) D.A. Webb). The experiment was carried out during the year 2019, in an almond orchard with two cultivars (Constantí and Vairo) located in Alfândega da Fé, northeastern Portugal (lat. 41°20'N long. 6°56'W; alt. 550m). Two irrigation strategies were established based on crop evapotranspiration: 100% of the ETc (control) and 100% of the ETc until the hardening time of the shell reducing the irrigation to 35% ETc during fruit filling stage. Within the two irrigation treatments, kaolin was applied to the same number of trees (14) in randomized blocks.

Along the experiment trees water status were evaluated trough predawn leaf water potential measurements. After harvest, almonds were dried for some weeks and one hundred per sample were randomly selected. Biometric parameters of fruits with shell (weight, length, width, thickness) were measured. The fruits were hulled and the same biometric parameters of kernels and kernel yield were measured. Several indexes were calculated: length to width ratio (L/W), length to thickness ratio (L/T), width to thickness ratio (W/L), volume (V). The indices related to form, I1 and I2 were calculated as T/L and W/L, respectively. The leaf water potential results revealed a moderate stress on deficit irrigation trees, but without differences in the application of kaolin. In terms of kernel yield, the reduction of irrigation did not cause a reduction of this parameter. These preliminary results showed that in the regulated irrigation strategy, in which water consumption was significantly reduced, in combination with the kaolin application, there were no significant losses in yield or changes in morphological parameters, which can make this strategy a sustainable irrigation strategy for almond orchards.

Keywords: sustainability, deficit irrigation, Prunus dulcis, harvest quality

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0279

SOIL MICROBIAL RESPONSE TO TERMINATION METHOD OF COVER CROPS UNDER TWO IRRIGATION LEVELS

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The termination method of cover crops (CC) in annual rotations may affect the benefits that CC provide relative to soil health. The roller crimper is an emerging termination technique, which may be used alone or combined with glyphosate in certain circumstances. It is still unclear the effect of roller crimper on the soil microbial status by the time the subsequent main crop is seeded and starts growing. To evaluate how termination method impacts on a selection of soil microbiological parameters, a microcosm experiment was established using an alkaline soil with five termination treatments under different irrigation levels and maize as main crop. We evaluated four methods to terminate CC (a mixture of Hordeum vulgare L. and Vicia sativa L): roller crimper, glyphosate, roller crimper + glyphosate, mowing and incorporation of CC residues by tillage, versus a control without CC, which were all combined with two irrigation levels (high H; low L=75% of H dose). Microbiological effects were evaluated at maize pre-emergence (14 days after glyphosate application) and at 57 days after maize seeding. The abundances of different groups of microorganisms (total bacteria, total archaea, total fungi, and Glomeromycota) estimated by gene copy numbers, together with hyphae length and root colonization were measured. The effects of CC termination methods changed with the time elapsed since CC termination. At pre-emergence, the use of glyphosate alone reduced the total bacteria abundance, mainly at high water level, whereas roller crimper, with or without glyphosate, stimulated total archaea. In general, fungi were favored by the combination of roller with glyphosate. About 2 months after seeding, the method of mowing+incorporation generally resulted, regardless of water level, in higher microbiological values for all parameters studied compared with the other termination methods. Also, roller crimper alone tended to enhanced total archaea, total fungi, hyphae length and root colonization, while decreasing total bacteria. The effect of glyphosate was variable and conditioned by the water level. Overall, preliminary results indicate that water level modulates the microbial response of soil to CC termination methods, with potential effects on growth and nutrition of the subsequent crop. Further research is needed to understand the interaction between termination method, water level and soil type to assist in the choice of the best CC management practices in a variety of soils and climates.

Keywords: glyphosate, roller crimper, qPCR, maize.

0284

EFFECTS OF ROW SPACING ON SEED YIELD AND QUALITY OF SPRING CANOLA (BRASSICA NAPUS L.)

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Field experiment was conducted in 2019 at Valgamaa, Estonia (57°58'47.6"N 26°11'32.8"E) on the production field. The aim of this experiment was to research how different row spacing affects rapeseed yield and quality

and to find out optimal row spacing for rapeseed cultivation.

The field experiment was established with rapeseed in four different row spacings (125;250;375;500mm) and with two different varieties: hybrid Brando and conventional Proximo. Fertilization and crop protection were the same for all plots of field experiment. Set of plants (15) were gathered from plots before harvesting to analyze them in the laboratory. Then the plots were harvested, and seed samples were taken for chemical analysis.

Correlation between seed yield and row spacing had strong negative relationship (r= -0,99 correlation coefficient). With wider row spacing the seed yields were lower, compared to narrower rows. Between varieties the variability was higher. Highest and lowest seed yield was harvested in row spacing of 250 mm. The seed yield of the conventional variety Proximo was 230,7 g m-2 and that of the hybrid variety Brando was 141,3 g m-2. Row spacing had no effects on oil content or had negative correlation depending on varieties. Oil content varied from 38,2% to 41,2%. There was no correlation between row spacing and oil content in conventional variety (r = 0,09) and negative correlation in hybrid variety (r = -0,93).

Protein content varied from 42,9% to 45,9%. Correlation between protein content and oil content depending on row spacing differed depending on varieties. Row spacing affected conventional variety Proximo's protein content positively. In wider row spacing protein content was higher compared to narrow row spacing. In variety hybrid Brando there was no effect of row spacing on protein content.

Keywords: Rapeseed yield, row spacing, rapeseed seed quality, yield components

0290

CHEMICAL AND BIOCHEMICAL FERTILITY OF SOIL UNDER DIFFERENT DEFICIT IRRIGATION STRATEGIES IN OLIVE AND ALMOND ORCHARDS

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In this work we evaluate the effect of different deficit irrigation strategies on the chemical and biochemical fertility of the soil. Soils of two trials were analyzed, in two different commercial plots located in the province of Seville. One is located in the municipal district of Dos Hermanas (Finca "la Florida"), with waters from an irrigation canal, and the other, in the municipal district of Carmona (Finca "El Morillo"), with residual waters from a treatment plant. Both farms have an experimental design of four blocks with four irrigation treatments each. The four irrigation treatments were: C. Control 100% crop evapotranspiration, RDI-1. Regulated deficit irrigation (RDI) with a period of water stress during kernel filling (phase II) and full irrigated conditions for the rest of the season. RDI-2. Regulated deficit irrigation for the same period that RDI-1, but with 100 mm of maximum seasonal water applied. SDI. Sustained deficit irrigation throughout the experiment with 100 mm maximum seasonal water applied.

Soil samples were taken from the surface layer (0-20cm). The parameters analyzed were: soil moisture, pH, electrical conductivity, organic matter, water-soluble carbon content, N-Kjedahl, P Olsen and K available. Four enzymatic activities were also determined: dehydrogenase, indicator of the general microbial activity of the soil; β-glucosidase, involved in the carbon cycle; phosphatase, involved in the phosphorus cycle; and urease, involved in the nitrogen cycle.

The results showed that the Controlled Deficit Irrigation techniques did not significantly affect the chemical and biochemical properties of the soil. A slight trend towards more favourable values was observed in the Control treatment probably due to the highest soil water content. The quality of the residual treated water was high enough not to adversely affect the quality of the soil the olive cultivation. The use of sensors of variation of the trunk and the hydric potential of the stem, allowed to plan adequately the Controlled Deficit Irrigation, but it did not suppose neither negative nor positive impact in the soil.

Keywords: soil water content, enzymatic activities, soil organic matter, soil nutrient contents.

Session 3.3: Instruments for resource management: models, monitoring, and decision-making tools

0026

COMPARISON BETWEEN FUMIGATION-INCUBATION *VS.* FUMIGATION-EXTRACTION METHODS TO QUANTIFY SOIL MICROBIAL BIOMASS

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Soil microbial biomass (SMB) includes living microorganisms and accounts for 1-3% of soil organic C. It plays a fundamental role in the decomposition of residues while contributing to nutrient cycling. The amount of SMB is a parameter of soil quality because of its sensitivity to detecting management effects on soil. Two analytical methods are commonly used for SMB assessment: fumigation-incubation (FI) according to Jenkinson & Powson (1976) and fumigation-extraction (FE) according to Vance et al. (1987). The aim of this work is to compare results on SMB when using these two methods in the context of a fertilizer experiment where different strategies (mineral and organic fertilizers and different N rates) were being applied. The experiment was set up in a semiarid Mediterranean area, in a calcareous soil with a silty loam texture. Average SOM content, in the upper layer, was around 2%. Soil was sampled in November (0-0.10m depth) just before winter cereal sowing. Each sample was analysed in triplicate according to both methods (FE, FI). Samples were divided in two, one half was fumigated and the rest were not. In the FI method fumigated samples were reinoculated and all subsamples were incubated for 10 days in jars with a NaOH trap subject to final titration. In the FE method, in both subsamples, soil C was extracted by K_2SO_4, followed by digestion and titration. No differences were found in SMB between the two methods in the SMB range from 5 to 30 mg C 100 g^{-1} dry soil. However, the FE method has a better aptitude for implementation in routine soil laboratory tests as it makes it possible to deal with a large number of soil samples in much less time than the FI method (24-36h *vs.* 11d). Besides, it does not require expensive equipment, which allows it to be easily implemented in a laboratory routine.

Keywords: calcareous soil, fertilization, laboratory methods, soil quality.

