EAPR Pathology & Pests Section Meeting, together with the International *Spongospora* Workshop

1st to 5th September 2019 - Neuchâtel - Switzerland

Reducing pesticide use while preserving potato productivity and profitability

Pathology and Pests Symposium 2019

Sunday
01.09.19

18:00
Welcome Reception
Hotel Alpes et Lac

Monday
02.09.19
UNINE - Faculty of Science
Lecture theatre Louis-Guillaume

		speaker
09:00		Congress Opening
		Epidemiology and management *Chair: P. de Werra*
09:10	K1	M. Feitknecht Fenaco - CH
09:40	O1	I. Toth the James Hutton Institute - UK
10:00	O2	N. Rosenzweig Michigan State University - USA
10:20	O3	L. Woodell University of Idaho - USA
10:40	O4	Ch. Debonneville BIOREBA AG - CH
11:00		(coffee break)
		Vector-borne diseases *Chair: B. Dupuis*
11:30	O5	E. Wenninger University of Idaho - USA
11:50	O6	A. Karasev University of Idaho - USA
12:10	O7	J. Whitworth USDA-ARS - USA
12:30	O8	D. Levy the Hebrew University of Jerusalem - IL
12:50		(lunch)
		Oomycetes *Chair: L. Weisskopf*
14:20	K2	L. Weisskopf University of Fribourg - CH
14:50	O9	A. Lees the James Hutton Institute - UK
15:10	O10	D. Gaucher Arvalis - F
15:30		(coffee break)
16:00	O11	C.R. Wilson University of Tasmania - AUS
16:20	O12	K. Bouchek-Mechiche INRA & RD3PT - F
16:40	O13	K. Sullam Agroscope - CH
17:00		End

organized by : Agroscope, BFH Bern University of Applied Sciences, unine Université de Neuchâtel

Tuesday
03.09.19
UNINE - Faculty of Science
Lecture theatre Louis-Guillaume

		speaker
08:30	K3	J. Waespe Federal Office for Agriculture - CH
		Tuber Blemishes *Chair: L. Tsror*
09:00	O14	J. van der Waals University of Pretoria - ZA
09:20	O15	J. Brierley the James Hutton Institute - UK
09:40	O16	S. Gush University of Pretoria - ZA
10:00	O17	A. Keiser BFH-HAFL - CH
10:20	O18	J. Massana Agroscope - CH
10:40		(coffee break)
11:10	K4	D. Boomsma HZPC - NL
		Blackleg and bacterial wilt *Chair: A. Keiser and J. van der Wolf*
11:40	O19	B. Dupuis Agroscope - CH
12:00	O20	J. van der Wolf WUR - NL
12:20	O21	L. Tsror ARO - IL
12:40		(lunch)
14:00		Poster Session P1-P10
14:30	O22	G. Secor North Dakota State University - USA
14:50	O23	J. van der Waals University of Pretoria - ZA
15:10	O24	I. Acuña INIA - CL
15:30		(coffee break)
16:00	O25	Y. Degefu University of Oulu - FI
16:20	O26	K. Sharma CIP - KE
16:40		Technical meeting of the EAPR - Pathology & Pests Section members
16:50		End

Sponsored by: swisssem, Swiss Confederation – Federal Department of Economic Affairs, Education and Research EAER – Federal Office for Agriculture FOAG, fenaco

Wednesday
04.09.19
Excursion

08:30 Bus
09:00 elevated field assays
La Frétaz
10:45 Cheese production
Grandsonnaz
11:30 Lunch
Grandsonnaz

Afternoon
13:00 Seeland
Soil,
pesticide
and
irrigation
16:30 Bus
17:00 Neuchâtel

Conference Dinner
18:10 Cruise on the Lake of Neuchâtel
18:30 cast off
21:30 docking
23:00 Very End

2nd International Spongospora Workshop

Thursday
05.09.19
UNINE - Faculty of Science
Lecture theatre Louis-Guillaume

		speaker
09:00		Workshop Opening
09:10	K1	U. Merz ETHZ - CH
09:50	O1	J. van der Waals University of Pretoria - ZA
10:15	O2	K. Bouchek-Mechiche INRA & RD3PT - F
10:40		(coffee break)
11:10	O3	L. Tsror ARO - IL
11:35	O4	G. Secor North Dakota State University - USA
12:00	O5	J. van der Waals University of Pretoria - ZA
12:25	O6	J. van der Waals University of Pretoria - ZA
12:50		(lunch)
14:10	O7	L. Tsror ARO - IL
14:35	O8	J. van der Waals University of Pretoria - ZA
15:00	O9	C.R. Wilson University of Tasmania - AUS
15:25	O10	C.R. Wilson University of Tasmania - AUS
15:50		(coffee break)
16:20		Closing discussion and remarks (U. Merz)
17:00		End

organized by : U. Merz (CH) and R. Falloon (NZ)

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General information

Reducing pesticide use while preserving potato productivity and profitability

Control of potato pests and diseases in Europe is becoming increasingly difficult due to the reduction of available pesticides. However, this provides a challenge for the research community to find innovative strategies for controlling pests and diseases. Control methods are required with reduced pesticide applications or novel bio pesticides, designed for low impacts on human health and the environment. Several invited speakers will present these important topics in various perspectives.

The organisers invite all potato researchers working on pesticide reduction to submit abstracts for this meeting. In addition, and as usual for the Pathology and Pests Section Meeting, researchers working on topics related to potato pest and diseases are also invited to submit their abstracts. All contributions are warmly welcomed! This conference will be an excellent opportunity for research interaction and collaboration, on a personal basis.

Location

University of Neuchâtel
Faculty of Sciences
Lecture theatre Louis-Guillaume, 2nd floor
Rue Emil-Argand 11
2000 Neuchâtel, Switzerland.

Organising Commitee

Brice Dupuis (Agroscope, CH)
Patrice de Werra (HAFL, CH)
Andreas Keiser (HAFL, CH)
Sergio Rasmann (Unine, CH)
Ruedi Schwaerzel (Agroscope, CH)

Chair, EAPR Pathology and Pests Section

Leah Tsror (ARO, IL)

Coordinators, International Spongospora Workshop

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Swiss Confederation

Federal Department of Economic Affairs, Education and Research EAER
Federal Office for Agriculture FOAG

BIOREBA

Programme

Sunday 01.09.19

Welcome reception at Hotel Alpes et Lac, salle des Lustres

In front of the train station of Neuchâtel

Start 18h00

09:00 Congress Opening

Epidemiology and management Chair: P. de Werra

09:10 K1 **M. Feitknecht** *(Fenaco cooperative – CH)*
Balancing consumers' expectations and self-sufficiency targets : insights from an agricultural cooperative along the food value chain

09:40 O1 **I. Toth** *(the James Hutton Institute – UK)*
Scotland's centre of expertise for plant health.

10:00 O2 **N. Rosenzweig** *(Michigan State University – USA)*
Integrated management of soilborne disease for enhanced soil health in potato production in Michigan, USA.

10:20 O3 **L. Woodell** *(University of Idaho – USA)*
Use of post-harvest applied phosphorous acid for control of potato storage diseases.

10:40 O4 **Ch. Debonneville** *(BIOREBA AG – CH)*
Detection of quarantine and blackleg disease-causing bacteria in potato seeds by PCR.

11:00 coffee break

Vector-borne diseases Chair: B. Dupuis

11:30 O5 **E. Wenninger** *(University of Idaho – USA)*
Effects of potato psyllid vector density and time of infection on zebra chip disease development after harvest and during storage.

11:50 O6 **A. Karasev** *(University of Idaho – USA)*
Strain-specific resistance to potato virus y in potato: effects on strain prevalence in the field.

12:10 O7 **J. Whitworth** *(USDA-ARS – USA)*
Russet potato varieties with resistance to potato mop-top virus and coordinated variety and virus resistance research efforts.

12:30 O8 **D. Levy** *(the Hebrew University of Jerusalem – IL)*
Detection of potato virus Y (PVY) and strain variability in potatoes (*Solanum tuberosum* l.) at different developmental phases by melting analysis of an oligonucleotide virus probe.

12:50 lunch

Oomycetes Chair: L. Weisskopf

14:20 K2 **L. Weisskopf** *(University of Fribourg – CH)*
The potential of potato-associated bacteria and their metabolites for late blight control.

14:50 O9 **A. Lees** *(the James Hutton Institute – UK)*
Potato late blight: tools for integrated pest management.

15:10 O10 **D. Gaucher** *(Arvalis – F)*
Monitoring sensitivity to caa, qii and fluazinam among populations of *Phytophtora infestans* collected from french potato producing areas in 2016 and 2018.

15:30 coffee break

16:00 O11 **C.R. Wilson** *(University of Tasmania – AUS)*
Pink rot of potato – a re-emerging problem in tasmania – characterisation of *Phytophthora erythroseptica* isolate diversity, fungicide resistance, pathogenicity and population dynamics in the soil.

16:20 O12 **K. Bouchek-Mechiche** *(INRA & RD3PT – F)*
Potato leak due to pythium: identification and pathogenicity of associated species.

16:40 O13 **K. Sullam** *(Agroscope – CH)*
Evaluation of potential alternative treatments to control potato late blight.

08:30 K3 **J. Waespe** *(Federal Office for Agriculture – CH)*
Strategy for a sustainable plant protection

Tuber Blemishes Chair: L. Tsror

09:00 O14 **J. van der Waals** *(University of Pretoria – ZA)*
Role of *Rhizoctonia solani* AG 3-PT inoculum source on disease development on potatoes under field conditions in South Africa.

09:20 O15 **J. Brierley** *(the James Hutton Institute – UK)*
Exploring the interaction between soil organic matter and severity of disease on potato caused by *Rhizoctonia solani.*

09:40 O16 **S. Gush** *(University of Pretoria – ZA)*
Elucidating the role of biotic factors and water stress in causing corky crack blemishes on potato tubers in South Africa.

10:00 O17 **A. Keiser** *(BFH-HAFL – CH)*
Monitoring black dot and silver scurf in commercial potato crops from plantation to shop shelf.

10:20 O18 **J. Massana** *(Agroscope – CH)*
Susceptibility to black dot and silver scurf of potato cultivars grown in switzerland.

10:40 coffee break

11:10 K4 **D. Boomsma** *(HZPC – NL)*
Role of resistance breeding in reducing pesticide use on potato

Blackleg and bacterial wilt Chair: A. Keiser and J. van der Wolf

11:40 O19 **B. Dupuis** *(Agroscope – CH)*
Economic incidence of Pectobaterium and Dickeya species on potato crops in Switzerland.

