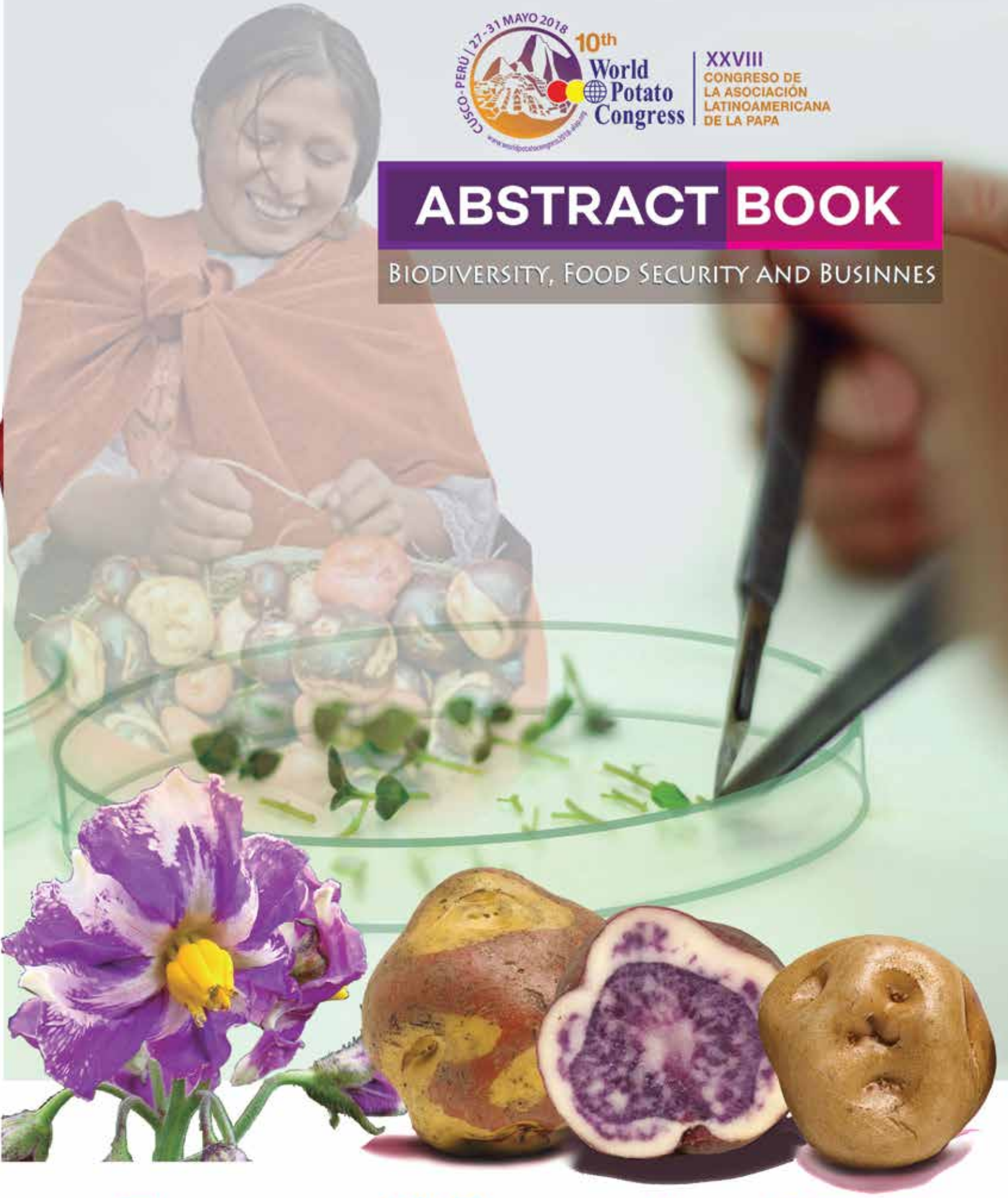
CUSCO - PERÚ | 27 - 31 MAYO 2018

10th World Potato Congress

XXVIII CONGRESO DE LA ASOCIACIÓN LATINOAMERICANA DE LA PAPA

ABSTRACT BOOK

BIODIVERSITY, FOOD SECURITY AND BUSINNES



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Organización de las Naciones Unidas para la Alimentación y la Agricultura

ABSTRACT BOOK 10th WPC- XXVIII ALAP 2018 CONGRESS
Biodiversity, Food Security and Business

Instituto Nacional de Innovación Agraria-INIA

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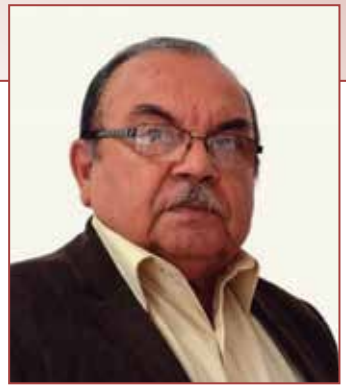
WELCOMES



From the National Institute for Agricultural Innovation

It is my pleasure to welcome you all to the 10th World Potato Congress and the XXVIII Latin American Potato Association Congress, organized by Peru's National Institute for Agricultural Innovation – INIA, in collaboration with the International Potato Center - CIP. Let me first remark that this is the first WPC to be held in Latin America, and more significantly, in Cusco, the historic capital of the Inca Empire, and the "*navel of the world*", as it was once known to native Peruvians. Cusco is the gateway to the Sacred Valley of the Incas, and the place where both the Inca and the Spanish cultures merged to create a unique city. I cordially invite all of you to enjoy the magnificence of Cusco and admire its rich and astonishing heritage, whilst sharing at the same time the warmth of its people.

Potato was domesticated thousands of years ago by our people living in the highlands of the Andes to become a staple food for them and for millions of people all over the world. The enormous ecological niches characteristic of the Andes mountains gave rise to a huge variety of potatoes of all shapes, skin and flesh colors, flavor, texture, etc. This genetic variability still remains in the fields there, g"arded at elevations that reach to the skies. Potato has a cultural and religious meaning for Andean highlanders and is related to their religious festivities paying tribute to the *Pachamama*, "the mother earth" and to their *Apus*, the sacred mountains.