Acknowledgements: This study was supported by MINECO-INIA through the projects RTA2013-57-C5-5 and RTA2017-88-C3-3 and the Department of Agriculture, Livestock, Fisheries and Food (Generalitat de Catalunya, Spain). Dr M.R. Yagüe benefits from an INIA contract (ref: INIA-DOC-CCAA2015) in IMIDRA (BOE 25/07/2015).

0029

MAPPING COVER CROP DYNAMICS IN MEDITERRANEAN PERENNIAL CROPPING SYSTEMS THROUGH REMOTE SENSING AND MACHINE LEARNING METHODS

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About 1.5 Mha of olive orchards are found in the southern Spanish region of Andalusia, representing over 15% of the world olive surface. Some of the most critical rates of soil erosion in Mediterranean agriculture have been found in the local steep slopes of olive orchards (> 61 t ha-1 year-1), where soil is frequently tilled to avoid crop-weeds competition. Conservation agriculture has been proposing alternative strategies such as the use of inter-row cover crops (CC), sown or indigenous, during the period of lowest evaporative demand, with effective (chemical or mechanical) control in spring to avoid significant inter-specific competition for water during the critical period. However, despite the efforts of policy making and scientific research, the use of CC has not been fully adopted yet and a high variability regarding the fraction of ground cover is still observed in the region. In this sense, a better understanding on the main factors driving such variability is required and the development of an up-scaled methodology for mapping and analyzing CC dynamics in olive orchards could considerably contribute to it. In this light, we developed and tested a 'big data' approach trained to quantify the fractional green canopy cover (FGCC) as a key diagnostic variable of CC dynamics. We started by collecting the time-series of summer vegetation signals in order to represent FGCC in the absence of CC, assuming that the fraction of bare soil was maximum in summer as CC was controlled before the maximum evaporative period. Therefore, the

FGCC of olive trees was directly derived from summer imagery and inter-row FGCC (%CC) was calculated as the difference between 'real time' and summer FGCC (assumed as constant for mature plants in the absence of pruning or other canopy-reducing factors). A validation dataset (N=1600) was built from Deimos-2 satellite data (4x4m), assessed with an image processing package (Fiji Image-J) and based on a binary classification according to the structure of each pixel brightness histogram. Different machine learning (ML) methods taking into account all satellite bands were tested against standard vegetation indices (NDVI, EVI, BI). A higher robustness in predicting FGCC was achieved when using ML methods rather than vegetation indexes, especially for the case of PLS regression, Bayesian Ridge or Multiple Linear Regression Models (MLR). A model based on PLS was tested on Sentinel-2 data for more than 16.500 plots and evaluated with both the Deimos-2 validation dataset and field observations. The PLS model revealed a satisfactory potential to be used from crop field (10x10m) to landscape scale, with a temporal resolution of 5-10 days in cloud-free conditions. Pixel classification showed higher accuracy when distinguishing between higher CC densities (high from >60 to medium <50 %CC), than between lower ones (from low <20 to medium 20-50 %CC). We observed a negative response of potential %CC to field slope, which eventually suggests adjustments on policy targets established for steeper plots. An exploratory exercise was conducted, the annual cover management factor (C-factor) of the RUSLE equation was calibrated for three different levels of estimated %CC, and relative changes of annual soil loss were predicted. This exemplifies alternative uses for both policy making and landscape planning apart from the CC mapping for farm management. However, further measurements are needed as accuracy can be substantially improved mostly when shifting from discrete to continuous scales of prediction.

Keywords: Remote sensing, Monitoring tools, Farming systems

0140

CHANGES IN THE AVAILABLE PHOSPHORUS CONTENT OF THE AGRICULTURAL SOIL OF THE VOJVODINA PROVINCE, SERBIA

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The increasing phosphorus fertilizers use in agricultural production requires monitoring of the available phosphorus content in the soil. The AL available concentration of a soil is a key index that can be used to evaluate the P supply capacity of the soil and to estimate the optimal P fertilization rate. The aim of this paper was to examine the changes in the available phosphorus content in agricultural soil of Vojvodina Province, in the framework of soil quality monitoring. The examination included 1600 samples of agricultural soils from representative sites, properly distributed in a 4x4 km squares network. The available phosphorus content was determined by spectrophotometric method in AL extract (Egner and Riehm). The results of the research were compared with the results of the previous project in 1992, in order to detect the tendency of soil quality.

The results indicated that soil class with the optimal content (15-25 mg/100 g) covered the largest area (21.4%), while the smallest area (5.4%), included soil with a toxic content (< 100 mg/100 g). The area of soil with very high to harmful content (50-100 mg/100 g) amounted to 5.8%. Compared to results from 1992, the amount of available phosphorus increased in all types of soil by 4.67 mg/100 g, except in the humofluvisol. The area of poorly supplied and soils with phosphorus content over 50 mg/100g has been increased. Research indicated inadequate application of fertilizers compared to the previous period.

Keywords: available phosphorus, AL method, soil quality.

Acknowledgments: This study was conducted as part of the Project No. TR 31072 "Status, trends and possibilities to increase the fertility of agricultural land in the Vojvodina Province", which is supported by the Ministry of Education, Science and Technological Development of the Republic of Serbia.

0185

MODELLING WINTER WILD OAT IN THE SOUTH OF SPAIN, USING A NON PARAMETRIC REGRESSION

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Use of non-parametric regressions can improve our understanding of weed emergence patterns at the species-level, leading to improvements in weed management programs. Currently, parametric non-linear regressions are the predominant technique for modeling environmental indices, like thermal and hydrothermal time, to predict seedling emergence. However, this kind of regression has many statistical limitations. Our model used a Gaussian kernel distribution to describe the emergence of winter wild oat (Avena sterilis spp. ludoviciana (Durieu) Gillet & Magne), the most widely spread wild oat in Spain. The model was based on two different sites, Tomejil (37°24'08.4"N, 5°35'21.4"W) and Sevilla-ETSIA (37º21'07"N, 05º56'20"W), during two (2006/07 and 2007/08) and three (from 2005/06 to 2007/08) growing seasons, respectively. In both sites, 200 seeds of A. sterilis were sown each growing season under rain-fed conditions, simulating cereal field conditions. Each new sowing was placed next to the one made the previous year without disturbance. Seedling emergence was measured from each sowing during the two growing seasons. This, together with the accumulation of daily thermal or hydrothermal degrees starting at the first relevant rain, produced eight different growing conditions to train the model. Overall the mean emergence was 25.82% in the first-year sites and 11.25% in the second year. This model presented a high degree of accuracy describing the winter wild oat emergence at both sites. Weed emergence appeared to peak at approximately 200 hydrothermal degrees. Application of models like this that are based on growing conditions could optimize the timing of the control, resulting in reduced herbicide use, greater efficacy, and lower production costs.

Keywords: Hydrothermal model, Avena sterilis spp ludoviciana, weed emergence model, kernel estimation.

0198

USING HAND-HELD X-RAY FLUORESCENCE SPECTROMETRY FOR QUICK ANALYSIS OF ORGANIC AMENDMENTS

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The determination of heavy metals in organic amendments, such as compost, manure, biofertilizer, and sludge, generally involves the digestion of samples with *aqua regia*, and the determination of those in the solution using various techniques. Hand-held X-ray fluorescence (pXRF) has many advantages in relation to traditional analytical techniques. However, pXRF determines the total elemental content and, until now, its use for the analysis of organic amendments has been limited. The objective of this work is the calibration of a pXRF instrument to determine the *aqua regia*-soluble elemental contents directly in solid samples of organic amendments. In this way, we will avoid the digestion step and the use of other more laborious and slower laboratory techniques. A training set of samples corresponding to the MARSEP-WEPAL (Wageningen evaluating programs for analytical laboratories) program was used for obtaining calibration functions that allow the prediction of the *aqua regia*-soluble contents from the pXRF readings of total contents. The calibration functions (obtained by multiple linear regression) allowed the quantitative determination of the *aqua regia*-soluble contents of Fe, K, P, S, Zn, Cu, Pb, Sr, Cr, and Mn, as well as the organic matter content and a semi-quantitative assessment of Al, Ca, V, Ba, Ni, and As contents. For each target element, additionally to their own pXRF readings, the readings of Si, Fe, Al, Ca, K, or S were used as correction factors and introduced in the multiple linear equations, indicating that the calibrations functions found are truly based on the chemical composition of the sample matrix. This study will allow a fast, cheap, and reliable field analysis of organic amendments and of other biomass-based materials. In this way, immediate analysis can be made in the field that would allow, for example, adapting the application to the characteristics of specific batches or discarding non-compliant batches. More complete information on this work can be obtained from López et al. (2019).