12:00 O20 **J. van der Wolf** *(WUR – NL)*
Use of disease suppressiveness in the battle against potato blackleg.

12:20 O21 **L. Tsror** *(ARO – IL)*
Characterization of *Pectobacterium carotovorum* subsp. *brasiliense* in israel and seed treatemts to control tuber soft rot.

12:40 lunch

14:00 **Poster Session P1-P10**

14:30 O22 **G. Secor** *(North Dakota State University – USA)*
Integrating next generation technologies for blackleg and soft rot management in the usa: a progress report.

14:50 O23 **J. van der Waals** *(University of Pretoria – ZA)*
Irrigation water as inoculum source of soft rotting bacteria

15:10 O24 **I. Acuña** *(INIA – CL)*
Advances in the quantification of *Pectobacterium* spp. in the potato seed as a method to determine seed quality under an integrated management approach in chile.

15:30 coffee break

16:00 O25 **Y. Degefu** *(University of Oulu – FI)*
Fifteen years of monitoring, detection and characterization of soft rot and blackleg causing bacterial species of *Dickeya* and *Pectobacterium* in the High Grade seed potato growing area in north Finland.

16:20 O26 **K. Sharma** *(CIP – KE)*
Emerging and re-emerging *Ralstonia solanacearum* species complex strains causing bacterial wilt of potato in Sub-Saharan Africa.

16:40 Technical meeting of the EAPR - Pathology & Pests Section members

Wednesday 04.09.2019 — Excursion and conference dinner

Morning excursion

8h30 Start in front of the Hotel des Arts

Visit of the agronomic fields trials site La Frétaz above the Lake of Neuchâtel, one of the highest (1’200 m.a.s.l) agronomic site in Europe.

Lunch at the “low alpine” Restaurant La Grandsonnaz-Dessus (1’486 m), and visit of the local cheese production.

Afternoon excursion

Vegetables Production in the Seeland aera, an ancient floodplain which is now the most important regions in Switzerland for growing vegetables.

17h00 Back in Neuchâtel

18h00 Conference dinner (meeting point at the Shipping Pier Neuchâtel) – cast off at 18h30.

Cruise on the Lake of Neuchâtel and the Lake of Morat. Dinner is served on board. Take a Jacket with you!

Docking at 21h30

Very end at 23h00

Thursday 05.09.2019

International *Spongospora* Workshop

Program available separtly

Abstracts oral presentations

Keynote speakers

K1

BALANCING CONSUMERS' EXPECTATIONS AND SELF-SUFFICIENCY TARGETS : INSIGHTS FROM AN AGRICULTURAL COOPERATIVE ALONG THE FOOD VALUE CHAIN

Michael Feitknecht

fenaco cooperative Bern, Switzerland

The fenaco/LANDI Group (fLG) is an agricultural cooperative which was founded from six regional cooperatives in 1993, with the purpose to support the farmers in the economic development of their businesses. In its four strategic business fields, the fLG operates with extended activities along the value chain, and therefore is an important link between producers and consumers. In its sustainability goals, fLG aims to play a leading role in the market of alternative crop protection. Minimizing risk in the use of plant protection products and supporting its farmers in implementing strategies will help to achieve this objective.

The sustainable cultivation of crops in Switzerland requires an adequate protection against weeds, diseases and pests, regardless of the production method. Crop failures or quality-related failures lead to increased food waste, to financial losses for the producer and to fluctuations in market coverage. This can cause the loss of profitability of the local production and thus increase food imports as a substitution. In order to avoid this development and continue to offer consumers market-compliant domestic products, the use of plant protection products must continue to be adequately available as a possible option in the future. At the same time, the public perception and the consumer's expectations increasingly turn against chemical-synthetic plant protection.

With various initiatives, fLG is already working to ensure that Swiss food production can continue to increase in terms of safety, quality and sustainability. The support of research projects in collaboration with ETH, Agroscope and other institutions is a key pillar in this approach. fLG also supports the Plant Protection Action Plan of the Swiss government, for example with the promotion of cover crops and the use of beneficials (Trichogramma / maize). Moreover, fLG invests in the development of innovative concepts with the combination of technologies such as beneficial drones, hacking robots and digital consulting.

K2

THE POTENTIAL OF POTATO-ASSOCIATED BACTERIA AND THEIR METABOLITES FOR LATE BLIGHT CONTROL

Mout De Vrieze, Delphine Chinchilla, Sébastien Bruisson, Silvan Meyer, Fanny Germanier, Charlotte Joller, Abhishek Anand, Floriane L'Haridon and Laure Weisskopf

Department of Biology, University of Fribourg, Chemin du Musée 10, CH-1700 Fribourg

Plants are colonized by a diverse microflora both at the root and at the shoot level. This microbiome is thought to contribute to plant health, e.g. by depriving pathogens of important resources, by secreting antimicrobial compounds or by inducing the plant immune defenses. We are interested in understanding how the plant microbiome contributes to the health of its host and we are using potato late blight as a model system to investigate this question. One major aspect of our research deals with the emission of disease-inhibiting volatile organic compounds (VOCs) by plant-associated bacteria. Earlier work has shown that the oomycete *Phytophthora infestans* causing late blight was particularly sensitive to such volatile metabolites. We also discovered that one chemical group of molecules, the sulfur-containing volatiles (S-VOCs), showed very promising anti-*Phytophthora* activity. Later work revealed that one compound in particular was able to inhibit the spread of the disease on plant material too, without being phytotoxic, while other S-VOCs showed the same efficiency but with much higher phytotoxicity. We investigated whether the disease-inhibiting effect of these S-VOCs was due to an induction of plant defenses, but quantification of the expression levels of several genes involved in different plant immunity pathways revealed that it was not the case. In contrast, a proteomic approach revealed that the disease-inhibiting activity was linked to strong perturbation in the oomycete metabolism. Proteins involved in detoxification, in redox balance and in sulfur metabolism showed altered expression levels in S-VOCs-exposed *P. infestans* hyphae compared with solvent-exposed controls. This suggests that S-VOCs naturally emitted by potato-associated bacteria contribute to potato defense against late blight. The extent to which these promising results will be transferable into late blight control strategies will largely depend on ongoing studies investigating non-target effects of these potent anti-oomycete metabolites. In parallel to the study of S-VOCs emitted by potato-associated bacteria, our research also deals with the direct use of these bacterial strains to develop new biological control agents against late blight. Detailed phenotypic and genomic characterization of nine *Pseudomonas* strains isolated from potato roots and shoots revealed their differing abilities to interfere with several developmental stages of the pathogen, to inhibit disease in leaf disc experiments, and to colonize different potato cultivars as epiphytes (on the surface) or endophytes (inside the plant). Combining strains of differing modes of action led to more consistent protection of three cultivars against late blight, suggesting that strain consortia might be more promising than single strains to efficiently control potato late blight. Finally, the disease-protecting potential of selected *Pseudomonas* was tested against a newly assembled collection of *P. infestans* isolates differing in mating type, genotype, virulence profile and fungicide resistance. This study revealed that the sensitivity of the *P. infestans* isolates was in general negatively correlated with virulence, but that some *Pseudomonas* could efficiently inhibit virulent and fungicide-resistant *P. infestans* isolates. Altogether, these results highlight native potato-associated *Pseudomonas* and their metabolites as promising tools for efficient and sustainable control of potato late blight. Our aim is now to test their protective effects in greenhouse and field experiments.

K3

STRATEGY FOR A SUSTAINABLE PLANT PROTECTION

Jan Waespe

Federal Office for Agriculture, Switzerland

The Federal Council has approved the Swiss national action plan for plant protection products in September 2017. The action plan aims to reduce the use of plant protection products (PPP) and to minimize the emissions into the environment. He set therefore measurable and ambitious goals for the next 10 years and defined 51 measures to reach these goals. A good quarter of all measures are already implemented today. These are for example new contributions for a production without herbicides, contributions for washing places or stricter application rules to reduce run-off risks.

With the agricultural policy 22+, additional measures should be introduced to support the action plan. The proof of ecological performance to get direct payments in Switzerland should be strengthen: The use of PPP with an enhanced risk for the environment should be restricted, drift and run-off should be reduced by 75% and point sources should be reduced by 95%. In addition, production systems with a renunciation or reduction on fungicides, insecticides and herbicides should be supported.

The number of authorized PPP decreased the last years. On the other hand, demands on quality of consumers are constantly high. This is a challenge for producers, especially for producers of specialty crops. The development of new plant protection methods is needed.

K4

ROLE OF RESISTANCE BREEDING IN REDUCING PESTICIDE USE ON POTATO

Doretta Boomsma

HZPC Research B.V., The Netherlands

Theme of the EAPR Pathology & Pests symposium is “Reducing Pesticide use while preserving potato productivity and profitability”. Worldwide the annual production of potato is about 388 mln tonnes and the acreage about 20 mln ha. This intensive potato cultivation tends to increase pest and disease pressure, which often leads to intensive use of harmful pesticides. Resistant potato varieties and improved cultural practices can reduce or eliminate many common pests and diseases. HZPC is the innovative global market leader in potato breeding, seed potato trade and product concept development. Our vision and mission is respectively to develop food for the increasing world population and inspire the potato value chain worldwide. Because of climate change the percentage of available agricultural land is decreasing and, alongside the need of growers and customers, there is a social requirement for responsible agriculture. This is also one of the key issues of the United Nations Sustainable Development Goals (SDG) defined for 2030. Connected to these SDGs are the Corporate Social Responsibility (CSR) goals, also introduced within HZPC. One of the CSR goals which is a major concern of stakeholders and with major impact on HZPC is the development of new varieties maximizing/securing yield with reduced input! This requires not only resistant varieties, but also varieties efficient in water usage and nutritional values. HZPC wants to take all factors into account, from the quality requirements of the market, to growing conditions that are both ecologically and economically sound. Looking at the requirements from the market and for responsible agriculture on one side, and the complexity of potato breeding on the other side, developing sustainable resistant varieties is a great challenge. A way to show the ‘What’, ‘How’ and ‘When’ of resistance breeding is by using a so-called SWOT analysis: what are the Strengths, Weaknesses, Opportunities and Threats for Resistance breeding? Which Strengths can a breeding company use for developing resistant varieties? What are the Weaknesses/Bottlenecks within a company which can be improved? Which external developments can be considered as opportunities for resistance breeding and should be exploited? And finally, what are external threats which should be mitigated? Based on this SWOT analysis we can draw some conclusions on the role of resistance breeding in reducing pesticide use on potato.