This congress expects to host delegates from more than 37 countries, who will have the opportunity to share scientific knowledge and personal experiences in all aspects related to potato as a crop, as food, and as an industrial supply product. Also, during the field days, participants will be exposed to a great part of the genetic diversity that potato represents, much of it never having been shown together as you will have the chance to see it.

May this occasion serve to express my deepest gratitude to the Ministry of Agriculture of Peru, Eng. Gustavo Mostajo, representing the willingness and commitment of our government to full support this congress. Also my appreciation goes to the Organizing Committee in the persons of MSc. Jesús Caldas and PhD Rosa Sánchez from INIA, MBA. Amalia Perochena and MSc. Miguel Ordinola from CIP, and all the team involved, for the excellent job they have done which I am sure will result in us having the best congress ever.

I wish you a very productive week and a pleasant stay in Cusco.

Sincerely

Miguel Barandiarán

Head of the National Institute for Agricultural Innovation and Chair
of the Organization Committee of the 10th World Potato Congress and
the XXVIII Latin American Potato Association Congress

From World Potato Congress Inc

It is a real pleasure to welcome all delegates in Cuzco for the 10th World Potato Congress.

I am confident you will benefit from your decision to join this unique networking opportunity of the global potato value chain. Nearly 700 participants from 50 countries will embrace the themes “biodiversity, food security and business”. With the rich gene database resulting from the more than 3.800 native potato varieties grown in Peru, the link between the three congress themes becomes obvious.

The proposed program offers top rated speakers from within the different angles of the international potato value chain. On top, numerous social occasions and tours will offer you the opportunity for individual contacts enabling us to enlarge our global network.

Peru, as the birthplace of the domesticated potato and Cuzco, as the capital of the Inca Empire, offer a wonderful venue to host this congress. On top, the proximity of Machu Picchu, a UNESCO World Heritage Site and one of the New Seven Wonders of the World, offers the delegates a unique perspective of Peruvian history and cultural experience. You will surely also be able to enjoy the internationally renowned Peruvian cuisine.

On behalf of the Directors and International Advisors of World Potato Congress Inc. I wish to express appreciation to the host organizers INIA, CIP, FAO, the National Agrarian University - La Molina and PromPeru, and the entire WPC-team for their efforts in presenting an outstanding congress. The relationship between WPC Inc. and our hosts has been most pleasant and constructive.

In closing I invite you to indulge in Cuzco, embrace Peru and its people, and appreciate your conversations with delegates from all over the world, in order to return home with warm memories of a superb week in Peru.

Sincerely,

Romain Cools
President, World Potato Congress

From the Latin American Potato Association / ALAP Congress

On behalf of the Latin American Potato Association (ALAP), I warmly welcome the participants and guests to this, the first time where the XXVIII Latin American Potato Association (ALAP) Congress and the 10th World Potato Congress (WPC) come together in the historic city of Cusco, Peru. The main themes of the congress, "biodiversity, food security, and business", are also of the utmost relevance for the ALAP; especially now when the potato crop and its specialists must help to face worldwide population increase, climate change and a more demanding market.

One way that ALAP wants to help to resolve these problems is to stimulate the production and efficient use of potatoes, as well as increasing and disseminating the knowledge we have of this crop through the development of research and dissemination of technical and scientific advances achieved in the regional and global context. All these actions are aimed at awakening interest for this crop, with the certainty of achieving greater well-being in the communities that grow potatoes, and in the people who consume it in all its forms.

I am sure that the scientific and business program of the congress will be in great demand and will consolidate the integration of an international expert community and support the formation of new networks or strengthen existing ones.

Let me finally wish all participants a successful congress and fruitful discussion.

Sincerely,

Elisa Salas Murrugarra
President, the Latin American Potato Association

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(*in alphabetical order*)

PREFACE

PREFASE

The themes “Biodiversity, Food Security and Business” represent what Peru, as the host country and the most important center of origin of the potato, can show and share with the world. In this Congress, Peru and other Latin American countries showcase our great potential from a scientific point of view, where biodiversity, and its relationship with the development of new varieties, nutrition and health, represents a valuable and still unexploited treasure for the world. This is a unique opportunity to show how the conservation of the native potato has developed and persisted for generations in the Andes, and how from there it began its expansion to the rest of the world, contributing to the development of humanity.

The Congress also highlights the great contribution of the different improved and native potato varieties to global food security, and the development of pest and disease management technologies, especially in the face of climate change, as well as the development of technologies for postharvest and processing, and how all this dynamic progress impacts business , enabling the articulation between companies and the farmers that make potato a versatile food for fresh consumption, as well as in its processed forms.

The realization of this Congress for the first time in Peru and in Latin America, is the recognition of the contribution of this region to the world. The potato was domesticated thousands of years ago by our ancestors, to become the third primordial food for human consumption, estimating that more than a billion people consume potatoes worldwide.

It is important to point out that it is the first time that the 10th World Potato Congress and the XXVIII Latin American Potato Association Congress are being held together, promoting the interaction between the scientific, development and industrial sectors of Latin America and the world. This meeting takes place in the historic city of Cusco, which will house us for six wonderful days, in which we will share scientific advances and industry experiences, and where we will have a great opportunity to face the challenge of working together for sustainable development of the potato in the face of rapid growth in the world’s population and climate change.

In Peru, potato is not only a food or a business, it is part of our culture, our tradition, our customs and beliefs, In short, potato is our way of life.

The abstracts presented in this book provide a sample of the progress in scientific research, the development of potato and the potato industry, organized according to the seven technical themes chosen for this Congress:

- Climate Change and Potato Agri-food Sysetms.
- Trends in Potato Consumption and Markets.
- Potato Variety Development and Biotechnology
- Potato Pests and Diseases
- Potato Crop Management
- Post-harvest and Processing Technology
- Potato Biodiversity and its Relation to Breeding, Nutrition and Health.

The the 10th World Potato Congress and the XXVIII Latin American Potato Association Congress, brings together 747 attendees representing 37 countries. Of the 164 abstracts presented in this book, 67.8% come from Latin America, 18.8% from Europe, 1% from Oceania, 5.6% from Asia and 6.8% from Africa. Abstracts have been prepared by scientists with great experience in potato worldwide.