López-Núñez, R. et al. 2019. Int. J. Environ. Res. Public Health 16, 4317. https://doi.org/10.3390/ijerph16224317

Keywords: compost; sewage sludge; aqua regia-soluble content; heavy metal; organic matter determination

0225

NEURAL-NETWORK-BASED CLASSIFIER FOR ON-LINE WEED CONTROL IN CORN AND TOMATO FIELDS

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A major issue in weed control under a Precision Agriculture approach is to know weed distribution within the field. This task can be done by site-specific weed management. Usually, weed detection and mapping procedures are expensive and they can make this task economically unsustainable, therefore it is essential for the design and development of effective procedures for weed mapping. Remote sensing is considered as an effective technique for weed mapping. However, the use of satellite and airborne sampling methods is strongly dependent on sky cloudiness. The use of Unmanned Aerial Vehicle (UAV) can solve those deterrents. Although UAV can cover big areas reducing sampling times, they need to create a map for chemical o mechanical treatments. On-ground methods can avoid the mapping procedure by using fast on-line methods for real time treatments. The current systems look for a fast and realizable system based on machine learning procedures that can detect weeds in commercial fields. This system is for weed patch treatment through the standardized ISOBUS protocol. An automatic weed species recognition system was developed for three weed species: Portulaca oeracea L., Cyperus rotundus L., and Solanum nigrum L. The system is based on a Neural Network training system based on RGB images. The images were acquired on tomato and maize crops in the early post-emergency stage. Input information for the Neural Network was individual plants in RGB images. These images presented three scenarios: weeds, b) plants from tomato or corn crop or c) mixture of crop and weed. Each of them was spatially identified and labeled per species. The procedure was based on the identification and classification algorithm “Object Detection”. The validation process was done with a random selection of RGB images containing the aforementioned species. Sorting accuracy was calculated by recall and F-measure. An accuracy higher than 95 % in crop detection and weed species discrimination was obtained. The classification algorithm was connected to perform a site-specific treatment using a commercial sprayer. Thus, the system was able to communicate an Artificial Intelligence procedure with the on-the-market tools reaching an easy and budget tool ready for smart agriculture systems.

Keywords: Artificial Intelligence, ISOBUS, DACWEED, Precision Agriculture

Session 3.4: New avenues for managing biotic and abiotic stresses

0033

ENTOMOPATHOGENIC FUNGI EFFECTS ON THE PERFORMANCE OF WHEAT GROWN IN FIELD CONDITIONS

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The Green Revolution (GR) brought new varieties of staple crops that yielded three times the previous ones. However, these advances were linked to a grain nutrient dilution effect and an increase in agricultural inputs, which are responsible of the depletion of nutrients source and even soil and water pollution. The second Green Revolution is contributing through new genetic techniques, green-house technology and the use of microorganisms to make agriculture more sustainable. The latter strategy comprises a wide range of microorganisms, among which we have studied the entomopathogenic fungi *Beauveria bassiana* 04/01 TIP and *Metarhizium brunneum* 01/58-Su strains —catalogued as endophytes and biocontrol agents against insect pests— in their role as wheat growth promoters and nutritional enhancers.

Our study was carried out in the 2015/2016 and 2016/2017 seasons with two experimental fields each one. In the first season conidia were directly applied to the soil and in the second one by seed dressing, both at a concentration of 1×10^8 m^{-2}. A randomized block design with 4 blocks and 3 treatments (Control, *B. bassiana* and *M. brunneum*) was used in all fields; and plant colonization, aerial dry matter (ADM), grain yield and morphophysiological parameters were measured both seasons.

In the first season colonization of wheat was detected for *M. brunneum* (up to 10%) but not for *B. bassiana*, whilst in the second season (seed dressing treatment) both strains were re-isolated (up to 5%and 16.6, respectively). *B. bassiana* significantly increased leaf surface area whereas both fungal treatments increased ADM in 5 out of 7 samplings in the two seasons, the increase being significant at $P < 0.10$ in 3 and at $P < 0.05$ in 2 samplings at early and mid-growth stages of the plant. No statistical differences were observed in grain yield, however. These strains seem therefore to be promising not only for crop protection but also as growth promoters.

Keywords: Sustainable agriculture; Beauveria bassiana; Metarhizium brunneum; growth promotion; field conditions

0178

EFFECT OF MICROBIAL INOCULANTS ON WHEAT NUTRITION UNDER FIELD CONDITIONS

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Microbial inoculants used as biofertilizers may improve crop nutrition. This contributes to explain the growth promoting effect of some commercial microbial inoculants. *Bacillus subtilis* QST713 and *Trichoderma asperellum* strain T34 are known to enhance nutrition of plants grown under controlled conditions. However, it is unknown if these effects are significant under field conditions. This study aimed at studying the potential benefits of both microorganisms on durum wheat grown under field conditions. Thus, field experiments were carried out in two different locations (Tomegil and Espejo) in southern Spain during two cropping seasons. Each randomized block experiment included three treatments: control without inoculation, *Bacillus Subtilis* QST713 and *Trichoderma Asperellum* T34. Wheat (cv Amilcar) was sown in December, at a rate of 220 kg ha^{-1} and 250 plants m^{-2}. Nitrogen fertilizer was applied at pre-plant, 23 kg N ha^{-1}, and 121 kg N ha^{-1} at topdressing in Tomegil during both seasons, and 133 kg N ha^{-1} at topdressing in Espejo (first season). During the second season in Espejo 32 and 170 kg N ha^{-1} were applied at pre-plant and topdressing, respectively. The dry biomass production and nutrient uptake were determined by sampling at three different stages, following the Zadoks scale; Z2.0-Z 2.9 (initial), Z4.5-Z5.5 (middle) and Z9.2 (harvest).

The total biomass production was significantly higher in Tomegil (15.32 t ha^{-1} and 20.7 t ha^{-1}) than in Espejo (12.06 t ha^{-1} and 12.82 t ha^{-1}) in both seasons. The effect of microbial inoculants on plant nutrition was greater during the first crop season than in the second. The treatment with *B. Subtilis* increased the total acquisition of P ($p < 0.0395$) and Mn ($p < 0.0254$), and tended to increase that of N ($p < 0.0817$) with respect to *T. asperellum*. Also the P concentration in grain was in-

creased ($p < 0.0382$) but not the P harvest index, which was improved by *T. asperellum* ($p < 0.0352$) during the second crop season, with respect to *B. Subtilis.* The results showed that the effect of the microorganisms was more evident in the years with adverse climatic conditions during grain filling period.

Keywords: biofertilizer, nitrogen, phosphorus, efficiency, uptake

0210

MITIGATION OF DROUGHT DAMAGE TO RAPESEED (*BRASSICA NAPUS* L.) FROM FILM ANTITRANSPIRANTS OVER THE REPRODUCTIVE STAGE

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Rapeseed is strongly affected by water stress, especially over the reproductive stage. There is increasing need for rapeseed to improve the tolerance to drought in crop management practice. Film antitranspirants (AT) are agrochemicals that create a waterproof layer to block the stomata mechanically, and thus reduce water loss through transpiration. In this study, two pot experiments were carried out to investigate the effects of AT at five dose rates on rapeseed under drought over the flowering stage.

Results showed that drought decreased stomatal conductance of water stressed (WS) plants, by 64% on average compared to well-watered (WW) plants. AT application appeared to reduce photosynthesis rate only at some dose rates in WS plants, resulting from the decrease of stomatal conductance. Seed dry weight/plant under WS was reduced by drought by 59%, compared to WW plants ($p<0.001$). Following the application of AT, treatments increased seed weight by 0.4%-13% in all WW plants and by 0.9%-25% in WS except for 1.5 L/ha, compared to unsprayed droughted control. This was mainly attributed to the increase of pod number per plant ($p<0.001$, $R^2=0.77$) and seed number/pod ($p<0.001$, $R^2=0.69$). Our results indicate that application of AT may be considered as a novel crop-management method to mitigate the drought damage to rapeseed by ameliorating plant water stress, and reducing yield losses.

Keywords: Rapeseed; film antitranspirant; drought; gas-exchange; yield

0224

BIOFORTIFIED AND CLIMATE-RESILIENT FOOD AND FODDER PRODUCTION ON MARGINAL SOILS

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By 2050 the world's population will exceed 9 billion requiring the increase of food production by 70-85% (Dhankher & Foyer 2018), while ensuring food security and safety. To combat the decreasing productivity of arable soils and progressive climate changes, the project called "Biofortified and climate-resilient food and fodder production on marginal soils" (BioFoodOnMars) was started to develop new opportunities to increase the amount and quality of food and feed crops in Europe using new strategies for sustainable growth of plant production and increasing climate change resilience of agroecosystems.

Our aim is to map potential crop yields and the valorization opportunities on marginal soils under various regional conditions in Europe and try to optimize the biomass production and valorization with biofertilizers or soil additives, like silicon and selenium. Spring barley cv. Fantex was grown on the fields in Estonia, Lithuania, Poland and Germany in 2020. Same variety was grown in an ecotron in Belgium, where the future climate conditions were simulated. Barley and also 2 grasslands established at a contaminated site in France were treated with silicon and selenium (foliar spray). In all cases, the above ground biomass, resistance to abiotic and biotic stresses and yield were determined. The results will provide valuable information for farmers on how to increase the stress resistance of crops and produce biofortified crops on marginal soils.

Keywords: silicon, selenium, barley, grassland, crop stress, marginal soil

0229

EFFECT OF THE EXOGENOUS APPLICATION OF SPERMIDINE ON THE ANTIOXIDANT COMPOUNDS IN CAULIFLOWER (*BRASSICA OLERACEA* VAR. BOTRYTIS L.) UNDER HIGH TEMPERATURE STRESS.