Epidemiology and management

1_E_1 (01)

SCOTLAND'S CENTRE OF EXPERTISE FOR PLANT HEALTH

Ian K. Toth[1], A'Hara D[2], Burnett F[3], Hollingsworth P[4], Humphris S[1], Quine C[5], Saddler GS[2]

[1] *James Hutton Institute (JHI), Dundee DD2 5DA, UK*
[2] *SASA, Edinburgh, EH12 9FJ, UK*
[3] *Scotland's Rural College (SRUC), Edinburgh, EH9 3JG, UK*
[4] *Royal Botanic Garden Edinburgh (RBGE), Edinburgh, EH3 5NZ, UK*
[5] *Forest Research (FR), Edinburgh, EH25 9SY, UK*

The Plant Health Centre was set up by the Scottish Government in 2018 to help tackle plant health challenges for Scotland. The Centre works directly with the Chief Plant Health Officer for Scotland, Professor Gerry Saddler from SASA (a Division of Scottish Government), bringing together plant sectors for forestry, horticulture, environment and agriculture. Working with Scottish Government, public bodies and other stakeholders, we mobilise knowledge and provide scientific evidence and support for improved decision making and responses to threats from new and indigenous pests and pathogens to Scotland. The Centre is led by the James Hutton Institute, and has sector leads from Scotland's Rural College (agriculture), Royal Botanic Garden Edinburgh (horticulture and environment) and Forest Research (forestry).
Our Science Advisory and Response Team have been chosen from organisations across Scotland and England to bring a range of skills relevant to plant health, ranging from understanding of public perceptions to long-term disease forecasting.

Our main aims are to:

- Strengthen resilience and emergency response plans.
- Provide scientific evidence to support policy decisions and outbreak management.
- Improve rural industry resilience in Scotland.
- Enhance Scotland's capacity and capability to respond to threats and assemble scientific evidence.
- Contribute to expanding interdisciplinary networks to improve capacity to respond to threats across all plant health sectors.
- Engage effectively with stakeholders, providing evidence to meet their needs and encourage uptake of findings.

This presentation will look back over our first year of operation and to the future.

1_E_2 (O2)

INTEGRATED MANAGEMENT OF SOILBORNE DISEASE FOR ENHANCED SOIL HEALTH IN POTATO PRODUCTION IN MICHIGAN, USA

Noah Rosenzweig

Michigan State University, East Lansing, MI USA 48824

Potatoes (*Solanum tuberosum*) are consumed as fresh, chipping, frozen, or starch products and tubers must meet a high-quality standard in terms of cosmetic and physical appearance from producers. Potato production in Michigan ranks seventh nationally in the United States (US) with a farm gate value of nearly US$208 million annually. Approximately 70% of production in the state goes towards the chip processing industry. Over the last decade some potato growers in certain production areas of the both Michigan and the US have been experienced declining yields and marketability issues. Nearly 90% of major diseases that impact crops (including potato) are caused by soilborne pathogens. Soilborne disease complexes such as Verticillium wilt caused by *Verticillium dahliae* and potato common scab caused by *Streptomyces* spp. are recognized as a major cause of yield and quality declines. There is an increased awareness among growers across the US that current potato crop management practices such as intensive tillage and lack of crop rotation may be leading to an increase in soilborne disease and reduction in productivity of soils used in commercial production. Novel management strategies are needed to reduce losses due to diseases and enhance soil health in potato production. The improvement in our understanding of soil health, ultimately leading to a reduction of soilborne disease and crop inputs, will likely promote sustainable potato production in terms of environmental quality as well as economics. This presentation will highlight past, current, ongoing and future research focused on soil health and soilborne disease management in both Michigan and US potato production systems. These include: 1. Traditional field efficacy trials evaluating the direct and indirect impact on soil microbes (pathogenic and non-pathogenic); 2. Disease suppressive soils in potato production and 3. The use of spatial analyses and geostatistics to evaluate the consistency of relationships in space among biological, chemical, physical soil assessments, soilborne disease and plant health/productivity data. Finally, a recent joint effort by the US potato industry and US research community in securing a nationally coordinated agricultural research project funded by the United States Department of Agriculture National Institute of Food and Agriculture will be discussed.

1_E_3 (O3)

USE OF POST-HARVEST APPLIED PHOSPHOROUS ACID FOR CONTROL OF POTATO STORAGE DISEASES

Lynn Woodell[1], Nora Olsen[1], Jeff Miller[2], Phillip B. Hamm[3]

[1] *Department of Plant Sciences, University of Idaho, Kimberly, Idaho, USA*
[2] *Miller Research, Rupert, Idaho, USA*
[3] *Department of Botany and Plant Pathology, Oregon State University, Hermiston, Oregon, USA*

Harvesting and handling potatoes provide an opportunity for infected potatoes to come in contact with and/or provide inoculum to infect healthy tubers, which can lead to disease spread in storage. A post-harvest product application may be a tool to mitigate the risk of disease development in storage from field infected potatoes and/or to protect healthy potatoes from subsequent infection in storage. A series of experiments was conducted, which targeted multiple common storage diseases in North America, to evaluate how post-harvest applications of phosphorous acid (PA) may fit into a disease control program. Disease causing organisms studied included Phytophthora infestans (late blight), *Phytophthora erythroseptica* (pink rot), *Helminthosporium solani* (silver scurf), *Fusarium sambucinum* (dry rot) and *Pythium ultimum* (leak). Inoculated tubers were treated with a post-harvest spray application of PA, or other potential products, and water as a control treatment. All treatments were applied in an aqueous low volume spray at 2.1 ml/kg of tubers. Tubers were stored at an appropriate temperature (5.6-21°C) and interval (4 days-6 months) to optimize specific disease development prior to evaluation. Experimentation over 15 years demonstrated consistent and significant efficacy with post-harvest PA treatments to reduce late blight and pink rot development in storage. Product rate experiments confirmed PA to be effective at varying rates depending upon target disease, although large scale studies identified 335g a.i/MT as the PA rate for consistent results. Further studies revealed PA to be effective in controlling late blight and pink rot development when applied up to 6 hours post-inoculation. Comprehensive studies over 7 years demonstrated significant reduction in silver scurf development in storage with PA post-harvest sprays. Regardless of tuber maturity or disease pressure, PA spray applications did not provide control of dry rot development in storage. Recent studies targeting means to control leak in storage showed little to no reduction in leak development with PA applications. Although PA post-harvest applications do not offer significant dry rot or leak control, PA products have substantial application in the reduction of late blight, pink rot and silver scurf disease development and should be considered as a tool in post-harvest disease control program.

1_E_4 (O4)

DETECTION OF QUARANTINE AND BLACKLEG DISEASE-CAUSING BACTERIA IN POTATO SEEDS BY PCR

Christophe Debonneville, Denise Altenbach, and Dijana Stolz

BIOREBA AG, Christoph Merian-Ring 7, 4153 Reinach, Switzerland.

Potato is a vegetatively propagated crop and numerous diseases can be carried from one generation to the next. Pests like bacteria, viruses, fungi, and nematodes can cause significant damages (yield losses in field and in storage conditions).

The bacterium *Clavibacter michiganensis* subsp. s*epedonicus* (Cms) causing bacterial ring rot, and the bacterium *Ralstonia solanacearum* causing serious wilt disease in potato (bacterial wilt) are two major pathogens of potato. Both are regulated quarantine pests (EPPO lists). They can cause severe yield losses.

Another important group of bacteria are the pectolytic bacteria causing blackleg and soft rot diseases. Infection by various *Dickeya* and *Pectobacterium* species can lead to yield reduction and storage losses.

To avoid the spread of these economically significant diseases, monitoring of the pathogens in potato seeds is crucial. We will present methods, implemented in our testing laboratory as routine nucleic acid-based tests, to detect these bacteria in dormant tubers.

Vector-borne diseases

2_V_1 (05)

EFFECTS OF POTATO PSYLLID VECTOR DENSITY AND TIME OF INFECTION ON ZEBRA CHIP DISEASE DEVELOPMENT AFTER HARVEST AND DURING STORAGE

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"*Candidatus* Liberibacter solanacearum" (Lso) is an uncultured, phloem-limited bacterium that is associated with zebra chip disease (ZC) in potato and transmitted by the potato psyllid. Vector density and timing of infection have been shown to affect ZC prevalence at harvest; however, little work has been done on disease development during storage. Here we confirm with field-cage trials that ZC prevalence at harvest was greater with increased time between inoculation and vine kill. Moreover, we show that under growing conditions in the US Pacific Northwest, ZC can develop over time during storage. Plants inoculated 2 to 3 weeks before vine kill showed little or no ZC symptoms in tubers at harvest, but higher prevalence of symptoms after 3 months in storage. For plants inoculated at 4 to 5 weeks before vine kill, tubers exhibited notable symptoms at harvest, but still showed evidence of symptom development after storage. Plants inoculated within 1 week before vine kill exhibited little or no risk of ZC in tubers at harvest or after storage. Higher vector density tended to contribute to ZC prevalence, but was less important than timing of infection. These results underscore the potential danger of underestimating ZC prevalence at harvest for tubers being stored long term, and suggest that plants at risk of Lso infection should be protected from potato psyllids until at least 2 weeks before vine kill.

STRAIN-SPECIFIC RESISTANCE TO POTATO VIRUS Y IN POTATO: EFFECTS ON STRAIN PREVALENCE IN THE FIELD

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Potato virus Y (PVY) exists as a complex of strains adapted to different species of *Solanaceae*, and, more importantly, to different potato cultivars. In the past ten years, strain composition of PVY in potato in the United States changed from predominantly non-recombinant PVY^{O} to predominantly recombinant $PVY^{N\text{-}Wi}$ and PVY^{NTN} strains. These changes in strain prevalence correlated with a gradual rise in popularity of potato cultivars expressing various degrees of strain-specific resistance to PVY^{O}. Laboratory and semi-field experiments suggested that this strain-specific resistance was expressed as an incomplete or partial hypersensitive resistance (HR) that led to selection of recombinant PVY strains capable of overcoming this HR. Due to the wide availability of multiple HR genes in commercial potato cultivars, and the high volume of international trade in seed potato, further changes in PVY strain prevalence may be anticipated. This should be taken into account by the potato breeding programs, by the potato seed certification agencies, and by the diagnostic laboratories.