PROGRAM

Time	Sunday, May 27		
15:10-18:40	Registration (Convention Center)		
19:30-22:00	**Opening Reception at Qorikancha Temple Miguel Barandiarán** Head of INIA and Chair of Organizing Committee		
	Monday, May 28		
8:00-8:20	**Registration**		
8:20-8:40	**Opening Ceremony WPC - ALAP** Chair: PhD. Miguel Barandiarán Head of INIA and Chair of the Organizing Committee		
8:40-9:00	Martín Vizcarra Cornejo, President of Peru (to be confirm)		
9:00-9:20	Gustavo Mostajo Ocola, Minister of Ministry of Agriculture and Irrigation (to be confirm)		
9:20-9:40	Romain Cools, President & CEO - WPC Inc.		
9:40-10:00	Elisa Salas, Presiden of ALAP		
10:00-10:30	Coffee Break		
10:30-10:50	**Plenary 1: WPC-ALAP : The Potato. Global Approach** Chair: Mr. Romain Cools President & CEO - WPC Inc.		
10:50-11:10	PhD. Dave Nowell (FAO, Agriculture Officer , FAO Regional Office for Latin America and the Caribbean): Global Food and Agricultural Issues Trends		
11:10-11:50	PhD. Barbara Wells (CIP): The Role of Potato in Feeding the Future		
11:50-12:10	**Plenary 2: WPC-ALAP : Climate Change // Varietal Development & Biotechnology** Chair: Mr. John Griffin, Vice President WPC		
12:10-12:30	PhD. Marco Bindi (University of Florence, Italy): Global Effects of Climate Change in the Potato Crop		
12:30-13:10	Dr. Glenn Bryan (James Hutton Institute, UK): Future of Modern Biotechnology in Varietal Development		
13:10-14:30	Lunch		
14:30-14:50	**Technical Session "A" Climate Change and Potato Agri-food Systems** **Chair:** Dr. Peter Vander Zaag, Sunrise Potatoes // Cochair: Dr. David Ramirez, CIP	**Technical Session "B" Trends in Potato Consumption & Market** Chair: Mr. Ron Gall, Industry Representative Ex Potato New Zealand Business Manager // Cochair: PhD. Guy Hareau, CIP	**Technical Session "C" Potato Variety Development & Biotechnology** **Chair:** BSc. Ghislain Pelletier, Board Director for the Sustainable Agriculture Initaitive (SAI) Platform and WPC // Cochair: PhD. Marc Ghislain, CIP
15:50-16:20	Coffee Break		
16:20-17:20	**Technical Session "A" Climate Change and Potato Agri-food Systems** **Chair:** Dr. Peter Vander Zaag, Sunrise Potatoes // Cochair: Dr. David Ramirez, CIP	Technical Session "B" Trends in Potato Consumption & Market Chair: **Mr. Ron Gall,** Industry Representative Ex Potato New Zealand Business Manager // Cochair: PhD. Guy Hareau, CIP	**Technical Session "C" Potato Variety Development & Biotechnology** **Chair:** BSc. Ghislain Pelletier, Board Director for the Sustainable Agriculture Initaitive (SAI) Platform and WPC // Cochair: PhD. Marc Ghislain, CIP
17:20-18:40	Poster Session: Technical Sessions A, B and C (Available all day)		
	Commercial Exhibition **(Available all day)**		

Time	Tuesday, May 29		
8:00-8:20	Registration		
8:20-8:40	**Opening session 1**		
	Ambassador Kenneth M. Quinn (President The World Food Prize Foundation)		
8:40-9:00	**"Plenary 3: WPC-ALAP : Global Approach // Peru and its Biodiversity** Chair: PhD. Juan José Risi Carbone Vice Minister Agrarian Policies Ministry of Agriculture and Irrigation of Peru"		
9:00-9:20	PhD. Máximo Torero (WB): Potato Technology and Economic World Trends		
9:20-10:00	PhD. Andre Devaux (CIP)/ MSc. Miguel Ordinola (CIP): The Role of Potato Diversity in Peru on Food Security, Nutrition and Competitivity		
10:00-10:30	Coffee Break		
10:30-11:10	**"Technical Session ""D"" Potato Pests and Diseases** **Chair:** Mr. John Jamieson, Deputy Minister of Agriculture and Fisheries, Prince Edward Island, Canada // Cochair: PhD. Jan Kreuze, CIP."	**Technical Sessions "E" Potato Crop Management** **Chair**: Mr. David Thompson, Director of WPC Inc. // Cochair: Dr. Marcelo Huarte Former INTA, Argentina	**Technical Sessions "F" Post. harvest & Processing Technology** **Chair**: PhD. Nora Olsen, Professor and Potato Extension Specialist, University of Idaho // Cochair: PhD. Daniel Caldiz, McCain Foods
11:10-13:10	**"Technical Session ""D"" Potato Pests and Diseases** **Chair:** Mr. John Jamieson, Deputy Minister of Agriculture and Fisheries, Prince Edward Island, Canada // Cochair: PhD. Jan Kreuze, CIP.	**Technical Sessions "E" Potato Crop Management** Chair: Mr. David Thompson, Director of WPC Inc. // Cochair: Dr. Marcelo Huarte Former INTA, Argentina	**Technical Session "G" Potato Biodiversity and its Relation to Breeding** **Chair**: PhD. Daniel Caldiz, McCain Foods // Cochair: Dr. Alfonso del Rio, U. Wisconsin
13:10-13:50	Lunch		
13:50-14:50	Technical Session "D" Potato Pests and Diseases Chair: PhD. Jonathan Jones, The Sainsbury Laboratory UK// Cochair: PhD. Jan Kreuze, CIP.	**Technical Sessions "E" Potato Crop Management Chair**: Mr. David Thompson, Director of WPC Inc. // Cochair: Dr. Marcelo Huarte Former INTA, Argentina.	**Technical Session "H" Potato Biodiversity and its Relation to Nutrition and Health** Chair: PhD. Daniel Caldiz, McCain Foods // Cochair: Dr. Alfonso del Rio, U. Wisconsin.
14:50-15:10	Coffee Break		
15:10-15:30	"Plenary 4: WPC-ALAP : Summary and Strategies for Moving the Potato Forward Chair: Dr. Marcelo Huarte Former INTA, Argentina"		
15:30-15:50	PhD. Jeffrey Sachs, Director of the UN Sustainable Development Solutions Network and Commissioner of the ITU/UNESCO Broadband Commission for Development		
15:50-16:20	MSc. Lieve Van Elsen, Region Director Trias Andes/ Mr. Leoncio Pichihua Quito, Coopagros		
16:20-16:40	"Plenary 4: WPC-ALAP : Summary and Strategies for Moving the Potato Forward (wrap up) Chair: Marcelo Huarte Former INTA, Argentina		
16:40-17:00	Mr. Romain Cools, President & CEO - WPC Inc., Value Chain Tool Box		
17:00-17:20	PhD. Oscar Ortíz (CIP) / PhD. Miguel Barandiarán (INIA Perú)- Wrap up.		
17:20-17:40	Poster Session: Technical Sessions A, B and C (Available all day)		
17:40-18:00	WPC-ALAP Closing & Flag Ceremony		
18:00-18:20	Poster Session: Technical Sessions D, E, F, G and H (Available all day)		
18:20-19:40	Formal Cocktail at San Francisco Church and Convent (WPC-INIA-CIP-ALAP) John Jamienson-Deputy Minister for Agriculture and Fisheries and the Department of Rural and Regional Development of Canadá Minister of Ministry of Agriculture and Irrigation of Peru or Viceminister Agrarian Policies Romain Cools President & CEO - WPC Inc. Miguel Barandiarán Head of INIA and Chair og Organizing CommitteeBarbara Wells Head of CIP Elisa Salas President of ALAP		
19:40-22:00	Commercial Exhibition **(Available all day)**		