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Polyamines are involved in many physiological processes and respond to stress tolerance to various environmental factors, including high-temperature effect. To our knowledge, there is not any report about pre-harvest foliar application of spermidine in cauliflower as an effective ameliorating agent decreasing heat damage produced in its floret. Moreover, it is known that polyamines are important indicators of food quality with recognized antioxidant capacity. Cauliflower is a source of natural antioxidants which contains a high number of decisive phytochemicals, including phenolic compounds. The design of the experiments was completely randomized with five replications. The assay was performed to assess the effects of 1mM and 4mM spermidine on some bioactive compounds (the content of total phenolic compounds, antioxidant activity and polyamines), under three temperature treatments. The experiment was carried out in a polycarbonate greenhouse divided into three identical compartments located in Murcia, Spain. Six days before the end of the experiment, two parts of the total plants were sprayed with spermidine. The other third of plants was sprayed only with water. Three days later, different compartments were exposed to three temperature treatments. The compartment 1 was remained at room temperature (control temperature), in compartment 2 a gradient of control temperature +5 ºC was applied (high temperature) and compartment 3 achieved a gradient of control temperature +8 ºC (extreme temperature). Results showed that only the stress produced by exposure to high and extreme temperatures generated an increase of 10% and 51%, respectively, in total phenolic compounds and an increase of 59% and 170%, respectively, in the value of antioxidant activity obtained. Foliar application of spermidine produced a further increase from 10% to 17% in the total phenol content as the concentration of spermidine increased and the obtained antioxidant activity increased from 6% with spermidine to 1 Mm to 168% with spermidine at 4 mM. The polyamines content was increased in 65 % and 105% depending on plants were exposed to high or extreme temperature. An additional increase of 6% was achieved in the effect of foliar application when the spermidine applied was 1 mM, reaching an increase of 137 % when spermidine was 4 mM. As seen in this study, the content of bioactive compounds present in cauliflower have been improved after the application of a suitable combination of high temperature and foliar application of spermidine. This work has been financed by the European Regional Development Fund 80% Murcia Region (FEDER 1420-30).

Keywords: Polyamines, cauliflower, heat stress, UH-PLC-DAD, foliar treatment, spermidine, antioxidants.

0230

THE EFFECTS OF EXOGENOUS ARGININE IN CAULIFLOWER (BRASSICA OLERACEA L. VAR. BOTRYTIS) SUBMITTED TO HEAT SHOCK STRESS.

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Environmental stresses including heat stress, are severely affecting plant growth and productivity worldwide. One of the main challenges facing agriculture today is maintaining crop yields under adverse environmental conditions. In this challenge, polyamines can play an important role. Cauliflower (Brassica oleracea L. var. botrytis) contains many health-promoting phytochemicals. Strong epidemiological evidence shows that these compounds may help to protect the human body against damage by reactive oxygen species. This experiment was performed in a polycarbonate greenhouse divided into three identical compartments located in Murcia, Spain. This study was based on randomized complete block design with five replications, with the aim of evaluating how the application of arginine at two concentrations (1 mM and 4 mM) affects sugar and mineral content. To this end, plants from each compartment were divided in three groups. Plants from the first group only were sprayed with water, meanwhilst arginine at 1 mM or 4 mM were applied fairly in other groups. Later, heat stress was carried out. A different gradient of temperature was applied in each compart-

ment. The compartment 1 was the control (ambient temperature). In compartment 2, the gradient achieved was: ambient temperature +5 ºC (high temperature) and compartment 3 reached ambient temperature +8 ºC (extreme temperature). Results showed that sugar content was reduced 24 % when the exposure temperature was high, and 27% when plants were subjected to extreme temperature. However, when plants were subjected to extreme temperature and arginine was sprayed at 1 and 4 at mM, the sugar content registered increases of 19 and 47%, respectively. Our data also exhibited that potassium, phosphate and iron were the most abundant nutrients. It has been found a greater absorption of mineral content as consequence of spraying plants with arginine. In this sense, macroelements showed an increase of 4 % when arginine was at 1 mM and 10 % when arginine was at 4 mM. In case of plants were subjected to extreme temperature, the absorption of anions was 228 % when arginine sprayed was at 1 mM and 235% when arginine sprayed was at 4 mM. With results of this study, we may conclude that plants subjected to extreme temperature and sprayed with arginine at 4 mM can produce a higher number of health-promoting compounds. This work was financed by the European Regional Development Fund (ERDF) 80% - Región de Murcia (FEDER 1420-30).

Keywords: Polyamines, cauliflower, heat stress, UH-PLC-DAD, exogenous treatment with arginine

WORKSHOPS (extended parallel sessions)

Session 2: Towards efficient resource use: site-specific management

0043 KEYNOTE

POTENTIAL OF MULTI-SENSOR DATA-FUSION FOR SITE SPECIFIC SOIL AND CROP MANAGEMENT

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Precision management of farm input resources refers to the application the right rate of input in the right place and time using an integrated solution of sensing, modelling and control technologies. However, the first requirement for managing the within field spatio-temporal variability is the accurate measurement and mapping of parameters affecting crop growth and yield. But, the agriculture system even at field or sub-field scales is complex, as crops are affected by multiple limiting factors simultaneously, including soil attributes, crop biotic and abiotic stresses, topography and weather conditions. This necessitates an advanced sensing approach consisting on multiple sensor technologies and data fusion to maximize the quality of data collected and the creation of accurate and science-based variable rate recommendations of different farm input resources, e.g., fertilisers, water for irrigation, seeds, agrochemicals and manure. Data particularly on soil and crop is needed at high sampling density to allow accurate quantification of the spatial variability, which cannot be achieved with the traditional laboratory analysis methods as they are costly, time-consuming, requires expert technical operators and expose hazard chemicals into the environment. Proximal and remote sensing have been immerged in the last few decades as alternative solutions that can overcome the disadvantageous of the traditional laboratory analyses, and fulfil the requirement for variable rate applications.

This paper will provide an overview of the state-of-the-art of proximal sensing technologies, and applicability for the measurement of different soil attributes. It will cover the laboratory, in situ (non-mobile) and on-line (mobile) measurement modes, highlighting the degree of prediction accuracy that have been reported for different soil attributes so far.

The next topic will focus on the potential of multi-sensor and data fusion approach for variable rate applications. The majority of variable rate recommendations are made using either soil or crop data including yield. According to the agriculture system approach discussed above, recommendations derived with individual input parameter is not the ideal solution. This paper will discuss case studies of variable rate applications based-on the fusion of data on soil, crop normalised difference vegetation index (NDVI), present and historical yield and weather conditions. While this data fusion approach is implemented in map-based variable rate applications, case studies of sensor-based phosphorous fertilisation using a single data input of available P will also be discussed. Results of cost-benefit analysis demonstrating profitability in majority of case studies will be also presented. Since variable rate can also have environmental benefits, results in this regards will also be discussed for fertilisation, manure and agrochemical applications.

Having said that variable rate applications are more profitable and environmental friendly, compared to the traditional uniform application, the next burning question this paper will attempt to answer is that: should more input be applied in the poor fertility zones and vice versa or should the opposite approach be adopted? In other words, is the ideal variable rate solution can be achieved by feeding the poor (e.g., the Robin Hood approach) or feeding the riches (e.g., the Kings approach). Indeed, the current N application rate is usually subjective, depending on the farmer practical experience, which is not supported by scientific evidence. Therefore, this essential question needs to be answered to optimise variable rate applications that should ensure the entire field is providing the highest yield for the lowest input cost and environmental footprint.

With all advances made in the technology development for precision agriculture applications, the adoption rate by farmers lags behind. This is the most appealing issue that should be tackled so that the investment in precision agriculture can bring these technologies into the farmers hand. However, there are several issues that hinders the adoption, which will be discussed in this paper. Although profitability is the main derive for farmers to adopt the technology, environmental benefits and sustainability that can be achieved by precision agriculture is another factor that of interest to the farmer but of ultimate interest to the policy makers.

Keywords: Data fusion, variable rate applications, cost-benefit analysis, proximal sensing

0296 KEYNOTE

PRECISION FARMING – CHALLENGES, ACHIEVEMENTS, AND NEEDS

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Precision Farming aims to achieve cropping system goals, such as improved production, enhanced environmental protection, and improved sustainability by maintaining productivity and product quality. In essence, the same or more must be achieved with lower inputs of seeds, fertilizers and water, pesticides, growth regulators, and by optimizing soil cultivation, logistics, and mechanization.

Nitrogen and water are the most limiting elements regarding productivity, but both are frequently not sustainably used, meaning supra-optimal or even excessively. The overuse of nitrogen is affecting the environment and biodiversity. Hence there is a need to optimize further. This talk concentrates particularly on nitrogen by outlining recent achievements in Precision Farming, which should contribute to more sustainable management and briefly outlines Precision Phenotyping achievements, which could contribute to an enhanced and improved selection of more efficient cultivars.

The presentation is primarily focusing on arable crops such as winter wheat as grown in high productivity zones in the western part of Europe in Germany. The region, however, is also characterized by large gradients in rainfall distribution and different soil qualities, even though fertile soils dominate.

The presentation is deriving experiences obtained in the last two decades in Precision Farming and High-throughput Precision Phenotyping. However, principles and methods should apply to other regions and environments, as well as crops and management conditions.

Precision Farming and Precision Phenotyping have recently seen a surge, with the latter mainly driven by commercial providers offering among other satellite-based products. In contrast to initial efforts twenty years ago where methods or products were fairly intensively tested and rated, new products are frequently driven mainly by informatics, which allows a much more intense representation of nearly every field in the world. Besides, artificial intelligence is boosting recent achievements enormously, also contributing to new methodical insights.