2_V_3 (O7)

RUSSET POTATO VARIETIES WITH RESISTANCE TO *POTATO MOP-TOP VIRUS* AND COORDINATED VARIETY AND VIRUS RESISTANCE RESEARCH EFFORTS

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The detection of *Potato mop-top virus* in the U.S. and Canada started in 2001 and continued to be reported across the U.S. into 2014. Grower options for controlling the vector, *Spongospora subterranea* remain limited. Recent advances in testing soil samples for the vector and now for the virus itself have given growers a tool for detecting infested fields. To provide options for production fields with a history of spraing associated with PMTV, breeding efforts are now focusing on resistant varieties.

Replicated field plots in an infested field in central Washington state were used to screen new and advanced breeding clones from the USDA, Aberdeen, Idaho breeding program. These trials have been done over a five-year period. Five hill plots with four replications were planted into the field and normal cultural practices followed. At harvest, tubers from the plots were placed in cold storage until January. Sub-samples were tested with RT-PCR for *Tobacco rattle virus* and PMTV. These samples were cut into four sections and scored for presence of spraing and disease severity.

A wide range of symptoms were found in the clones entered into the trial. A number of symptomless PMTV positive clones were detected and those with symptoms ranged from 0 to 47% depending on the year. Clones that showed resistance, or at least insensitivity to symptoms were identified. Two varieties (Castle Russet, Pomerelle Russet) have been developed that show some resistance to PMTV associated spraing. Two of these varieties are now being trialed in a grower field in eastern Idaho and tubers will be assayed at harvest like what was described.

Few options are available to growers when a PMTV infested field is detected. The ability to plant a variety that has resistance to either the virus or the vector will allow continued production in an infested field. A soil test can now be used to detect the virus before a field is planted will allow growers to survey fields and determine whether to plant potatoes in affected fields. Presently, varieties which are asymptomatic (insensitive) but still harbor the virus give growers the opportunity to produce a crop on infested fields. Ultimately, varieties which are resistant to the virus will offer the best option. Breeding efforts are ongoing and focused on resistance to the virus. Multiple researchers are collaborating in a Specialty Crop Research Initiative grant focused on tuber necrosing viruses, including PMTV.

DETECTION OF POTATO VIRUS Y (PVY) AND STRAIN VARIABILITY IN POTATOES (*SOLANUM TUBEROSUM* L.) AT DIFFERENT DEVELOPMENTAL PHASES BY MELTING ANALYSIS OF AN OLIGONUCLEOTIDE VIRUS PROBE.

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In the Middle East, potatoes are cultivated twice a year, in the spring season and in the autumn-winter seaon. ‘Seed’ tubers for the autumn and winter plantings are produced locally in the preceding spring. The short time from harvest to planting does not permit grow-out tests for contamination control. Hence, a fast and accurate alternative assay for detection of tuners' born PVYis of paramount importance. Recently, We have developed a novel test based on a melting analysis of an oligonucleotide virus probe that identifies a mixture of PVY strains in a single test vial within 24-48 hours.

Field-grown tubers of potato (*Solanum tuberosum* L.) cultivars 'VR808', 'Gabriel', 'Joshua', and 'Caruso' were assayed by this method to assess the presence of Potato Virus Y (PVY) strains during maturation in the field, during storage and at sprouting. The melting analysis of an oligonucleotide virus probe was employed to detect and identify PVY strains. PVY was detected in tubers throughout these phases. Assays of the ‘rose end’ and the ‘heel end’ of tubers harvested in the spring prior to foliage desiccation provided a fast and efficient estimation of PVY incidence of ‘seed tubers’ grown for planting in the consequent seasons, thus allowing the rejection of virus-infected propagation material. Naturally occurring mixtures of the Potato Virus Y (PVY) strains O-FL, O-RB, N and NTN were identified in the ‘rose end’ and the ‘heel end’ of the tubers. Variations in the composition of PVY strains were observed in tubers and in the young leaves grown from the same tubers in a grow-out assay. The melting analysis of an oligonucleotide virus probe is shown to provide an accurate, fast and efficient method for PVY detection and strain identification in pre-dormant and dormant tubers. It can reduce PVY risks in the potato culture in the Middle East, in the Mediterranean basin and elsewhere, where two crops a year is common.

N. Rotem & C. Shtein & A. Rosner & D. Levy & H. D. Rabinowitch. 2016. Detection and Differentiation of Potato Virus Y Strains by Melting Analysis of an Oligonucleotide Virus Probe. Am. J. Potato Res. 93:620–625.

3_0_1 (09)

POTATO LATE BLIGHT: TOOLS FOR INTEGRATED PEST MANAGEMENT

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Potato late blight (*Phytophthora infestans*) is one of the most destructive and economically important crop diseases. Typically, UK potato farmers apply late blight fungicides prophylactically in a 7-10 day programme, resulting in 10-15 applications per season on average. Although chemical control is largely effective, crop losses are not always completely prevented and conversely, some fungicide applications may be unnecessary in a low disease risk year. Late blight control in the UK costs approximately £350/ha and up to £72M p.a. during high pressure blight seasons. Across Europe, the total financial loss associated with late blight is estimated at €1bn, representing 15% of the total farm gate price.
IPM approaches to late blight control, which could potentially reduce these inputs, are attractive. However, significant barriers to uptake remain, due to the risk, or the perception of risk, of total crop loss should these methods fail. This paper discusses a range of current and future IPM 'tools' and the drivers and barriers to uptake.
Control options include the use of host resistance, disease risk forecasting and optimal fungicide use, alone and in combination. The importance of a genotypic, and more critically a phenotypic, understanding of the local and international *P. infestans* populations, gained through initiatives such as the 'Fight Against Blight' campaign and the Euroblight network on practical control decisions, and ultimately IPM programmes, will be described.
Late blight risk forecasts typically assume that viable inoculum is ubiquitous and make a prediction based on the suitability of weather conditions for infection. The Hutton criteria are a set of weather conditions which reflect the characteristics of the current pathogen population and improve upon the accuracy of previously used infection risk criteria. However, viable inoculum is not always present and therefore such risk forecasts provide a conservative estimate of risk, potentially leading to unnecessary chemical applications. This is particularly the case at the start of a growing season when accurate information on risk is required to inform the initiation of a spray programme. Accurate prediction of high risk periods is also essential throughout the growing season in order to inform the use of the most effective products.
Although challenging, the aim of late blight IPM is to combine robust components in order to optimise the targeted and sustainable use of fungicides for effective disease management.

MONITORING SENSITIVITY TO CAA, QII AND FLUAZINAM AMONG POPULATIONS OF *PHYTOPHTORA INFESTANS* COLLECTED FROM FRENCH POTATO PRODUCING AREAS IN 2016 AND 2018.

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The main objective of this project was to characterize the sensitivity of *P. infestans* to several modes of action: CAA (dimethomorph, mandipropamid,…), QiI (cyazofamide, amisulbrom) and fluazinam.
ARVALIS (with the technical help of GERMICOPA) has set up, thanks to their collaborators and partners, potato late blight sampling in several commercial plots located in different production regions in France.
In 2016, 62 samples were received at the laboratory (CONIPHY) and 34 populations could be studied normally on the 3 modes of action. 2016 was the first campaign to implement this monitoring with an original experimental approach (population study, leaf disc tests, observation of symptoms under controlled conditions). In 2017, due to a very dry and hot weather, it was not possible to study any populations but in 2018, 32 populations were received at the laboratory and 25 populations could be studied normally on the 3 modes of action. This approach makes it possible to draw the following conclusions from the 34 populations in 2016 and 25 populations in 2018 analyzed on the 3 modes of action selected for these studies.

- Situation regarding CAA

The sensitivity of the populations of *P. infestans* is practically normal with respect to dimethomorph and more broadly CAA with a perfect control at a dose of 3 mg/l for 97% of the samples in 2016 and 92% in 2018. In 2016, just one population developed some symptoms in the presence of this dose of 3 mg/l. In 2018, only two populations developed some symptoms in the presence of this dose of 3 mg/l, or even 30 mg/l for a population. However, the complementary tests did not make it possible to isolate strains from these lesions (poor viability, very low frequency). The CAA still does not seem to be really affected by any particular resistance of the potato late blight in the context of this sampling network.

- Situation regarding QiI

All populations are perfectly controlled by the dose of 1 mg/l of cyazofamide. This dose of 1 mg/l is also the discriminating dose for other pathogens and in particular the grapevine downy mildew (*Plasmopara viticola*).The potato late blight sensitivity to QiI therefore remains normal.

- Situation regarding fluazinam

In 2016, first year of study with the detailed methodology, we identified at least 6 populations not controlled by the highest concentration of fluazinam. In 2018, we identified at least 11 populations (out of a total of 25) not controlled by the highest concentration of fluazinam (30 mg/l). These populations are clearly different from the basic sensitivity of this molecule. They are detected in all production basins. This criterion of resistance to fluazinam was validated during complementary tests on the populations but also on strains obtained from these samples.

3_0_3 (O11)

PINK ROT OF POTATO – A RE-EMERGING PROBLEM IN TASMANIA – CHARACTERISATION OF *PHYTOPHTHORA ERYTHROSEPTICA* ISOLATE DIVERSITY, FUNGICIDE RESISTANCE, PATHOGENICITY AND POPULATION DYNAMICS IN THE SOIL

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Pink rot of potato caused by the fungal pathogen *Phytophthora erythroseptica* is characterised by pink colouration of cut tubers exposed to air and a distinctly unpleasant odour. The rapid rotting of the tubers, whether in ground or in storage, results in significant yield losses and product downgrades or rejection. In Tasmanian over the last two years the incidence and impact of pink rot have increased substantially resulting in significant losses to the potato industries. This project is characterising isolates of *P. erythroseptica* collected from major growing regions in Tasmania. Genetic diversity was characterised morphologically using plate growth assays, pathologically using *in vitro* plug infection assays of whole potato tubers, and genetically by comparison of multiple conserved gene sequences. Because of the frequent usage of metalaxyl in commercial production the isolates were also tested for growth inhibition in plate assays amended with metalaxyl to examine if there was any evidence of fungicide resistance, which has been reported in other countries. Analysis of collected isolates remains preliminary and will be fully reported at the meeting. In addition, soil pathogen inoculum levels were measured by qPCR from several commercial fields which enabled pathogen dynamics to be determined through the growing season. Varying levels of the pathogen were identified from field environments with distinct changes over the cropping period recorded. The insights provided in this study provide useful knowledge on the biology of this important pathogen, a prerequisite for development of sustainable control options.