Time	Monday , May 30		
8:00-8:20	Registration		
8:20-9:40	**Technical Session "I" Late Blight global challenge workshop Chair:** PhD. Ivette Acuña, National Institute for Agricultural Research, INIA Chile // Cochair: PhD. Jorge Andrade, CIP	**Technical Session "J" In situ conservation challenges workshop Chair:** PhD. Severin Polreich, CIP// Cochair: PhD. Stef De Haan, CIAT Colombia	**Technical Session "K" Value chain for small farmers and culinary innovations workshop Chair:** PhD. Andre Devaux CIP// Cochair: MSc. Andrés Casas, UNALM Perú
9:40-10:00	Coffee Break		
10:00-11:10	**Technical Session "I" Late Blight global challenge workshopChair:** PhD. Ivette Acuña, National Institute for Agricultural Research, INIA Chile // Cochair: PhD. Jorge Andrade, CIP	**Technical Session "J" In situ conservation challenges workshop Chair:** PhD. Severin Polreich, CIP// Cochair: PhD.Stef De Haan, CIAT Colombia	**Technical Session "K" Value chain for small farmers and culinary innovations workshop Chair:** PhD. Andre Devaux CIP// Cochair: MSc. Andrés Casas, UNALM Perú
11:10-13:30	National Potato Day: Special Program (organized by Ministry of Agriculture and Irrigation of Peru)		
13:30-14:50	Lunch		
14:50-17-20	Round table I: Evaluation of potential commercialization and industrialization of potatoes in Latin America (organized by ALAP)	Round table I: Regional self-tuber seed supply in Latin America (organized by ALAP)	
17:20-20:00	ALAP Meeting: Special Program (organized by ALAP)		
20:00-22:00	Free		
	Commercial Exhibition (Regocijo Square) (closing time 17:20)		
Time	Thursday , May 31		
10:30-13:10	Field Trip 2 options A: Potato National Park B: INIA Agricultural Experimental Station (EEAA) Andenes Chair: Phd. Cinthya Zorrilla and BSc. Ladislao Palomino (INIA Peru)/ MSc. Elisa Salas (CIP/ALAP)		
13:10-14:30	Free		
14:30-17:20			

Plenary Session 1 : two hours
Plenary Sessions 2, 3 and 4 : one hour and twenty minutes
Technical sessions A-C : two hours and twenty minutes. Time for each oral presentation 20 minutes (7 x 20')
Technical sessions D and E : three hours. Time for each oral presentation 20 minutes (9 x 20')
Technical sessions F : one hour. Time for each oral presentation 20 minutes (3 x 20')
Technical sessions G and H : two hours. Time for each oral presentation 20 minutes (6 x 20')
Workshops I-K : two hours and twenty minutes. Two oral presentations of 30 minutes each and one round table

FIELD DAY

Andenes Experimental Station
National Institute for Agricultural Innovation

The Andenes Experimental Station is located in the district of Zurite in Anta Province in Cusco. Andenes is currently one of the National Institute for Agricultural Innovation´s 14 experimental stations. Covering an area of 50 ha., Andenes was created in 1975 as part of the Ministry of Agriculture's Research Subdivision .

A special feature of Andenes is that it is located on an archaeological site "Andenes de Zurite", which was declared a National Cultural Heritage site, on September 7th, 2000. Additionally, its terraces are part of one of the Globally Important Agricultural Heritage Sites recognized by FAO, located between Cusco and Puno (http://www.fao.org/giahs/).

Andenes has 33 terraces starting from 3350 masl up to 3480 masl. They are made of stone, limestone and sandstone, with rustic finishes, and in some cases simple masonry. The articulation between terraces is accomplished using staircases and stone irrigation channels which are still in use.

The terraces facilitate research on several crops such as potatoes, quinoa, corn, kiwicha, barley, grasses, forages, Andean roots and tuber crops, medicinal plants, and several more. Research areas include genetic breeding, seed production, genetic resources and conservation, among others. Aditionally, as a result of the research conducted at Andenes, several new potato varieties have been released including the following:

Crop	Name	Year
Potato	Chaska	1979
Potato	Valicha	1980
Potato	Kori-INIA	1986
Native Potato	Pallay Poncho	2007
Native Potato	Puca Lliclla	2007
Potato	Anteñita	2009

This field day promises to be stimulating both scientifically and culturally. Research from the main institutions investigating potatoes will present their work, among them: The National Institute for Agricultural Innovation, the International Potato Center, San Antonio Abad from Cusco National University, the National Agrarian University, La Molina, Pataz Association and the Huasahuasi Commitee. Companies, such as Empresa Hidroeléctrica Santa Cruz S.A.C, BioFlora and Ferreyros, will also be participating.