The question is allowed how much did/does the farmer/breeder profit from these achievements. It looks like some gap exists at present between methodical discoveries and the translation to practice, requiring particularly also a more intensive multiple-year on-farm testing proving potential advantages of such methods. No doubt, there is outstanding potential, which, however, needs to be harnessed more rigorously.

In this presentation, briefly current sensing principles are outlined, including hand-carried, vehicle-based, and aerial-based (UAV, airplane, satellite) sensors, mainly deriving their information from the electromagnetic spectrum. Recent progress has been driven by drones' flexibility, the high revisit time, and increased spatial resolution, such as e.g., free data from the Sentinel satellite mission. Those sensors are either based on a few bands, multispectral or hyperspectral information. Depending on the goal, it looks like that multispectral information is suitable enough in many instances and many applications. For more specific applications such as new achievements in deep phenotyping, which tries to relate information to specific plant organs, besides emerging imaging information adopting artificial intelligence, terrestrial hyperspectral sensors can serve as reference.

Tractor-based sensors, which are since long used for site-specific nitrogen management, growth regulator application, and pesticide application, might become replaced or supported by aerial-based remote sensing, which may deliver similar information at a lower cost. Depending on the region, some limitations in the availability of information, e.g., due to cloud coverage, rain, still may persist but could be filled by statistical or crop growth models.

The question remains how good are sensors. For some specific applications such as site-specific nitrogen management, they are interchangeable, whether being passive or active, handheld or vehicle-based, being in some instances more critical, which part of the electromagnetic spectrum is used. For example, in less dense crop stands, NDVI-based indices are useful to derive biomass or yield. In contrast, in denser crop stands in high-yielding regions, REIP-or NIR-based indices can better overcome possible saturation in later growth stages. Whereas the general suitability of indices has been proven, still plenty more are being developed offering slight advantages in specific applications, however the precision to derive differences in biomass or nitrogen uptake should be more addressed, this means shifting from an overall illustration of the closeness of the relationship (large variances allow to achieve close relationships) to a more subtle consideration of a specific differentiation in a given location/management situation, which is better illustrated by particular measures such as RMSE values. It is wishful to arrive at more robust relationships offered by simple indices. In contrast, for specific applications, more intense evaluations based on e.g., non-linear statistical models may be useful but will probably be less amenable to extrapolations for other situations. For more simple applications, contour plots, analyzing all pairwise possible wavelength relationships, offer a straightforward way to identify optimized relationships.

It further looks but requires more intensive testing, that drone-based multispectral sensing may be as good or even better than terrestrial-based sensing, e.g., in tall row crops such as maize. Recent simulations suggest as well that the multispectral resolution of some satellites (such as Sentinel) is offering an adequate resolution and performance compared to terrestrial sensing. However, more on-farm real comparisons will be required to prove the reliability and precision in recognizing more subtle differences in biomass or yield. Whereas for some applications, this may be sufficient and satisfactory, for other applications, more close-range sensing may be advantageous based on an airplane or drone-based sensing.

A spectacular rise in new methodical developments has been recently seen in the field of High-throughput Precision Phenotyping, which is of relevance in highly controlled field plot experimentation as well for improved selection in breeding nurseries. Similarly, the same principles and methods with some additions apply as in Precision Farming. Successful possible applications have not only been shown in plot-based sensing but, more recently, also in single rows, which are the base for selecting improved lines in early selection cycles. Concerning more complex traits, such as drought tolerance, nitrogen use efficiency, phenomic information derived from high-throughput phenotyping seems nowadays to be ahead of an improved genomic understanding.

Whereas in plant selection, the mere phenomic information may serve breeders' needs, phenomic information in agriculture must frequently be linked to decisions, requiring much more and continued efforts in developing management actions in multiple year investigations.

Suitable methods to detect differences in soil qualities have been developed to delineate management zones and better understand differences in site-specific differences in biomass or yield. The soil remains the primary source leading to differences in plant growth, although not all soils differ that much and require differentiated management action. Improved availability and a significantly deepened understanding of satellite information will pave the way for enhanced usages. Besides geophysical or hyperspectral airplane-based soil assessments, plants represent the easiest way to derive site-specific information regarding soil heterogeneity. Some crops are more suitable for this purpose, and the response may differ, which requires care when compiling data across the season and/or years.

In many environments, particularly also under temperate conditions, the plant available water capacity of soils represents the crucial limiting factor that is mimicked in differences in plant growth. Choosing an appropriate time the crop status can be very indicative in this regard.

Previous efforts have shown that nitrogen supplies should be matched with the plant available water capacity, reducing inputs at lower plant available water capacities, thus decreasing harmful losses to the environment. In general, there is no indication that even in very fertile zones, nitrogen inputs should be increased beyond optimal requirements. In many instances, map-based approaches based on a piece of long-term information can be as successful as on-line approaches and are in water-limited regions even more preferable. A combination of both methods may offer further advantages.

Seen that by far, not all fields are heterogeneous, new concepts should be developed to optimize inputs in this case. A somehow new idea, the GreenWindows concept, which is briefly illustrated, may further optimize various inputs being fertilizers, seeding rates, or pesticides. The main factor includes the active participation of the farmer himself supported by digital information. The significant advantage is seen in a possible self-learning system that allows fine-tune inputs over the years, not excluding the possibility of adjusting the inputs in a given year.

In summary, Precision Farming offers excellent potentials for improved management, also fulfilling recent requests to comply with the Farm-to-Fork concept. Exciting methodical approaches and vast data collection must be better materialized by shaping management algorithms, which requires intensive on-farm testing and by gradually implementing new tools developed in high-throughput phenotyping on farmers' and breeders' sites. Available scientific knowledge must be substantially more transferred in practice/translated in action, requiring to step from novelty driven methodological advances to the implementation and verification of such worthy information on-farm and in agronomical experimentation and breeding.

Session 3: Efficient use of resources in agriculture

0191 KEYNOTE

CANOPY DESIGN AND MANAGEMENT IN INTENSIVE FRUIT ORCHARDS

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Introduction

Intensification of crop production is an inevitable reaction to increasing population and cost of human labour, shortage of agricultural land and the demand for land for nature and other human values. Horticultural crops (fruits and vegetables) offer additional gains to field crops related to greater possibility for improvement of quality attributes, flavour, colour, texture etc. The enabling technologies are mechanization, new sensing technologies during growth and robotics in product separation during and after harvest. These provide opportunities for growers to reduce costs of production and to meet changing market demands, although at greater levels of investment.

Traditionally, common pome- and stone-fruit crops (all deciduous) were grown widely spaced to allow for increasing size (that is what trees do!) and were mostly pruned to a vase-shape to allow entry of sunlight and air into the canopy and formation of fruit additional to that of the periphery. Evergreen citrus crops were not usually pruned to a vase shape, although management of large trees did require opening of the canopy for the same purpose.

A common development

The evident trend in most fruit crops is towards the development of hedgerow orchards that allow entry of machinery for soil surface management, heavy lifting, spraying for disease control, pruning and fruit harvesting. There is a wide range of hedgerow designs reflecting inadequate, and yet developing, knowledge of individual crops and how they respond to hedgerow micro-environments. Comparison of trends reveals that hedgerows are becoming smaller to the advantage of human intervention and the size and cost of mechanization. The revolution is progressing by trial and error with experimentation mostly at commercial scale. The old notion that “trees should be managed as trees” has been lost. Plant physiological knowledge has to catch up in order to help resolve issues of design and management.

Development of hedgerow systems

Comparison of development of hedgerow form in various crops reveals how attention has shifted from size to increase in area/ha of well-illuminated hedgerow walls where fruit are produced and most easily harvested.

In the case of olive, intensification occurred in two overlapping phases of increasing plant density and arrangement. First, an increase in tree density to ca. 250-350/ha (7 x 5 m inter-and intra-row) produced high-density orchards (HD) followed by super-high-density orchards (SHD) (e.g. 1250/ha (4 x 2 m) to 2200 (3 x 1.5 m) inter-and intra-row). In HD, trees are tall (4-5 m) and maintained in traditional vase-shaped form but in SHD they are shorter (2.0-2.5 m) grown to a central leader and are more heavily pruned, to which few cultivars are suited. Some HD orchards are irrigated, often strategic rather than complete, but SHD orchards are usually fertigated. In HD, harvest can be by tractor-mounted, whole-tree shakers with catchers or side-x-side harvesters, but over-row harvesters are needed for orchards that form hedgerows, as do always SHD, harvester size depending on row height and width. Intensification has gradually adapted height and width of hedgerows to harvesters and vice versa. With irrigation yields are 8-10 and >10 t FW/ha for HD and SHD, respectively

Principles of hedgerow design

Hedgerows are continuous walls of foliage that form more quickly with close intra-row spacing. Row height, width and slope define a range of cross-sectional shapes. Productivity of hedgerows depends on interception and distribution of solar radiation and their effects during the sequence of flowering, fruit set, fruit growth and quality. The principles are applicable to a wide range of crops; fruit, leaf, deciduous and evergreen. The key questions are how is yield related to mature orchard structure, inter- and intra-row tree spacing, hedgerow height, and how can that result be modified by row orientation and slope of canopy wall? Most hedgerow orchards are planted NS for equal diurnal illumination on E and W sides but what opportunities exist for manipulation of yield and quality.