POTATO LEAK DUE TO PYTHIUM: IDENTIFICATION AND PATHOGENICITY OF ASSOCIATED SPECIES

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Potato “leak” occurs in most areas where potatoes are grown, and is particularly problematic as a cause of post-harvest tuber decay and rotting. The primary causal agent of potato leak in Canada and the USA is *Pythium ultimum var. ultimum*, and *P. aphanidermatum* in warmer regions (eg. Tunisia). A number of other *Pythium* spp. have also been isolated from tubers, but their prevalence and pathogenicity on potato have not been well documented to date. The aims of our study are thus 1) to identify the main species associated with potato leak in France, 2) to assess their pathogenicity and finally 3) to study their biology.
The occurrence of *Pythium* spp. was determined by collecting isolates from 81 potato lots with tuber leak symptoms, originating from different areas in France between 2016 and 2018. Different methods and media for isolation were compared in order to enhance the efficacy of *Pythium* isolation. The most efficient method allowed the isolation of 150 strains belonging to eight different *Pythium* species, according to phylogenetic analysis of the rDNA ITS region: *P. utltimum ultimum, P. sylvaticum, P. intermedium, P. paroecandrum, P. glomeratum, P.attranheridium, P. heterothallicum*, and one unidentified *Pythium* sp. The prevalence of the different species within the 81 lots was 65% for *P. ultimum ultimum*, 15% for *P. sylvaticum* and 9 % for *P. intermedium*. The frequency of any other species did not exceed 3% each. Under controlled conditions, *P. ultimum ultimum* isolates proved more pathogenic than other species, whatever the tested cultivars. The infection rate by *P. sylvaticum* isolates was low to moderate, whereas the rate of infection by *P. intermedium* and *Pythium* sp isolates was moderate to high. The less common species were either not pathogenic or weakly pathogenic. The optimum temperatures for growth and infection of the different species, as well as the behaviour of a set of potato cultivars are currently under investigation.

3_O_5 (O13)

EVALUATION OF POTENTIAL ALTERNATIVE TREATMENTS TO CONTROL POTATO LATE BLIGHT

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To reduce copper use in organic potato production, we evaluated the use of alternative treatments and their combination with reduced copper regimes to control potato late blight. The alternative treatments included a botanical, a microorganism, electro-chemical activated water and a plant elicitor. Compared to the untreated control, the botanical and reduced copper treatments both with and without the addition of an alternative product were more successful at controlling late blight. However, no substantial difference between the reduced copper treatment and the reduced copper treatment with alternative products was found. These results suggest that the application of a decreased copper amount can help to control late potato blight to the same degree that the addition of the evaluated alternative products do. The utilization of the decision support system, (Bio-) PhytoPRE, may help improve the results of the alternative products, particularly if the model is adapted to their mode of action and the best window for spraying is established. To address possible shortcomings with PhytoPRE, planned work to fine-tune the decision support system PhytoPRE with the use of field sensors will be discussed.

4_T_1 (014)

ROLE OF *RHIZOCTONIA SOLANI* AG 3-PT INOCULUM SOURCE ON DISEASE DEVELOPMENT ON POTATOES UNDER FIELD CONDITIONS IN SOUTH AFRICA

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The fungus *Rhizoctonia* causes severe qualitative and quantitative economic losses to potato production. Management of *Rhizoctonia* diseases on potatoes relies on integrated strategies that include fungicide application, use of tolerant varieties, crop rotation, seed certification systems and biocontrol agents. *Rhizoctonia* disease epidemics on potato crops caused by AG 3-PT can be initiated by soil- and/or seed tuber-borne inoculum. The relative importance of seed tuber- and soil-borne inoculum of *R. solani* AG 3-PT on potato disease development and the genetic structure changes of a *R. solani* AG 3-PT experimental field population over the growing season were evaluated and investigated. Two distinct sets of genetically-marked isolates as revealed by PCR-RFLP analysis were used as seed tuber-borne and soil-borne inocula in a mark-release-capture experiment. Both inoculum sources were found to be equally important in causing black scurf disease, whereas soil-borne inoculum appeared to be more important for root and stolon infection, and seed-borne inoculum contributed more to stem canker. The proportion of isolates with genotypes that differed from the inoculants increased over the growing season and across growing seasons indicating the possibility of gradual genetic evolution of the pathogen in the field. Therefore, efforts to reduce primary inoculum should focus on reducing pathogen population on seed tubers to prevent introduction of different genotypes into the field.

4_T_2 (O15)

EXPLORING THE INTERACTION BETWEEN SOIL ORGANIC MATTER AND SEVERITY OF DISEASE ON POTATO CAUSED BY *RHIZOCTONIA SOLANI*

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Interactions between soil organic matter (SOM) and disease on potato caused by *R. solani* are complex and dependent upon the composition of the organic matter. Organic matter incorporated into field soils can have antagonistic properties on soil-borne *R. solani* and result in decreased disease severity on potato, but conversely, increasing SOM may provide a substrate which enhances mycelial growth of the pathogen resulting in increased disease severity. We have been investigating the impact of SOM on disease caused by *R. solani* through a combination of glasshouse experiments, field trials and monitoring of a 6- year rotation. The rotation is an experimental platform which includes a comparison of soil management practices which in turn affects the level of SOM. Through monitoring soil and seed inoculum levels pre-planting (determined by real-time PCR) and visually assessing tubers post-harvest we have found that an increased level of SOM appears to be correlated with an increased risk of black scurf on progeny. Additionally, in a field trial which had been amended with *R. solani* prior to planting, plots in which a typical source of OM used in Scottish Agriculture (barley straw mixed with cattle manure) had been incorporated resulted in delayed emergence, and had a significantly higher rate of stolon pruning than plots which had no added SOM. Further investigations to explore the interaction between SOM and disease caused by *R. solani* have been undertaken in the glasshouse.

4_T_3 (O16)

ELUCIDATING THE ROLE OF BIOTIC FACTORS AND WATER STRESS IN CAUSING CORKY CRACK BLEMISHES ON POTATO TUBERS IN SOUTH AFRICA

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Potato tuber blemishes are of economic importance in potato production since they reduce the quality of potato tubers destined for seed and fresh produce markets. In recent years, the incidence of potato tuber blemishes such as 'corky cracks' has been on the increase in South Africa and other potato producing areas globally. Various reports have attributed *Streptomyces* and *Rhizoctonia* species, and viruses like Potato Virus Y (PVY) to be the cause of many tuber blemishes including corky cracks. Previous research by Gush et al. (2019) showed that *Rhizoctonia solani* AG2-2 IIIB is not associated with corky cracks but causes elephant hide on potato tubers in South Africa.
In an effort to confirm the causal agent(s) of corky crack blemishes, bacterial and fungal species were isolated from corky crack symptoms on potato tubers sampled from different potato growing regions of South Africa. Bacterial and fungal species were identified by morphological and molecular techniques. *Streptomyces yaanensis, S. cinerochromogenes, S. viridochromogenes, S. corchorussi, S. griserubens* and *S. collinus* were the most common bacterial species isolated. *Rhizoctonia solani* AG-A and *R. solani* AG-R as well as *Fusarium oxysporum* were the predominant fungal species isolated from the corky crack symptoms. Pot trials using the isolated microorganisms alone and in combination were done to confirm Koch's postulates. *R. solani* AG-3PT was also incorporated into the pot trials. No corky crack symptoms were observed in single inoculations for either fungal or bacterial microorganisms, however, corky crack symptoms were observed on the progeny tubers inoculated with a combination of the three *Rhizoctonia* species. This suggests a synergistic interaction between the three *Rhizoctonia* species. Disease index was higher under normal watering conditions, suggesting the fungal preference to moisture for infection to take place. Results from PVY screening suggest that no corky crack symptoms are associated with viral infection.

Assuming that corky cracks are of biological origin, further work on microbial profiling of culturable and unculturable microoganisms from which the causative agent can be deciphered is currently in progress. Correctly identifying and establishing the causative agent(s) of this disease in South Africa will help in the deployment of integrated control strategies to prevent the recurrence of the disease.

Keywords: Corky crack blemishes, *Streptomyces* species, *Rhizoctonia solani*, viruses, synergistic interactions, microbial profiling

4_T_4 (O17)

MONITORING BLACK DOT AND SILVER SCURF IN COMMERCIAL POTATO CROPS FROM PLANTATION TO SHOP SHELF

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In recent years, silver scurf (*Helminthosporium solani*) and black dot (*Colletotrichum coccodes*) have caused significant economic losses along the potato supply chain in Switzerland. In a collaborative project launched by HAFL, Agroscope and FiBL in 2016, several approaches were studied in order to develop an integrated management strategy to control both diseases in Switzerland. In this monitoring project, disease development in 25 commercial potato crops was evaluated over a three-year period (2016-2018) from plantation through storage to packaging. The soil inoculum levels of black dot and silver scurf were analysed by qPCR, and seed quality by qPCR and visually. Tuber samples at various dates from tuberisation to packaging were analysed with qPCR and visually. Crop management data and all relevant site parameters were collected.

In all three years and with few exceptions, the two diseases were found to co-exist on the same potato lots. Disease incidence was strongly year-dependent. Black dot incidence was highest in 2016 with a humid spring, whereas silver scurf incidence was highest in the dry year 2018. QPCR analyses at the beginning of tuberisation for black dot and silver surf were only positive for 10 and 17 fields, respectively, out of 75. A significant increase of pg DNA/g tuber skin was observed for both diseases between haulm destruction and harvest.
For black dot, higher disease levels were most often found in fields with higher soil inoculum. The average soil inoculum level was higher in crop rotations with three-year intervals compared to five or more years (81% and40% respectively > 100pg DNA/g soil). All fields free of soil inoculum had intervals between five and seven years. In two fields, higher soil inoculum levels over 500pg and over 1000 pg DNA/g soil were found in rotations with longer intervals between two potato crops, which cannot be explained by the crop rotation, since no other important host plants such as carrots or onions had been planted in these fields. High volunteer numbers, which have been more often observed in recent years, could perhaps explain these results.

Higher levels of black dot on progeny tubers at harvest were also observed in some fields where disease-free seed tubers had been planted. In these cases, a higher soil inoculum level was measured. No correlation was found between seed potato infection and the disease level at harvest.

For silver scurf, soil inoculum was detected with qPCR in only one of the 75 potato fields. In contrast, visual control and qPCR analysis showed that the seed lots of all fields 2016 - 2018 were infested. No correlation was observed between the seed infestation level and the disease level of progeny tubers at harvest.