Visitors will discover the fascinating culture and traditions of Cusco with presentation of traditional dances, and rituals. As part of the visit, visitors will enjoy a delicious lunch based on traditional dishes from Cusco and other regions of Peru.

Event presentations:

Greenhouse demonstrations

- Diversity in Potato Wild Relatives in the *Solanum* Section Petota
- National Register of Native Potatoes
- Efficient Growth Systems (hydroponics, areoponics, water stress and conventional)

Technologies

- Precision Agriculture
- Molecular Diagnosis in Field Conditions
- Genotyping of P. infestans using FTA cards

Biodiversity

- Diversity of Native Potatoes
- Conservationist Farmers

Health and Nutrition

- Biofortification: Developing Potatoes with High Iron and Zinc Concentration
- Developing Potatoes with High content of Functionals and Anthocynins

Climate Change and Crop Protection

- New Potato Varieties with Resistance to Late Blight and Heat Tolerance
- New Potato Varieties with Resistance and/or Tolerance to Biotic and Abiotic Factors
- Selection of Clones for Resistance to Frost
- Participatory Potato Varietal Selection using the Mother&Baby Method to Obtain New Potato Varieties with Late Blight Resistance and Adaptation to Climate Change
- A Simple, Hand-held Decision Support System to Manage Potato Late Blight by Andean Farmers

Seeds

- Effect of Different Seed Categories on Yield and Tuber Quality
- Mixed-crop Systems: Andean Crops Related to Potatoes
- Prebasic Seed Production Module of High-quality Seed by Huasahuasi Farmers

Business

- BioFlora
- Ferreyros S.A.

The Potato Park

Located one and a half hours from the city of Cusco, this communal initiative for the conservation and sustainable use of potato brings together six Quechua communities in Pisaq, who have merged each of their communal lands in celebration of the diversity of the Andean potato in its original center of domestication. Quechua farmers in the communities of Amaru, Chawaytire, Cuyo Grande, Pampallaqta, Paru Paru and Sacaca cultivate about 1400 varieties of native potato in an area that covers more than 9,000 hectares, making this fragile Andean ecosystem guardian to the richest diversity of potatoes on the planet, where a sustainable production model is practiced, at a range of scales, integrated at the landscape level.

The 6,000 indigenous people who live in this traditional Andean agricultural landscape, located between 3400 and 4600 meters above sea level and bordering the Sacred Valley of the Incas, research, cultivate, and improve Andean potatoes much as their ancestors did for more than seven millennia. The holistic way of life of the people of the Potato Park remains rooted in traditional ancestral cultural and spiritual values, using received wisdom, practices and agricultural and ecological management technologies inherited from the Incas. Here the potato is cherished as part of the family; cultivated in an interwoven mosaic of crops, natural spaces and native forests, where farmers use small terraced plots to intermix native Andean crops with introduced varieties. Beautiful lakes, the wildlife of the high Andes, the presence of the Andean potato's wild relatives alongside Inca archaeological sites; all come together to highlight the biocultural richness of this extraordinary landscape.

The farmers of the Potato Park keep traditional wisdom, practices and innovation alive, actively applying them in their conservation and development efforts and reinforcing them with modern agroecological methods. Local producers maintain dynamic relationships with national and international scientists and research centers, taking an active role in diverse research projects using methodologies that bring together modern science in harmony with traditional wisdom. The result is a biocultural practice that has generated an innovative process of integrated land management at the park. The sustainable development approach focuses on identity, and entrepreneurship focuses on the development of a basket of biocultural goods and services based on the special agroecological characteristics of the landscape and the potato as a 'charismatic species'.

As part of the field day program of the the 10th World Potato Congress and the XXVIII Latin American Potato Association Congress to be held in Cusco on May 31, 2018, the communities of the Potato Park will host a number of distinguished visitors interested in this integrated approach to Andean potato conservation. The Potato Park together with its partner, the ANDES Association, have developed a visitor program designed to share the communities' experiences and learning related to: in-situ conservation, native Andean potato development, dissemination of knowledge, information and evidence, governance of genetic, biological and cultural diversity associated with the Andean potato, and the contributions of this model to sustainable development. The visit will take in five of the Potato Park's communities, set amongst the biodiverse geography of the high mountains and small Andean towns full of tradition.

The visit is organized around four themes: (i) Origin and ecology of the Andean potato; (ii) The genetic diversity of the potato; (iii) Uses, benefits and local livelihoods and support; and (iv) Participatory research and knowledge management. Four sites have been chosen to represent each one of the topics, where work is ongoing in collaboration with the International Potato Center (CIP), the National Institute of Agricultural Innovation (INIA) and Oxfam-Novib (Holland). Each group will visit two sites in the morning and two sites in the afternoon. During each visit, groups will be able to exchange experiences and knowledge with local residents.

At lunchtime, the four groups will meet up in the community of Chawaytire at "Papamanka", a restaurant dedicated to the Andean potato, for a traditional celebration lunch. "Pachamanka" (pot of the earth) is where meat, cultivated and wild native potatoes, and other local delicacies are cooked underground, symbolically connecting the food directly with "Pachamama" (Mother Earth). This signature dish, the most representative culinary heritage of the Incas, will be prepared by the Potato Park's women's gastronomy group, who run the "Papamanka" restaurant.

SPEAKERS BIOGRAFIES

SPEAKERS BIOGRAPHIES

Plenary 1:

The Potato Global Approach

PhD. Dave Nowell

FAO Agriculture Officer,
FAO Regional Office for Latin America and the Caribbean

In December 2017, David Nowell joined the FAO Regional Office as the FAO Agricultural Officer, covering Plant Production and Plant Health in Latin America and the Caribbean. A major focus of this work is plant biodiversity and in particular its conservation and responsible usage in the region. Other major activities include sustainable production, Globally Important Agricultural Heritage Systems (GIAHS), anti-microbial resistance in the environment, emergency pest response and phytosanitary standards.