Optimum orchard structure is a balance between yield per unit hedgerow length and the length of hedgerow per ha. A widely spaced hedgerow has maximum production/m because all surfaces are well illuminated. Closing distance between rows, shades lower walls and hence reduces productivity but also increases the total hedgerow length/ha, as also does narrowing hedgerow width. The initial search for optimal hedgerow structure for maximum production used a simple model of sunlight interception and identified the key relationships of sunlit area/ha and the ratio height-to-alley width. More recent and detailed work extends from surface to internal irradiance and its impact on fruiting, fruit growth and quality. Inclusion of transmission provides a better basis to understand the irradiance within wide hedgerows and the shaded sides of EW hedgerows.

Maintaining optimal structure

Early attempts with SHD were unsuccessful because structure was not maintained. Hedgerows grew too tall and closed alleys with the result that yield declined or was inaccessible. Olive is an evergreen tree in which continuing growth is required to form fruiting wood. Frequent pruning needed to control hedgerow height, width, and porosity can be reduced by attention to nutrition and water management.

There are few studies of response of olive to pruning but large areas of commercial olive hedgerows are being pruned to maintain productivity, paying attention to canopy slope and height-alley ratio. Annual topping and less frequent pruning of alternating sides can be mechanized with timely implementation. The question is how much and how often will maintain structure within an optimum range. New photographic and lidar techniques offer methods to capture quantitative definitions of structure to guide management.

Finally

A large amount of experimentation is under way at commercial scales driven by the need for mechanization and application of new technologies to achieve profitability. Progress would benefit from further physiological understanding and models of the response of olive to new forms of production.

Sustainable, intensive horticulture production systems

0188

MODELLING MACRONUTRIENT UPTAKE OF GREENHOUSE TOMATO WITH THE VEGSYST MODEL

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In south-eastern (SE) Spain, irrigation and nutrients are applied to greenhouse crops using technically advanced fertigation systems combined with drip irrigation. These systems are used with both soil-grown and soilless crops. They have the technical capacity to apply nutrients and irrigation as required throughout an individual crop. However, there is a large gap between the potential offered by these systems, for on-demand nutrient management, and how they are actually used. Most farmers apply nutrients and irrigation based on local experience of what guarantees a profitable crop. To match nutrient supply to crop demand, knowledge is required of the rates of crop uptake of different nutrients throughout the crop. The most effective method to obtain information of the dynamics of nutrient absorption, for the variable crop cycles of vegetables, is the use of simulation models. These models can calculate nutrient uptake curves for individual crops as a function of the dates of the crop and climatic conditions. The VegSyst model, calculates irrigation and crop N uptake of greenhouse-grown vegetable crops, including tomato, in SE Spain. In this work, the VegSyst model was adapted to simulate the daily uptake of K, P, Ca and Mg in greenhouse tomato. It was also validated for these simulations. Dilution curves, i.e. the relationship of the content (%) of each nutrient to dry matter production (DMP) were determined using pooled data of six different treatments from two early greenhouse tomato crops. The relationships of the contents of K, P, Ca and Mg to DMP of the pooled data were described by power equations with R^2 values that ranged from 0.92 to 0.72 for all nutrients, with the exception of the Mg-DMP relationship that had a R^2 of 0.40. Daily nutrient uptake was modelled as the product of nutrient content and modelled DMP. The model of K, P, Ca and Mg uptake was validated using a spring soil-grown tomato crop and two long season soilless cherry-tomato crops grown in 2016 and 2017. Apart from Mg, where the model had poor performance, the model adequate-

ly simulated seasonal uptake of N, K, P and Ca in the three validation crops with the cherry 2017 crop having the best performance (RE≤0.2). This modelling work will be used as part of a Decision Support System to provide recommendations for N, K, P, Ca and Mg concentrations in nutrient solutions for greenhouse tomato crops grown in both soil and with soilless cropping.

Keywords: Solanum lycopersicum, fertigation, modeling, phosphorus, potassium

0201

EFFECTS OF NITROGEN FORM AND APPLICATION RATES ON PRODUCTIVITY AND QUALITY OF TOMATO (*SOLANUM LYCOPERSICUM L VAR. ANASTASIA*).

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Considerable nitrogen loses from intensive vegetable system crops have become an important source of environmental damage. To minimize N pollution a high-efficiency N application is desired. Fertigation practices have been proposed for decreasing nitrogen leaching losses, including the use of nutrient solutions with low concentration of N and application of a percentage of ammonium as a source of nitrogen fertilizers. The effects of N form, application rates, on the productivity, quality of tomato and nitrogen leaching, were tested. Three treatments were established, T_1: control-standard nutrient solution (149 mg L^{-1} of N-NO_3^-), T_2: changing N form (149 mg L^{-1} of N, 85:15 NO_3^-: NH_4^+) and T_3: application rates 65% of control (99.12 mg L^{-1} of N- NO_3^-). The trial was carried out in a polyethylene greenhouse (Almeria, Spain), with a 1,700 m^2. The crop was *Lycopersicum esculentum* L. var. Anastasia. Fertigation with drip irrigation was adopted with one dripper per plant. The soil utilized in the trials was a traditional mulching sandy soil quite common in this Mediterranean area. Fruit were collected weekly, classified according to size categories, and weighed. Fruit firmness, total soluble soil, pH and titratable acidity were measured. Each repetition consists of 3 crop lines (144 plants per repetition). Rigid plastic lysimeters were built for the study of water balance and N, P and K leaching. Soil solution were collected with suction cup. Treatments did not generate differences in total yield and commercial quality production. The results showed that firmness and total soluble solids, decrease in treatment with 65 % of N application. However, pH and titratable acidity in fruit juice doesn't present any difference between treatments. The use of 65 % of nitrogen and 15 of NH_4^+ achieved a significant reduction in nitrogen concentrations in leachate solution. T_2 led to 30 % and 29% of reduction of N and K leaching respectively and 65 % of N application 20 % of N and 20% of K. However, no differences in P leachate were found. Nitrogen form and N application rates did not have any effect on the nutrient level of the soil solution. Values range for pH, EC, N, P and K in soil solution was 7.97-8.56, 2.57-3.12 dS m-1, 7.97-8.56, 0.03-0.08 and 3.11-3.84 mmol L^{-1} respectively.

Keywords: leaching, NH_4^+, suction cup, N, P and K

0209

A DEEP LEARNING APPROACH TO THE AUTOMATED DETECTION IN-FIELD TOMATOES RIPENING USING A MOBILE PLATFORM

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Harvesting tomatoes at their optimum ripening point is one of the challenges the industry faces. In recent years, the emergence of mobile platforms for field data collection has driven the crop characterization using different strategies and sensors. In this study, a mobile system has been developed to detect the percentage of ripe tomato fruit using image analysis techniques with deep learning. For this purpose, a multi-purpose platform equipped with a Kinect V2 sensor was used in a commercial tomato field. We sampled a 20-meters-long row divided into one-meter-long plots. Images and depth-scans from each plot were automatically taken, while additional images were took in order to build the training dataset for the deep learning model. For accuracy assessment, we manually harvested and separated of the ripened and non-ripened tomatoes from each plot. A dataset of 1000 images was binary labeled (ripe tomato and non-ripe tomato). We implemented a pre-trained YOLOV3 model with the Darknet-53 architecture using transfer learning techniques. Preliminary results show that the model detects ripe tomatoes with food accuracy (95%). However, some model inaccuracies were detected in the automated recognition of the non-ripened ones. The results were also compared with manual ground-truth measurements. A statistically significant linear correlation (R2 ≥ 0.76) was observed between the tomatoes detected with the Yolov3 model and the number of tomatoes counted manually. Taken together, the results suggest that this methodology can be used to estimate the yield before harvesting.

Keywords: Tomato, Fruit detection, Deep learning, Yield estimation and Harvest.

0211

EFFECT OF VOLATILE COMPOUNDS PRODUCED BY *MICROBACTERIUM* SPP. AGAINST *BOTRYTIS CINEREA* IN LETTUCE SEEDLINGS

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During the last decades, the search for new biopesticides has been a field of study of special interest within agrobiotechnology. The main goal of this search has been to minimize the application of chemical pesticides, highly harmful from an environmental and sanitary point of view.

In this research work, a collection of 29 strains included in the genus *Microbacterium* was studied. The objective of this work was to determine if the production of volatile organic compounds (VOCs) could act antagonistically against the fungus *Botrytis cinerea*, which causes gray mold disease. At the same time, it was possible to confirm the growth promoter effect in lettuce seedlings after the treatment by seed *biopriming*. Strains showing positive results *in vitro*, both for the biopesticide effect and for growth promotion, were selected for an *in vivo* test, in which both effects were evaluated simultaneously.

Results derived from this work showed that the application of certain strains of *Microbacterium* spp. VOC-producing, caused a remarkable plant growth promoting effect, in addition to the buffering effect of damage caused by *Botrytis cinerea* on lettuce seedlings. With a view to the application of future agrobiotechnological strategies, the M707 (*M. profundi*) and M55 (*M. aerolatum*) strains were selected as the most effective and, therefore, those of greatest agronomic interest. Both strains showed a degree of *in vitro* growth inhibition of *Botrytis cinerea* greater than 30%. They were able to significantly stimulate the *in vitro* germination of seeds, increasing root weight by up to 45%. Finally, the priming effect in lettuce seeds caused a certain plant growth promoting effect, as well as suppression of the harmful effects of *Botrytis cinerea* in lettuce seedlings.