Disease development for the two diseases was clearly different from harvest to shop shelf. Potato lots with low disease severity for black dot at the beginning of storage stayed clean during storage and after packaging. In all three years, the average black-dot disease severity (%) of all lots did not increased significantly (2016: 6.4% to 8.1%; 2017: 3.1% to 6.1% and 2018: 2.1 to 3.9%). In contrast, average disease severity for silver scurf increased significantly (visually and PCR) (2016: 1.2% to 6.6%; 2017: 3.3% to 11% and 2018: 3.4% to 12%). For silver scurf, important increases were also observed on potato lots which were visually almost free of silver scurf at the beginning of storage. Silver scurf disease severity also increased after washing and packaging in plastic bags. The risk of a serious reduction in tuber quality from harvest to shop shelf seems to be higher for silver scurf than for black dot.

The preliminary results show a diverging development of the two diseases. The analysis of the data across all three years from 2016 to 2018 will allow the infection-risk periods in the various stages to be determined and hence the optimal time to control these diseases by integrated pest management to be identified.

4_T_5 (O18)

SUSCEPTIBILITY TO BLACK DOT AND SILVER SCURF OF POTATO CULTIVARS GROWN IN SWITZERLAND

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Black dot -caused by *Colletotrichum coccodes* (Wallr.) S. Hughes-, and silver scurf –caused by *Helminthosporium solani* Durieu & Mont.- are two blemish diseases of potato tubers that have an important economic impact, especially during the storage period[1,2]. In a collaborative project launched by HAFL, Agroscope and FiBL in 2016, several approaches were studied in order to develop an integrated management strategy to control both diseases in Switzerland.

Among these approaches, cultivar susceptibility to silver scurf and black dot was studied. The disease severity of the most common consumption potato cultivars grown in Switzerland was determined during a three-year period in field trials. Interestingly, the effect of the cultivar on disease severity was higher than that of other factors –such as field conditions- indicating that cultivar choice might be important for the control of black dot and silver scurf. Notably, the results of the field assays on cultivar susceptibility against black dot and silver scurf indicate that some cultivars are very sensitive to both diseases (e.i. Lady Felicia), to one of them (Lady Christl to silver scurf) or relatively resistant to both of them (Gwenne). These cultivars were selected for an in-depth analysis of their metabolome in a controlled greenhouse experiment in presence –or not- of fungal infections. To this end, LC-HRMS/MS analysis were conducted on a methanolic extract of the tuber peel of the different cultivars for a thorough metabolomics investigation.

Statistical analysis using AMOPLS showed that i) metabolomics differences were important among healthy cultivars; ii) inoculation with the fungus induces changes in the metabolome of all cultivars and iii) some of the responses to the fungal infection are distinctive among cultivars. Dereplication processes and the use of metabolic networks were used to putatively identify tolerance related compounds.

These results might be of interest to better understand the resistance mechanisms of potatoes to blemish diseases, but also to potentially introduce biomarkers on breeding programs towards cultivars with a better performance when confronted with these diseases.

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5_B_1 (O19)

ECONOMIC INCIDENCE OF PECTOBATERIUM AND DICKEYA SPECIES ON POTATO CROPS IN SWITZERLAND

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As the fourth most prevalent food crop, the potato is very important in the global economy. This crop is affected by many pests, and by many bacterial, viral and fungal diseases. Among those pathogens, the bacteria of the Genera *Pectobacterium* and *Dickeya* are responsible for two important potato diseases, namely blackleg by inducing rotting of the stems, and soft rot by inducting rotting of the tubers. As far as we know, the economic incidence of those bacteria has never been quantified so far.

The main objective of this work is to study the economic incidence of *Pectobacterium* and *Dickeya* in Switzerland. Our study covers a period of 13 years between the years 2004 and 2017. We have considered the economic incidence of those bacteria both for ware and seed potato production. The analysis considers the loss of yield, the loss due to downgrading and rejection of infected seed lots, as well as the loss due to tuber soft rots.

Through the analysis of the data obtained from the various actors of the potato sector in Switzerland, we showed that the average annual loss due to *Pectobacterium* and *Dickeya* between 2004 and 2017 was about 270 CHF/ha for seed potato production, about 140 CHF/ha for ware potato production dedicated to fresh market, and about 45 CHF/ha for processing potatoes.

The analysis of the data also revealed that there is less variation in the economic losses for ware potato production as it is less depending on symptoms expression in the field. Nevertheless, years with humid conditions before harvest favor soft rot of the progeny tubers and increase the rejection rate of ware potato lots. However, based on the literature, these significant losses are lower than those caused by Potato Late Blight (*Phytophthora infestans*), which is considered to be the most economically damaging potato disease in Europe.

5_B_2 (O20)

USE OF DISEASE SUPPRESSIVENESS IN THE BATTLE AGAINST POTATO BLACKLEG

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Blackleg is a major disease problem in the cultivation of seed potatoes, despite all efforts to avoid introductions of soft rot *Pectobacteriaceae* (SRP's), and measures to reduce dissemination of the pathogens within a seed lot. The disease is hard to manage due to its unpredictable nature. Infections frequently occur already in a first-generation crop grown from mini-tubers, which were initially pathogen-free, but the infection sources are still not conclusively identified. For several generations infections can remain symptomless in the seed lot, but at conditions conducive to SRP's, outbreaks can occur with considerable financial consequences for the grower. So far, the instruments to manage the disease are limited and are largely based on the use of certified (pathogen-free) seed, hygiene and cultivation measures. In a search for new management tools, we explored the existence and potential use of suppressiveness of potato plants against SRP's.

In two consecutive years, seed lots of two cultivars inoculated with the same density of *Dickeya solani* were planted in a field using a randomized block design. Plants grown from these seed lots showed a high variation in blackleg incidence, for cv. Spunta between 0 and 28% and for cv. Kondor between 10 to 88% indicating that seed-borne suppressiveness against *D. solani* exists. We did not find indications that suppressiveness was based on minerals in tubers or tuber dry weight. We tested also whether the differences in susceptibility were associated with the microbiome in the potato tubers and stems, using 16S rDNA amplicon sequencing on seed lots with high or low disease incidence. Only for the periderm of tubers significant differences were found between the species diversity of both classes for both cultivars. Some microbial phylotypes were positively associated, while others were negatively associated with disease incidence. In a follow-up project, the association between metabolites and disease suppressiveness will be studied.

This project was financed by the Dutch Ministry of Economic Affairs via the TopSector Programme and the Dutch seed potato industry via the NAO projectenfonds

5_B_3 (O21)

CHARACTERIZATION OF *PECTOBACTERIUM CAROTOVORUM* SUBSP. *BRASILIENSE* IN ISRAEL AND SEED TREATEMTS TO CONTROL TUBER SOFT ROT

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Potato cultivation in Israel in the spring is based on seed tubers imported from Europe while local seeds (produced during the spring) are used in the fall-winter season. Pectinolytic bacteria, primarily *Dickeya solani* (Ds), *Pectobacterium carotovorum*, *P. c. brasiliense* (Pcb) and *P. parmentieri*, are the causal agents of pre-emergence seed rot, blackleg and wilt, and tuber soft rot. Disease symptoms vary with climate and development and disease expression in field may particularly favored under warm-climate conditions which prevail in Israel. Latent infections with Ds and Pcb in imported seed lots affect crop yields in both spring and winter seasons, causing economic losses. Pcb strains obtained from European imported seeds and from potato plants and progeny tubers grown in Israel were characterized by Pulse Field Electrophoresis Gel and by sequencing the *gapA* gene. A major group of 40 strains (out of 60 tested strains) produced the same pattern with either *Avr*II or I-*Ceu*I. Their pathogenicity, evaluated by tuber maceration test, revealed a considerable variation in maceration ability within the tested strains related to the source of the plant material.

Latent infection of Pcb was evaluated in symptomless weed plants from 13 genera and 10 families, collected from areas where Pcb-infected potato plants were identified. Pcb was isolated only from *Malva nicaeensis* (incidence of 16.7%), indicating it may serve as an alternative host for Pcb allowing the pathogen to survive in the absence of the host crop.

The efficacy of seed tuber treatments on reducing seed decay and tuber soft rot was evaluated in early winter planting (September) when temperatures are relatively high. Seed treatments included dry steam, oxolinic acid (Summit Agro International Ltd), mancozeb and MB5K (surface sterilizing agent, Adama Ltd) applied prior to planting. All treatments reduced seed decay or tuber rot to different extent. However, the results were inconsistent within field trials conducted in different years. Nevertheless, because no control means are available and these treatments have a potential use by farmers, research is being continued.

5_B_4 (O22)

INTEGRATING NEXT GENERATION TECHNOLOGIES FOR BLACKLEG AND SOFT ROT MANAGEMENT IN THE USA: A PROGRESS REPORT

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A four-year national research project in the USA started in 2017 in response to a widespread outbreak of potato soft rot causing serious stand losses to growers. The outbreak was particularly serious in the eastern US and the primary cause of disease identified as *Dickeya dianthicola*, a bacterium species new to the US. The project is funded by USDA-NIFA and coordinates research of 15 scientists with strong industry input and support. This presentation will provide an update and summary of research activities by this project. Some of the research activities to be presented include optimization of *Dickey*a detection in seed lots, a summary of seed lot testing results, latent sub-lethal infection of seed, spread of *Dickeya* in the field, spread of Dickeya by seed handling and cutting, infection mechanics, economic impact of various levels of seed infection, potential sources of *Dickeya*, development of *Dickeya* specific primers, and screening potato germplasm for resistance to *Dickeya* decay. Work is also being conducted on emerging *Pectobacterium* species.

IRRIGATION WATER AS INOCULUM SOURCE OF SOFT ROTTING BACTERIA

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Soft Rotting Pectobacteriaceae (SRP) namely *Pectobacterium* and *Dickeya* spp., are responsible for causing diseases on potato plants such as blackleg, aerial stem rot and soft rot of tubers. These diseases are of major concern to the potato industry not only in South Africa but throughout the world. In South Africa, up to 85% of potatoes are produced under irrigation. Therefore, detection and identification of *Pectobacterium* and *Dickeya* species in water sources used for irrigation is extremely important for more effective management of the diseases these pathogens cause. Various water sources in eight potato production regions of South Africa, namely the Western Cape, Eastern Cape, Limpopo, Free State, Kwazulu-Natal and Gauteng, were sampled. A total of 333 samples were collected from 39 sources including dams, boreholes, rivers and overhead irrigation systems. Detection of SRPs in water samples was done using Crystal Violate Pectate selective culturing from enriched water samples and subsequent PCR identification of the isolates. SRPs were detected in 37% of the overhead irrigation water samples. Species known to cause potato diseases that were isolated included *Dickeya* spp., *Pectobacterium carotovorum* subsp. *brasiliense* (Pcb), *Pectobacterium carotovorum* subsp. *carotovorum* (Pcc) and *Pectobacterium atrosepticum* (Pa). This is the first report of *P. atrosepticum* in South Africa. Virulence testing of isolates was done on potato tubers as well as potato plants. The majority of isolates tested caused significant soft rot disease on potato tubers. Aerial stem rot developed on plants sprayed with contaminated irrigation water. This is an important finding for the South African potato industry, indicating the potential of agricultural irrigation water to act as a source of inoculum of soft rotting Pectobacteria.