Nowell worked in the International Plant Protection Convention (IPPC) Secretariat, based in FAO in Rome Italy, from 1998 to 2016 primarily covering information exchange, communication, national reporting obligations and related capacity building. This included phytosanitary standard setting within the framework of the World Trade Organization´s Sanitary and Phytosanitary Agreement (SPS Agreement) - with the objective of facilitating safe trade from a plant health perspective.

Nowell graduated from the University of KwaZulu-Natal (UKZN) in 1981 with a BSc (Agriculture) majoring in plant pathology. He was awarded his PhD in 1997 (UKZN) while working full time in the seed industry. During this period, he also served on a number of national industry committees and industry/government working groups.

PhD. Barbara Wells

International Potato Center

Dr. Barbara H. Wells is the Director General of the International Potato Center (CIP), joining the organization in early 2014. She is an accomplished senior executive with extensive scientific and business experience in research, general management, strategic planning, regulatory processes, and the technical development and commercialization of products in agricultural and forestry markets throughout the world. Her agriculture and forestry expertise spans more than 30 years. Throughout her career, Dr. Wells has worked directly with farmers to apply science at the farmer level to improve their livelihoods and productivity. Additionally, she has had extensive board experience, having served on several private sector, industry association, and non-for profit boards and advisory committees.

Prior to joining CIP, she was Vice President of Global Strategy at Agrivida, Inc., a firm that develops enzyme solutions for animal nutrition and feed-stocks for the production of biofuels and bio-products. Dr. Wells was responsible for planning and implementing the company's global commercial development strategy and scientific collaboration activities with an initial focus on Latin America.

From 2002 to 2012 she was President and Chief Executive Officer of ArborGen, Inc., a global forestry tree seedling and tree breeding business. In this post Dr. Wells led the transformation of the organization from a start-up biotechnology company to a fully operational business with commercial sales of more than 250 million tree seedlings in the US, New Zealand and Australia.

Prior to joining ArborGen, Dr. Wells was Vice President responsible for growth initiatives and investments in Latin America for Emergent Genetics, an agricultural investment firm.

Dr. Wells previously spent 18 years at Monsanto as Co-Managing Director of Brazilian operations and in several leadership roles in field product development across the world for many crops including cotton, corn, soybeans, tree crops, and other products.

Dr. Wells has spent a large part of her life outside of the USA. She grew up in Peru and Bolivia and spent much of her career based in Brazil. She is fluent in Spanish and Portuguese.

Dr. Wells received her PhD. in Agronomy from Oregon State University, her M.S. degree in Plant Pathology and her B.S. degree with Honors in Horticulture from the University of Arizona.

Plenary 2:

Climate Change, Varietal Development and Biotechnology

PhD. Roberto Ferrise

University of Florence

Researcher at the Department of Agri-food Production and Environmental Sciences, is co-author of 37 papers on refereed international journals dealing with agrometeorology, crop modelling, climate change, eco-physiology (Scopus H-index = 12). He is lecturer of the courses “Land Evaluation” and “Climate Change and Ecosystems” at the University of Florence. He was involved in several international and national projects (AgMIP, MACSUR, SmartSOIL, CIRCE, ENSEMBLES). His main research activities are the assessment of climate change impacts on typical Mediterranean crops and the investigation of possible adaptation and mitigation strategies. He worked on coupling crop models with medium-term weather forecasts for precision agriculture. He is currently working on the identifi cation of adaptation strategies and related uncertainties for durum wheat in the Mediterranean by using multi-model ensembles and climate probabilistic projections. Further interests are the use of crop modelling for designing future climate resilient crops and incorporating the eff ects of pests and diseases.

Dr. Glenn Bryan

James Hutton Institute

Dr. Glenn Bryan leads the Potato Genetics and Breeding group at the James Hutton Institute in Dundee. He has made significant advances in the genetic mapping of some of the most effective sources of pest and disease resistance in potato, as well as tuber quality and developmental traits. He also led the UK contribution to the Potato Genome Sequencing Project.

He serves as one of the co-chairs of the global SOL project, whose role is to facilitate research into Solanaceous plant species. He serves on various committees, such as BBSRC grant review panels and the UK Knowledge Transfer Network (KTN) Plant Sector Group advisory panel. His current research is focused mainly on development and use of germplasm resources for potato trait analysis, and the genetic analysis of commercially relevant potato traits in potato, especially those impacting on marketable yield, such as tuber dormancy and resistances to important pests and pathogens.

OPENING SESSION

Kenneth M. Quinn

President of The World Food Prize Foundation

On January 1, 2000, Kenneth M. Quinn assumed the presidency of the World Food Prize Foundation in Des Moines, Iowa, following a 32-year career as an American diplomat, which focused signifi cantly on refugee and humanitarian relief eff orts and culminated with his service as U.S. Ambassador to the Kingdom of Cambodia. For the past 18 years, Ambassador Quinn has endeavored to build the World Food Prize Foundation, founded by the Father of the Green Revolution, Dr. Norman E. Borlaug, so that it could come to be seen as the “Nobel Prize for food and agriculture.” Each October, more than 1,200 people come from 50 countries to Des Moines, Iowa, for the Borlaug Dialogue international symposium, which has been called the “premier conference in the world on global agriculture.” Ambassador Quinn’s foundation also operates one of the most unique youth education programs for high school students in America.

Plenary 3:

Global Approach, Peru and its Biodiversity

PhD. Máximo Torero

World Bank

Maximo Torero has been the World Bank Group Executive Director for Argentina, Bolivia, Chile, Paraguay, Peru and Uruguay since November 2016.

Prior to joining the Bank, Dr. Torero led the Markets, Trade, and Institutions Division of at the International Food Policy Research Institute (IFPRI). His major research work lies mostly in analyzing poverty, inequality, the importance of geography and assets (private or public) in explaining poverty, and in policies oriented towards poverty alleviation based on the role played by infrastructure, institutions, and on how technological breakthroughs (or discontinuities) can improve the welfare of households and small farmers. His experience encompasses Latin America, Sub-Saharan Africa, and Asia

Dr. Torero received his PhD. from the University of California at Los Angeles (UCLA), held a postdoctoral fellow position at the UCLA Institute for Social Science Research (ISSR), and is a professor on leave at the Universidad del Pacífico and an Alexander von Humboldt Fellow at the University of Bonn, Germany. He has won the World Award for Outstanding Research on Development given by the Global Development Network (GDN) twice.