Keywords: Sustainability; Crop quality; Fertilization; Organic farming; Crop management

0213

USE OF A COOLING EVAPORATIVE SCREEN IN A SOIL-GROWN SWEET PEPPER CROP IN A MEDITERRANEAN GREENHOUSE

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In horticultural crops growing during the summer period in Mediterranean greenhouses, low-cost cooling systems are required for reducing air temperature, increasing air humidity and/or decreasing vapour pressure deficit. A sweet pepper crop was grown from 11 July 2009 to 5 February 2020 in two similar greenhouses, one with a low-cost evaporative screen and another heavily whitened (control). The latter is the most common cooling system in the region. The evaporative screen system consisted of a hydrophilic woven material (65% viscose rayon and 35% polyester) placed above each plant row forming a gable roof. A drip irrigation pipe was inserted in the middle of each screen to maintain wet the screen when greenhouse air cooling was needed. The emitters supplied water every 15 minutes when the relative air humidity was below 85%. The greenhouse whitening and the evaporative screens were removed on the 31 October 2009. The greenhouse with screens was also whitened but using a lower carbonate calcium concentration in order to get a similar solar radiation greenhouse transmittance in both treatments. From July to October, the control greenhouse presented a mean daily solar radiation transmittance of 36%, compared to 28% for the greenhouse with evaporative screens. Greenhouse air temperatures were slightly lower in the greenhouse with evaporative screens: the mean daily value, averaged over the cycle, was about 0.5°C lower in the greenhouse with screens, compared to the control, and the maximum daily temperature was approximately 1°C lower. These differences can be mainly attributed to the lower radiation load together with the water evaporation (sensible to latent energy

exchange) in the greenhouse with screens. Substantial differences between treatments were observed for the hygrometric air status, particularly during the summer crop period. The mean daily relative air humidity, averaged over the cycle, was about 7% higher in the greenhouse with screens and the air vapour pressure deficit was clearly higher in the greenhouse control, which usually presented values higher than 2 kPa at midday during the summer period. Once the screens and the greenhouse whitening were removed, the solar radiation and the thermo-hygrometric air properties were similar in both greenhouse treatments. At the end of the sweet pepper cycle, no significant differences were found between treatments for the total shoot biomass (1314 and 1390 g m^{-2} in the greenhouse with evaporative screens and control, respectively) or the cumulative fresh weight of marketable sweet pepper fruits (6890 and 7170 g m^{-2}, respectively).

Keywords: air temperature, air vapour pressure deficit, microclimate, sustainability, shading screen

0218

THE COMPLEX OF PLUTELLA XYLOSTELLA PARASITOIDS IN SUSTAINABLY GROWN WHITE CABBAGE

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Plutella xylostella (Linnaeus, 1758) (Lepidoptera: Plutellidae) is one of the most harmful cabbage pests in Lithuania. In a sustainable vegetable system the same active ingredients of insecticides can't be used more than two times per season, and the harvest intervals have to be 1.5 times longer than it is indicated on the label. Plant protection products labelled as "Very toxic" and "Toxic" can't be used. Studies were conducted from 2017 to 2018 to identify parasitoids attacking *P. xylostella* in sustainably grown white cabbage. In total, 5 parasitoid species from three Hymenoptera families were found attacking larvae and pupae of *P. xylostella*. These included the larval parasitoid *Diadegma fenestrale* (Holmgren, 1860) (Hymenoptera: Ichneumonidae), *Diadegma semiclausum* (Hellen, 1949) (Hymenoptera: Ichneumonidae), *Microgastrinae* sp. (Hymenoptera: Braconidae); a pupal parasitoid *Diadromus collaris* (Gravenhorst, 1829) (Hymenoptera: Ichneumonidae) and a pupal parasitoid chalcid wasp (Hymenoptera: Chalcidoidea). Measures ought to be taken to conserve these natural enemies through agricultural practices and use of non-toxic insecticides.

Keywords: agricultural practice, natural enemies, pest

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0220

BIO-FORMULATIONS BASED ON MICROORGANISMS PRODUCING SALICYLIC ACID FOR THE PREVENTIVE TREATMENT OF BACTERIAL CANKER IN TOMATO PLANTS

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Agriculture represents an essential activity at an economic, social and environmental level. Some of the challenges that such activity faces are related to the management and improvement of plant health. To this end, different products based on chemical formulations have been used for decades, which have been highly successful in controlling pests and plant diseases. Unfortunately, the excessive use of such products can generate serious environmental and health damage, as well as the appearance of resistance by the pathogens against which they were initially used. Despite these drawbacks, some plant pathogenic microorganisms are capable of causing serious damage to crops of global importance, so the control of these by means of phytosanitary products is still essential. This is the case of *Clavibacter michiganensis* subsp. *michiganensis* (Cmm), the bacterial canker-producing agent of tomato plants. In this context, biological control is proposed as a powerful alternative. Thereby, the main objective of this work was to search for biopesticidal and phytostimulant microorganisms from a collection of salicylic-acid producing bacteria isolated from a plant-based composting process. The selection of the best strains was based on the capacity to inhibit the in vitro growth of Cmm by dual cultures, using cell cultures (direct protocol) or acellular extracts (indirect protocol). On the other hand, germination bioassays with watercress seeds were performed in order to detect the phytostimulant capacity of the strains. Finally, *in-plant* tests were carried out to determine the ability to promote the growth of tomato plants (*Solanum lycopersicum*) and to prevent the development of the disease caused by Cmm. From the results obtained, it was concluded that the strains showing the best capacities to be applied as biological control agents (BCAs) belonged to the Bacillus and *Pseudomonas* genera. Specifically, the 2265 strain (*Bacillus subtilis*) was the most effective, especially when applied directly. Using BCAs directly is, in itself, an environmental and economically sustainable treatment. In conclusion, the use of microbial formulations represents an improvement in agricultural systems, as well as an advance towards an increasingly demanded circular economy.

Keywords: Salicylic acid; Clavibacter michiganensis subsp. michiganensis; Solanum lycopersicum; Bacillus subtilis, Biological Control Agents.

0228

PRIMING TREATMENT WITH CYANOBACTERIA EXTRACTS TO REDUCE DAMPING-OFF CAUSED BY PYTHIUM ULTIMUM IN CUCUMBER SEEDLINGS

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The practice of intensive agriculture has traditionally been related to the application of chemical pesticides used to combat plant pathogens that can spoil crops. Today, there are strict regulations on the use of chemical pesticides, so efforts have focused on developing alternatives to synthetic chemicals for pest and disease control. This work highlights the ability of various cyanobacterial extracts to control the incidence of *damping-off* caused by *Pythium ultimum* in cucumber seedlings. The applied protocols to characterize the collection of cyanobacteria were very useful in predicting their phytotoxic, phytostimulating and biopesticidal capacity. First, the phytostimulatory or phytotoxic potential of a collection of 31 sonicated cyanobacterial extracts was analyzed by calculating the germination index in watercress seeds, and the increase or loss of seedling weight. Likewise, the collection was characterized according to its ability to inhibit the growth of *P. ultimum* by means of bioassays in dual culture and leaf-detached tests. After selecting the most effective extracts, a preventive bioassay based on *biopriming* of cucumber seeds was performed. *Tolypothrix* sp. SAB-M465 was positioned as the most efficient strain against *P. ultimum in vitro* growth, while *Anabaena* sp. SAB-B912 was more discreet in this regard, but proved to be the most effective as a germination stimulator. Both caused a healthy effect on the crops, reducing the action of the pathogenic oomycete. The *biopriming* strategy of seeds with sonicated extracts of cyanobacteria revealed a remarkable promoter effect in the early stages of the plant development, although only SAB-M465 was positioned as an effective control agent against the *damping-off* caused by *P. ultimum* in seedbeds of cucumber.

Keywords: Sustainability; Organic farming; Crop quality; Crop management

0231

INTEGRATION OF PASSIVE COOLING AND HEATING SYSTEMS FOR VEGETABLE PRODUCTION IN MEDITERRANEAN GREENHOUSE

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Greenhouse horticultural production on the Mediterranean coast is carried out under low-cost greenhouse systems with minimum energy consumption by now. Limited technological development has characterized this horticultural system, in which greenhouses are even not provided with active climate-control devices. As a consequence, crop development obtained is mainly related to the local climate pattern, which usually supposes an important limitation on crop yield and fruit quality. The main objective of this study is greenhouse climate conditions improvement, considering a technological development consistent on the integration of heating and cooling passive systems. The effect of this hybrid passive system on greenhouse climate and sweet pepper bio-productivity has been evaluated in the present study. Sweet pepper type California cv. 'Numanthia' was grown up on perlite substrate bags. The experiment was developed in two similar greenhouses situated in IFAPA La Mojonera (Almería,

Spain). Both greenhouses were provided with natural ventilation and fertigation automatic control systems. The reference greenhouse (R) was provided with a fixed external shadowing screen during the warmest period. The passive cooling and heating greenhouse (P) were provided with a mobile shadowing screen, used as well as a thermal screen during the coldest period and heat accumulators consisting in NIR absorbing PE film sleeves, filled with tap water. Results show that the cooling passive systems reduced the maximum air vapor pressure deficit in P treatment. In addition, higher leaf area index resulted in significantly higher early yield when comparing with R treatment. The heating passive system in P treatment increased minimum temperatures. By the end of the crop cycling, commercial production was 25% higher in P vs. R treatments owing to higher fruit number. The application of the proposed technological development, integrating cooling and heating passive systems for climate improvement seems to be interesting for sustainable cropping systems in Mediterranean greenhouses.