ADVANCES IN THE QUANTIFICATION OF *PECTOBACTERIUM SPP* IN THE POTATO SEED AS A METHOD TO DETERMINE SEED QUALITY UNDER AN INTEGRATED MANAGEMENT APPROACH IN CHILE.

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Soft rot and blackleg in the potato crop have been increasing in the last years, due to various factors, among those the quality of potato seed, the use of irrigation systems and the climate change. These factors have led to an increase in the incidence and severity caused by *P. atrosepticum* and *P. carotovorum* subsp *carotovorum* with losses up to 30% on susceptible cultivars and rejection of seed lots up to 24%. Currently farmers do not have the tools to determine the quality of their seed, focusing on the use of agrochemicals that do not necessarily give good results. Due to this situation, the objective of this work is to implement a seed potato tuber quantification technique based on a real time PCR assay as a seed rot potential to determine the sanitary risk.

First, the conditions for the detection of *Pectobacterium* using real time PCR with Taqman probes were standardized. After, dilution series of known reference cultures of *P. atrosepticum* and *P. carotovorum* were used to prepare the standard curve, relating the amount of DNA extracted with the total bacterium cells. Then, free bacterium minituber were inoculated with an increasing number of bacterial cells (10^0 to 10^6 cfu/ml. Results showed that the minimum level of detection is 30 fg of DNA, equivalent to 7 average bacterial cells in the reaction, considering a Ct value of 32.8-35. A positive correlation was found between the amount of inoculum in the minituber and the bacterial quantification. This would be a promising methodology to determine seed quality under an integrated management approach.

5_B_7 (O25)

FIFTEEN YEARS OF MONITORING, DETECTION AND CHARACTERIZATION OF SOFT ROT AND BLACKLEG CAUSING BACTERIAL SPECIES OF *DICKEYA* AND *PECTOBACTERIUM* IN THE HIGH GRADE SEED POTATO GROWING AREA IN NORTH FINLAND.

Yeshitila Degefu

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The supply of healthy or disease free and physiological sound seed is fundamental to sustainable potato production. The selected High Grade zones in the five European countries including Finland, if properly managed or protected, have a lot to offer in this regard. The implementation of the principles and provisions underlying the High Grade status which includes steps to maintain the high plant health status of the potato crop and prevention importation of seed potatoes from areas where certain harmful organisms are present are very crucial. However, the enforcement of these rationales are often challenged by the existing free market economy, trade agreement and trade liberalization policies and fast transportations which allow planting materials to transit international borders relatively easier and faster. It is, therefore, very important to consistently monitor the introduction and establishment emerging and re-emerging potato pathogens in Finland, a country which holds the High Grade status granted by the European Union since 1995. In order to reinforce the obligations and provisions attached to the High Grade status and prevent the outbreak and spread of old and new soft rot and blackleg causing bacterial species of *Dickeya* and *Pectobacterium*, consistent monitoring, surveillance and characterization of disease outbreaks have been carried out particularly in the designated areas in north Finland over the past fifteen years. The necessary infrastructure for research and development for seed certification have been in place at location close to the HG zone. Methods for the molecular detection and characterization of *Dickeya* and *Pectobacterium* have been validated and standardized and analysis services have been provided to seed potato producers and companies for the detection and diagnosis of the species currently known to occur on potato in Finland. Research focused on the incidence, ecology and diversity of the bacteria has been conducted. The knowledge gained during these one and half decade period indicated significant transformation of the blackleg and soft rot complex and some cases of renewed risks and challenges in the management of the diseases. An overview of the information accumulated over this long period of research and services will be highlighted and discussed in the presentation.

EMERGING AND RE-EMERGING *RALSTONIA SOLANACEARUM* SPECIES COMPLEX STRAINS CAUSING BACTERIAL WILT OF POTATO IN SUB-SAHARAN AFRICA

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Potato is a staple food and a major source of household income in Sub-Saharan Africa (SSA). Despite its importance, yields remain low due to lack of proper agronomic practices, inadequate supply and use of high-quality seeds, and pests and diseases. In particular, Bacterial Wilt (BW) caused by *Ralstonia solanacearum* species complex (RSSC) strains is an emerging threat to potato production in SSA. BW, once established in field, is one of the most difficult diseases to manage, largely due to the nature of the pathogen being soil, seed and water borne. Informal seed system and the use of latently infected seed are the major reasons for RSSC spread and introduction of *Ralstonia* into their smallholdings. BW has become very widespread in SSA- it was detected from 158 of 263 in Ethiopia, 128 of 176 farms in Kenya, 62 of 104 farms in Rwanda and 166 of 228 surveyed farms in Uganda, resulting in 30-100% yield losses. Genetic diversity and distribution of RSSC strains from these countries were identified, and then isolates with the same sequevar were further analysed by multi-locus MLVA typing schemes. In Ethiopia, all of the RSSC strains were identified as Phylotype II sequevar 1, whereas in Uganda, 80% of strains were identified as Phylotype II sequevar 1, followed by Phylotype I sequevar 31 (18.5%) and phylotype III (1.5%). Kenyan samples were identified as phylotypes I (24%) and II (75%). Finding of phylotypes I in Kenyan and Ugandan highlands indicates that earlier recommendations for crop rotation as a management strategy may not be working as Phylotype I strains have a much wider host range and are able to survive better on alternative hosts including weeds. VNTR profiling of these strains suggested that Phylotype II sequevar 1 strains play an important epidemiological role in BW of potato and likely being disseminated via latently infected seed. Additional sampling of the pathogen from neighbouring countries would provide a clearer population structure of RSSC strains, map and trace the movement of epidemiological RSSC strains causing bacterial wilt of potato in SSA to provide evidence-based recommendations for policy makers on seed movement.

The presenters of these posters are requested to stay close to their poster during this session to answer questions.

P1

SYTRANSPOM: DEVELOPMENT OF COLLABORATIVE AND INNOVATIVE ALERT AND DECISION SYSTEMS PROMOTING INTEGRATED PROTECTION AGAINST FUNGAL POTATO DISEASES

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Key words: Potato crop, Fungal pathogens, collaborative platform, molecular tools, decision support systems in crop protection

Abstract

Potatoes are an economically important crop in Belgium and France. Fungal potato pathogens cause many damages in crops. The most important leaf fungal pathogens are *Phytophthora infestans* and *Alternaria solani*, responsible of late blight and early blight respectively. In order to develop or improve decision support systems for the potato crop, **SYTRANSPOM** (Interreg V Program FrWVl), a collaborative cross-border research project, was set up. It started in April 2018 thanks to the combination of multidisciplinary expertise of four partners in each of the three regions: ARVALIS (France), CARAH (Wallonia), PCA and INAGRO (Flanders).

SYTRANSPOM is structured around 4 main research axes:

(i) Development of a cross-border collaborative platform to centralize known data (e.g. climatic and soil data, …) and register new data collected from weather forecasting, precision farming, field trials and laboratory experiments
(ii) Development of laboratory qualitative and quantitative molecular methods to characterize fungal pathogens
(iii) Implementation of experimental field trials, with the support of molecular tools, to obtain early diagnosis of infections, monitoring the development of diseases and improving integrated disease management.
(iv) Development of complete decision support systems for the potato grower incorporating warning systems for several foliar pathogens

The first laboratory and field results will be presented and discussed.

DUAL FUNGICIDE RESISTANCE IN *ALTERNARIA SOLANI* AND *ALTERNARIA ALTERNATA* FIELD ISOLATES IN BAVARIA

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Alternaria leaf disease of potato caused by *Alternaria solani* and *Alternaria alternata* can result in economic important yield losses due to premature leaf senescence and defoliation. Reduced sensitivity of *A. solani* and *A. alternata* field isolates towards fungicides of the Quinone outside inhibitors (QoI) class (strobilurins) has been observed in the European Union for a decade. QoI-insensitive *A. alternata* isolates characteristically carry a G143A amino acid exchange caused by a single nucleotide polymorphism (SNP) in the cytochrome *b* gene. *A. solani* has evolved a similar F129L mutation that reduces sensitivity towards QoIs. In this study, 55 *A. alternata* and 47 *A. solani* isolates were collected in 2016 from major potato growing areas in Bavaria, located in southeastern Germany in Central Europe, to update the current status of QoI mutation spread. 85.1 % of *A. solani* and 74.5 % of *A. alternata* field isolates showed the F129L and the G143A mutation, respectively. For *A. solani*, this is a roughly 10 % increase since the last reported survey in 2011. German *A. solani* populations are composed of two genotypes. F129L mutations were previously exclusively observed in genotype II. We found 74.5 % of *A. solani* isolates to belong to genotype II with a 100 % of them carrying the F129L mutation. However, we also found the F129L mutation in genotype I with a frequency of 41.7 %. This presumably recent evolution of the F129L mutation in *A. solani* genotype I in Bavaria explains the 10 % increase seen in the total F129L mutant *A. solani* isolates abundance. We found F129L mutated *A. solani* isolates at high levels in all examined Bavarian potato growing regions which indicates a geographical spread as the F129L mutation was reportedly unevenly distributed before. To get a hint on the mode of spread, we analyzed the composition of the underlying SNPs causing the F129L mutation. Albeit there was some diversity in the SNPs and also an indication for the region Lower Bavaria as hotspot for *A. solani* F129L mutation evolution, the dominance of the TT<u>A</u> SNP in genotype II (88.6 % of isolates) and of the <u>C</u>TC SNP in genotype I (80 % of isolates) in the examined regions rather pointed to a physical spread than to multiple independent evolutions. Reduced sensitivity of *A. alternata* and *A. solani* field populations towards succinate dehydrogenase inhibitors (SDHI) fungicides (boscalid), which are the other major compound for Alternaria control, are recognized as an emerging problem in Europe. We randomly selected 23 of our *A. alternata* and 19 of our *A. solani* field isolates and screened them for the presence of SDHI mutations in the subunits SDHB, SDHC and SDHD of the succinate dehydrogenase enzyme complex (SDH). 43.5 % of *A. alternata* and 42.1 % of *A. solani* isolates were found to carry a mutation in one of the examined SDH subunits. Mutations in the SDHB subunits were with a frequency of 26.1 % of isolates predominant in *A. alternata*. It was in 83.3 % caused by the H277Y mutation. The H278Y mutation of subunit SDHC was with 36.8 % of isolates most common in *A. solani*. Remarkably, all identified SDH-mutant *A. solani* and *A. alternata* field isolates simultaneously carried a QoI fungicide resistance mutation. The presented results clearly show that QoI fungicide resistance mutations are widespread in Bavaria and that dual resistance against QoI and SDHI fungicides is an upcoming problem in chemical *Alternaria* spp. control in potatoes in Bavaria.