PhD. Andre Devaux

International Potato Center

André Devaux has a PhD. in Agriculture Science from the Université Catholique Louvain (UCL), Belgium, and has 30 years' experience. Most of his career has been associated with the International Potato Center (CIP). He has also worked with FAO and the Swiss Agency for Development and Cooperation (SDC). He has developed expertise in strengthening agriculture research and development programs with multidisciplinary teams in Latin America, Africa and Asia. He has extensive research experience in potato production systems, innovation for inclusive value chain development, and food and nutrition security

He has published more than 50 articles, books and reports. He is now based in Ecuador as CIP's Latin American Regional Program Director, coordinating CIP activities with national and international partners in the LAC region and in a more global context.

MSc. Miguel Ordinola

International Potato Center

Miguel Ordinola is an economist with a MSc. in Agricultural Economics and over 25 years' experience in the related specialties of agribusiness project management, agricultural policy, and agricultural marketing and management activities. Throughout his career he has combined academic and applied activities (agricultural policy, agribusiness, innovation development) with research, management of agricultural development projects, formulation and evaluation of industrial projects (private companies), agricultural research and extension, marketing and product development, and university teaching (marketing).

His work combines work experience in the private sector, international technical assistance and advice to the public sector. During his career he has developed several successful projects in business development, articulating smallholders to more demanding markets as was the case of native potatoes, artichokes boneless trout, alpaca meat, quinoa, yellow potatoes, special coffee, cocoa quality, among others. He has over 70 publications in national and international media.

Plenary 4:

Summary and Strategies for Moving the Potato Forward

MSc. Lieve Van Elsen

Region Director Trias Andes

Master of Science in Water Resources Engineering, Bio-engineer; tropical agriculture and soil conservation. Since 2000, Lieve Van Elsen has been working in development cooperation, as a natural resource management advisor in SNV (Dutch Cooperation), with responsibilities in the Andean Countries. Since 2009, she has been working for Trias, a Belgian NGO, strengthening capacities of farmer organizations in order to reach social, economic and environmental sustainibility, by improving production, giving added value and promoting access to markets with fair prices for producers, and giving farmers a voice to stand up for their rights.

As Regional Director of Trias Andes, she has been supporting COOPAGROS, a potato cooperative in Kishuara – Apurimac, since 2011, organizing the potato growers to improve their livelihoods, generating increased income through the creation of better associative services (production and access to markets). In 2016 they started a new production line to give added value to the potatoes, with the construction of Peru's first "Chuño" enterprise, with high potential for new markets and better prices for the farmers of Coopagros.

Mr. Leoncio Pichihua Quito

COOPAGROS

Leoncio Pichihua Quito is an agricultural producer who was elected president of "The Andes of Kishuará", association from 2005-2010 this being the first association of its kind in the district of Kishuará. The "Los Andes" association promoted technical management of potato production, with the aim of increasing the sale of different potato varieties to wholesalers in Lima, such as huayro, canchan, peruanita, Yungay potatoes, etc. Their successful approach led to the association's growth, and the achievement of its aims. From 2006-2009, he was also president of the Central Association of Potato Producers for the province of Andahuaylas, working together with the mayor of the province, and enabling the association to become the first to send potato varieties such as huayro, peruanita, canchan, Yungay and other native potatoes to wholesalers in Lima and Cusco and other cities, thereby supporting farmers both in Kishuará and the province of Andahuaylas.

Plenary 5:

Summary and Strategies for Moving the Potato Forward - Wrap up

PhD. Oscar Ortíz

International Potato Center

Oscar Ortiz has worked at CIP for more than two decades. An agronomist by training, Oscar began his career working on impact assessments of integrated pest and disease management in 1992. He was the leader of the Integrated Crop Management Research Division and of the Integrated Crop and Systems Research Global Program between 2004 and 2012, when he was appointed Deputy Director of Research for Regional Science Programs. In 2014, he was appointed Deputy Director General for Research and Development.

He has extensive experience in participatory research related to integrated pest and disease control, integrated crop management, agronomy and seed management, impact assessment of research and extension activities, and the use of innovation system approaches for research and development. He has a PhD. in agricultural innovation and rural development from the University of Reading, U.K. and has published extensively in peer review journals, book chapters and conference proceedings.

PhD. Miguel Barandiarán

National Institute for Agricultural Innovation

Agricultural Engineer, (National University of Pedro Ruiz Gallo, Peru), M.Sc. (University College of Wales, UK), PhD. (Iowa State University, USA) Expert in agriculture research and plant breeding. Expert in seed production and germplasm development. Highly experienced in basic and applied research, and in adaptation and participatory research. Wide experience in project proposals and management, and fund raising. Most of my professional career was in the National Institute for Agricultural Innovation – INIA, where I started as junior researcher. In the following years at INIA my posts were as National Coordinator for both the Corn and Pastures and Forages National Programs, National Director in Crop Research, and Director General of Agricultural Research. My actual post is Head of INIA. I also worked as a scientist on the Maize Program of the International Maize and Wheat Improvement Center – CIMMYT, and as University Lecturer.

PLENARY SESSIONS

PLENARY SESSIONS

Plenary 1:

The Potato Global Approach

PhD. Dave Nowell

The Potato: A Global Perspective

This presentation will provide a global perspective of the potato as the fourth most important crop in the world based on Food and Agriculture Organization of the United Nations (FAO) statistics. The potato, which is cultivated globally, originated in the Andes region and has since spread to all corners of the world as a staple or important crop and source of food. During this process, there has been a considerable narrowing of the germplasm utilized (over many years) in production, but a phenomenal concurrent increase in total and per area production. While being an important commercial crop in most major first world countries, it also remains a cornerstone for food security for many family farmers and less developed countries around the world. While FAO serves all countries in the world, much of its focus and efforts concentrate on assisting developing countries, and in particularly, family farmers to meet the UN Sustainable Development Goals (SDGs) within the context of food and agriculture. Within this context, there are a number of very important current challenges to current agricultural food systems. These food systems and countries need to adapt to these challenges in the short- to long-term. Lessons learnt and future considerations will be identified to help meet current challenges such as food security, climate change and sustainable production. Possible new opportunities and areas to be re-visited will also be highlighted. This information is provided to get participants to think of achievements, opportunities and challenges within the larger global perspective.