Keywords: storage heater, evaporative screens, thermal screens, shading mesh, sweet pepper, substrate, microclimate

0240

MACROPHOMINA PHASEOLINA INCREASES CANKER DISEASE IN BLUEBERRY 'STAR' CULTIVAR COINFECTED WITH LASIODIPLODIA THEOBROMAE

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Huelva (Spain) is the largest European producer of blueberry for early spring harvest. Blueberry fields in Huelva are intensively cultured. Canker or stem blight of blueberry and the resultant twig dieback caused mostly by botryosphaeriaceous species has become a serious problem throughout blueberry producing areas worldwide; although the presence of *Botryosphaeriaceae* species associated with this disease varies. In Huelva, blueberry canker or stem blight has been attributed to *Neofusicoccum parvum*, *N. australe* and *Lasiodiplodia theobromae*. Meanwhile, *Macrophomina phaseolina* has been associated with blueberry charcoal rot. The frequent appearance of plants with branches exhibiting canker due to *Botryosphaeriaceae* species and also root rot due to *M. phaseolina* in a plantation where the canker disease is very severe has led to the possible interaction of these infections being considered. Thus, a plantation experiencing high canker severity was sampled, and the stems and roots were examined. The disease was reported to progress quickly after June pruning and the high temperatures of the weeks that followed. For this reason, here, we designed bioassays with pruned stem inoculations of *N. parvum* or *L. theobromae*, with and without *M. phaseolina* radical inoculation. The bioassays indicated that canker disease severity increased due to radical coinfection of *M. phaseolina*, with *L. theobromae* inoculum but not with *N. parvum*. These findings show that the disease is more complex than previously thought, and should be considered in the development of more effective control measures.

Keywords: Disease complex, Pruning wounds, Stem blight, Synergistic interactions, Twig dieback

0253

IRRIGATION CONTROLLED BY A WETTING FRONT DETECTOR AS A TOOL TO IMPROVE WATERMELON FRUIT QUALITY UNDER GREENHOUSE CONDITIONS.

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The correct irrigation timing is of paramount importance to reduce both evaporation and lixiviation of irrigation water. Thus, the right amount of water should be applied to fulfill the water consumption of the crop or ETc. Identification of the wetting front is one of the easiest tool that can be used to improve irrigation management, and consequently crop yield and product quality. The device used to detect wetting fronts FullStop® (WFD) is a funnel- shaped container that is filled with soil and buried at an appropriate depth in the soil, and with the black tube protruding above the soil Surface. Free water produced at the base of the funnel then flows through a filter into a cavity and activates a float switch. The experiment was carried out with watermelon plants (Citrullus lanatus) cv Premium F1 with a planting frame of 1.56 x 1.2 m in a 680 m2 multi-tunnel greenhouse equipped with 8 independent lysimeters, the distribution being 18 plants in 3 rows for each lysimeter . The objectives were to determine fruit quality of watermelon, under to two irrigation strategies. The control treatment consisted of irrigation using the A-class evaporation pan / crop factor method. The other treatment consisted of using the wetting front detector (FullStop®). One detector was placed with the float switch at 200 mm depth (shallow detectors), other detector at 400 mm depth and one at 600 mm depth (deep detectors). Additionally, both treatments received the same fertilization. The fruits produced with the irrigation scheduling according to the wetting front detector method were those that reached higher content in % total protein and in citric acid, as well as the concentrations of minerals such as Ca, K, Mg, P, and Zn compared to the standard method of class A pan evaporation. The highest concentration of β-carotene, ºBrix and dry matter percentage in the fruits occurred in the A-class evaporation pan treatment. Moreover, the color, pH, lycopene and total phenolics concentration of watermelon fruit were not affected by the irrigation treatment.

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Keywords: Citrullus lanatus, class A pan evaporation, wetting front detector.

0254

EFFECT OF TEMPERATURE ON LEAF MINERAL CONTENT AND CARBOHYDRATES IN THREE PEPPER CULTIVARS AT DIFFERENT CONCENTRATIONS OF CO_2

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The effect heat shock was studied in three pepper (*Capsicum annuum* L.) cultivars: "Guindilla Vasca", "Loreto" and "Agio" under ambient (400 ppm) and elevated (1000 ppm) CO2 concentration. Plants were grown in pots with coconut fiber and irrigated with a modified Hoagland solution, with a day/night photoperiod conditions of 14/10 hours. The temperatures were 28/24/20 ºC (6:00-20:00/20:00-0:00/0:00-6:00) with a relative humidity of 60%. The plants were grown for 18 days under these conditions and afterwards were submitted to a heat shock (40/33/28 ºC) for 72 hours. Irrigation was set to maintain 35% drainage. The results show that the heat shock and [CO2] had not impact on leaf concentration of Ca and Mg, but was dependent on cultivar, being the concentration of Ca significantly higher for Agio and Loreto cultivars with respect to Guindilla Vasca. The concentration of P was significantly increased with heat shock, being unaffected by [CO2], while Loreto showed values significantly higher than other two cultivars of pepper plants. With respect to the concentration of K, Loreto showed a significant increase at ambient [CO2], being unaffected by temperature; whereas heat shock and [CO2] had not effect on Guindilla Vasca and Agio. On the other hand, fructose concentration in the three pepper cultivars was not affected by heat shock, but [CO2] had an important impact. Agio and Loreto cultivars showed significant decreases at high [CO2], whereas Guindilla Vasca increased fructose concentration. Regarding glucose concentration, Guindilla Vasca leaves had the same impact that fructose concentration; but Agio and Loreto cultivars showed that heat shock increased fructose concentration at low [CO2], being significantly increased compared with their controls and the high [CO2] treatment. Thus, Guindilla Vasca and Agio showed that the effect of heat shock on sucrose concentration at low [CO2] was significantly increased with respect to control treatment (ambient temperature) and high [CO2] treatment. Moreover, the effect of temperature and [CO2] did not affect sucrose concentration in Loreto cultivar.

This work was financed by the European Regional Development Fund (ERDF) 80% - Región de Murcia (FEDER 1420-30).

Keywords: Capsicum annuum L., heat shock, environmental CO2.

0281

EFFECT OF RHAMNOLIPID JBR-425 ON THE DEVELOPMENT OF *BRASSICA JUNCEA* IN SOILS OF URBAN GARDENS OF SEVILLA (SPAIN)

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The current need to recover soils contaminated with potentially toxic metals to lessen their impact on the environment and on the food chain, leads different methods are being developed for their extraction. There is

an additional concern when contamination occurs in urban farm soil. Phytoextraction can be enhanced by applying biodegradable biosurfactants, promoting the bioavailability of contaminants and their subsequent uptake by the plant. This technique is called assisted or induced phytoextraction. This work aims to evaluate the extraction of heavy metals from contaminated soils from an urban orchard in the town of Sevilla using Brassica juncea plants, as well as to estimate the improvement that the application of a biodegradable biosurfactant (Ramnolipid JBR-425) implies. For this, a greenhouse trial was carried out with two soils from an urban park and an agricultural one in which Brassica juncea was grown. A solution of Ramnolipid JBR-425 with a concentration of 1000 mg kg-1 was added to half of the pots to evaluate its effect on the development of the plants (number of leaves, plant height). The data collected showed a negative effect produced both by soil contamination and by the presence of rhamnolipid. The soil used in the experiment, as well as the plants, were collected for further analysis. Plant samples were divided into aerial part, root and fruit, to determine the amounts of heavy metals in the soil and extracted in the aerial part. The determination of heavy metals in soil was carried out by ICP-OES after AEDT extraction. Likewise, parameters such as electrical conductivity and pH were also measured. For the extraction of the metals extracted by the plants, acid digestion of the plant samples was performed and then they were measured using ICP-OES. The plants treated with rhamnolipid showed less development both in plant height and in the number of leaves; likewise, the biomass production capacity was reduced. These factors may be due to the toxic effect of rhamnolipid, as well as the effect of Potentially Toxic Elements. Although the plants with rhamnolipid application had higher concentrations of heavy metals in their tissues, since there was a notable decrease in biomass, they did not extract as much as the plants without treatment.

0283

URBAN AGRICULTURE IN THE URBAN GARDENS OF SEVILLE

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Urban agriculture has different benefits for people and may contribute to reducing socio-economic and environmental problems. Urban gardens are very common in Andalusia (S. Spain) and they often represent a food supply.

The objective of this study was to study the main characteristics (agronomic practices, garden users, regulation) of urban gardens in Seville city. Seville has 12 urban gardens that occupy a total of total de 27,5 ha. In this study we sampled 6 urban gardens and analyzed information regarding the gardener, food destination, species cultivation, the agronomic practices and the urban garden legislation.

The main users of urban gardens are men with an age between 50-65 years that are retired or unemployed and received little training in organic agriculture. They cultivate vegetables for private use and consumption even if there are some gardens for schools or associations destination (only 10%). The most common vegetables cultivated in these urban gardens are tomato, pepper and onion planted on ridges under drip-irrigation. The plot surface is different among gardens and varying from 4.5 to 150 $m^{2.}$

Keywords: Urban agriculture, gardeners, vegetable, plot

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