P3

LATE BLIGHT RESISTANCE AND EXPRESSION OF *Rpi-Smira2/R8* GENE IN *R8* POTATO DIFFERENTIAL PLANTS

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Potato (*Solanum tuberosum* L.) is the fourth most important food crop in the world and its production is highly threatened by *Phytophthora infestans*, a causal pathogen of late blight. The genetic resistance to *P. infestans* in potato has been classified as race-specific or vertical (qualitative) and race-nonspecific or horizontal (quantitative) resistance. One of the varieties with high quantitative resistance to late blight is Sarpo Mira, with five major *R* genes: *R3a*, *R3b*, *R4*, *Rpi-Smira1*, and *R8* gene. Several observations of contradicting resistance between detached leaf assay (DLA) level and whole plant level in Sarpo Mira have been reported, presumably due to the impact of meristems and roots on systemic resistance response. The goal of the presented research was to obtain differential *R8* plants to study the quantitative resistance of Sarpo Mira caused by *R8* gene on DLA level and whole plant level. 1230 progenies of crosses between Sarpo Mira and five late blight susceptible varieties (Rioja, Lusa, Colomba, Bikini, and Sylvana) were screened using molecular markers for the presence of the *R3a*, *R3b*, *Rpi-Smira1*, and *R8* genes. The screening for *R4* gene was performed using effectors and agroinfiltration with *Agrobacterium tumefaciens*. Since whole plant agroinfiltration in potato proved to be technically challenging and did not provide reliable results, we have combined agroinfiltration and DLA. With improved agroinfiltration method we have successfully selected the final collection of potato plants containing only *R8* gene – differential plants. Resistance tests will be performed on leaflets (DLA) and whole plants grown in greenhouses and experimental fields using several Slovenian and foreign *P. infestans* isolates. Assessment of the late blight severity will be performed by visually estimating percent coverage of foliar late blight lesions. Simultaneously gene expression of *R8* and other immune-response related genes will be observed. Thus we will be able to determine the impact of *R8* gene on late blight resistance on DLA and whole plant. Combining these approaches will enable us to determine the linkage between *R8* gene and quantitative resistance of Sarpo Mira.

USING SSCP ANALYSIS OF VIRULENCE GENES FOR GENOTYPING AND SCREENING STRAINS OF *PHYTOPHTHORA INFESTANS* THE CAUSATIVE AGENT OF POTATO LATE BLIGHT

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Potato growing is dramatically affected by late blight disease (the causal agent – oomycete *Phytophthora infestans*). Fighting late blight is greatly hampered by rapid changes in the pathogen populations: new pathotypes of *P. infestans* arise as a result of the pathogen evolution and migration. Newly arrived pathotypes damage varieties that were previously considered resistant, sometimes completely destroying the potato crop. Therefore, to effectively control late blight, it is vital to early recognize the changes in the populations of *P. infestans* and discern the appearance of new pathotypes. Here we introduce the SSCP (single-strand conformation polymorphism) analysis as the method for rapid screening of the virulence genes (*Avr* genes) involved in suppressing the host plant immune response and for evaluating the polymorphisms of these genes. SSCP analysis is a workable and high-performance method to reveal genetic DNA polymorphisms. SNP-dependent conformation changes produced by thermal and chemical denaturation of DNA fragments result in unique electrophoretic patterns. We employed SSCP analysis to examine ten *Avr* genes (*Avr1, Avr2, Avr3a, Avr3b, Avr4, Avr8, Avr9*, *Avr-blb1*, *Avr-blb2* and *Avr-vnt1*) in 21 single-cell *P. infestans* lines and validated the SSCP patterns by cloning and sequencing individual electrophoretic bands and comparing the sequences to the *Avr* prototype genes deposited in the NCBI Genbank. Such annotation allows to further employ SSCP patterns as barcoding descriptors for genotyping pathogen strains, rapid assessing pathotype profiles in *P. infestans* populations and early predicting the dramatic changes in their pathogenicity.

CONTROL OF POTATO LEAK CAUSED BY *PYTHIUM ULTIMUM*

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Potato leak caused mainly by *Pythium ultimum* characterized by brown-black lesions which usually begin in the stolon end and expand over the entire tuber and turning rapidly into a wet rot. The disease causes severe damage to the quality of the stored or marketed tubers, especially when also soft rot bacteria develop. The disease is particularly problematic in early planting (September with relatively high temperature) and harvest in January-February (relatively low temperature). Although the inoculum source is in the soil, the current study focus on evaluating the efficacy of fungicides applied by foliar sprays or by in-furrow treatment prior to planting, on reducing the disease. Two field trials were conducted in the winter seasons of 2018 and 2019 in commercial fields with naturally infested soil. In 2018, treatments included 1.3 L/ha metalaxyl (48% a.i.), 3 L/ha hymexazol (36% a.i.), 10 L/ha propamocarb HCl (72% a.i.); each fungicide was applied in three foliar spray immediately followed by overhead irrigation for washing the fungicides into the root zone (50, 90 days after planting and a combined treatment of 50 and 90 DAP). No Pythium symptoms were observed at haulm killing, but three weeks later, at harvest, disease incidence was 11% in the control. Only matalaxyl significantly reduced disease incidence by 55-94% with no difference between number and timing of the application. In 2019, only metalaxyl was evaluated in foliar spray and in furrow treatments. Disease incidence which was 7% in the control was reduced by both the in furrow treatment and the foliar spray applied two weeks before haulm killing. Residual levels of metalaxyl in the tubers, examined by GC/MS testing, were below the limit of quantification.

P6

EPIDEMIOLOGY AND CONTROL OF POTATO POWDERY SCAB IN FINLAND

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Powdery scab is an important disease and quality problem in potato crops worldwide. It is caused by a plasmodiophorid pathogen *Spongospora subterranea* f.sp. *subterranea*, which is also a vector of potato mop top virus (PMTV). Whilst PMTV has long been recognized as one of the major quality problems in potato production in Finland, the importance of potato powdery scab has increased dramatically only in recent years, especially after wet growing seasons. With global warming, both these diseases are likely to become more prevalent in future, and new control measures are urgently needed. The project starting in 2019, aims to investigate the epidemiology of powdery scab in Finland, and find new methods for its control. Improved management of powdery scab would also reduce the impact of PMTV. The work is implemented in co-operation with Natural Resources Institute Finland (Luke), University of Helsinki and Potato Research Institute (Petla) in close collaboration with potato growers, companies and international partners.

CHEMICAL CONTROL OF WIREWORMS IN POTATOES

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Wireworms are important pests in potato crops. In Switzerland, the predominant species feeding on potato tubers are *Agriotes lineatus, A. obscurus* and *A. sputator.* After the withdrawal of the insecticide Fipronil in 2013, no highly effective products were available on the market for wireworm control. Therefore, we tested a number of synthetic insecticides applied as coatings of oat seeds to evaluate their efficacy in wireworm control. Two application timings were compared: (1) application in the potato ridges at planting in spring (2015 and 2016), and (2) application as green manure sown in late summer (prior to potato planting in 2016 and 2017). None of the tested products had a significant impact on the percentage of tubers damaged by wireworms with the exception of "Goldor Bait" (active ingredient: Fipronil) used as a reference product. The efficacy of "Goldor Bait" was higher with an application in fall (89.5%) as compared to an application in spring (53.0%). This indicates that the application timing is important to achieve the best possible efficacy.

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BIOLOGICAL CONTROL OF WIREWORMS IN COVER CROPS

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Wireworms can cause substantial losses in marketable yield of potatoes by feeding on and tunneling through the tubers. Control options are limited, creating a demand for new alternatives, like the use of biocontrol organisms. Laboratory and semi-field trials revealed the potential of the entomopathogenic fungus *Metarhizium brunneum* isolate ART2825 against *Agriotes obscurus* and *A.lineatus*, two of the most detrimental wireworm species. In this study we integrate the fungus in the agricultural crop rotation and try to adapt the application method to its ecological and environmental requirements. Application precedes sowing of cover crops in late summer in order to enhance disease development through higher soil temperatures and extend effect duration by the absence of soil disturbance.

In the first year of field trials we were able to establish the fungus on site and demonstrate the infectivity of the treated soils in laboratory assays. Tendencies to lower potato damages were seen in the majority of locations but damage levels did not significantly differ from the control. In the ongoing season we aimed to improve plant protection efficacy by increasing the application rate and precise selection of application time. Reasons for the yet pending success will be further investigated and potential synergies with selected cover crop species explored.

TRENDS IN SWISS LATE BLIGHT EPIDEMICS SINCE 1990

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In the framework of PhytoPRE, the decision support system for potato late blight (PLB), the development of PLB-epidemics were evaluated using small, untreated potato plots distributed over the potato growing region in Switzerland. Since 1990, plots were planted with a highly susceptible potato variety, primarily Bintje, comprising the Agroscope Late Blight Observation (LBO) Network. LBO disease monitoring was conducted in collaboration with the cantonal plant protection offices and advisors. Epidemic trends, including the yearly start of the epidemic, the proportion of infected LBO plots, and the severity of the epidemic, in all of Switzerland (between 1990 and 2016) and regionally (between 2000 and 2016) were assessed. From the 27-year period analyzed, it appears that the first LBO infections on a country-wide and regional basis are not occurring earlier with time. On average, however, all infections during the season seem to occur earlier, perhaps suggesting that outbreak may be spreading faster. These results may be confounded by a reduction of LBO plots with time. No temporal trends in PhytoPRE's predictive ability were found.

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Map of the city of Neuchâtel