PhD. Barbara Wells

The Role of Potato in Feeding the future

In the last decades, there has been a growing concern about the impacts of unequal economic development and population growth on global food security and the environment. Feeding nine billion people by the middle of the century means more food production. Meeting the rising demand for food, and ending hunger and food insecurity require substantial improvements to the global food system – one that provides livelihoods for farmers with greater resilience to climate change as well as nutritious products for consumers while, at the same time, keeping agriculture's environmental footprint as low as possible. This challenge requires changes in agriculture production in terms of sustainable high yields, adaptation of cropping systems to climate change, genetic improvement of plant varieties, pest management and new farm practices.

This presentation highlights first, the importance of the potato as a food security crop especially in the developing world. The extraordinary adaptive range of the potato crop, combined with its relatively short maturity period and high nutritional value, has led to steady increases in potato consumption in developing countries contributing to responding to hunger and chronic malnutrition challenges. For the last 20 years, there has been a dramatic increase in potato production and demand especially in Asia and Africa.

Second, it describes innovations based on potato science that can be a significant vehicle for targeting food security challenges as part of a broader set of research and development activities. New research approaches in potato productivity are needed to increase yields and contribute to more nutritious crops such as new breeding technologies, improved seed systems, more efficient crop management practices and post-harvest management methods, including storage and value chain efficiency to reduce food losses.

Third, to achieve the strongest impact on food security, potato research and development needs to move towards food systems engineering, rather than focus explicitly on technology/solution development. Policies and investments that support agricultural productivity and expand risk management capacity will give potato farmers the best chance to meet future needs, while increasing their adaptability and resilience to foster food security.

Plenary 2:

Climate Change, Varietal Development and Biotechnology

PhD. Marco Bindi

Global Effects of Climate Change on the Potato Crop

Potato is acknowledged as an important food resource and supplies the main part of the daily carbohydrate intake of large populations. With a global production of more than 370 Mt yr-1 in the last five years (FAOSTAT 2017), potato is ranked as the 5th most important crop in the world, after sugarcane, maize, wheat and rice. Potato is grown under varied soil types and climatic conditions and despite its cultivated area being stable, at around 19 million ha since 1990s, its global productivity, which is currently more than 19 tons ha-1, is steadily increasing.

Nevertheless, understanding the potential impacts of climate change on potato production is critical for future global food security. Indeed, considerable efforts have been devoted to predicting the potential climate change effects on the potato crop and its management in different areas throughout the world. By affecting environmental conditions, climate change might have effects on crop phenology and crop physiology further altering the development and distribution patterns of plant diseases and pests. These may lead to changes in crop yields and suitable growing areas.

This work aims at providing a general overview of the scientific efforts that were carried out to identify and assess direct and indirect climate change impacts on potato production, further exploring the main potential adaptation strategies that were suggested for different production areas.

Dr. Glenn Bryan

Future of Modern Biotechnology in Varietal Development

Potato, the world's third most important food crop, is set to play a major role in ensuring global food security. Potato production is increasing rapidly in many regions of the world with significant levels of poverty, with roughly a third of production taking place in developing countries and over one billion people relying on potato as their staple diet. As a vegetatively propagated and highly heterozygous polyploid outbreeding species, the development of new potato varieties by conventional breeding is a challenging and slow process. The biological properties of potato have made it difficult to implement modern breeding methods, thus explaining the very slow rate of genetic gain in the crop. Moreover, marker assisted breeding, widely adopted in inbred crops, has been only slowly deployed in modern potato breeding schemes, despite extensive genetic analyses of key traits. Most important potato traits display continuous variation and are determined by several genes, making marker deployment more difficult than for monogenic traits. However, since the publication of the

potato genome sequence several years ago potato has benefited from the development of several resources, such as GWAS populations, dense SNP marker panels, exome capture, and other genomic tools. Dense genetic maps allied to use of the annotated genome render the identification of candidate genes for target traits relatively facile. More recently the ability to create diploid inbred lines and F1 hybrids has the potential to re-invent potato breeding, although significant challenges need to be overcome. Genetic modification as well as novel breeding technologies, such as CRISPR/CAS have been deployed in potato but have yet to be used widely in the development of novel varieties. Under the currently envisaged climate change scenarios, use of these and other technologies will have a vital role to play in improvement of this important crop.

Plenary 3:

Global Approach, Peru and its Biodiversity

PhD. Máximo Torero

Potato Technology and Economic World Trends

Potato is the most important tuber crop in the world. It is a major food crop that is grown in over 100 countries across the world. Moreover, potato's market potential and its positive attributes, particularly its high nutritional value, explain why the global market for potato has grown. Global potato production has grown steadily from 267 million metric tons in 1990 to 373.83 million metric tons in 2016. In 2016, the global potato area harvested amounted to approximately 19.25 million hectares and has remained stable during the last decade showing increase in productivity. International potato trade has doubled in volume and risen almost fourfold in value since the mid-1980s. This growth is due to unprecedented international demand for processed products, particularly frozen and dehydrated potato products (the global frozen potato market was valued at $50,755 million in 2016 and is projected to reach $66. 597 million by 2023, at a growth rate of 3.9% since 2017) mainly because of the growth of quick service restaurants and their major demand for French fries. Despite this growth, developing countries have not been able to benefit in most cases from this trade expansion and are mostly net importers, mainly because the potato market has not received the attention it deserves from governments. This has resulted in a lack of established marketing channels, inadequate institutional support and infrastructure, and restrictive trade policies that are significant impediments to commercialization.

This presentation will focus on assessing the potential for the potato market and highlight the major constrains faced by developing countries in increasing access to markets (local, regional and international) and in increasing value addition on the potato value chain. The presentation will focus on: (a) bottlenecks across the value chain, identifying the major causes and if they are driven by missing markets, markets failures, policy failures, lack of the proper technology, or because of insufficient infrastructure (for example the need for extremely low temperatures up to their freezing point to achieve preservation and protection of the food and the existing nutrients which seems to be one core element limiting market growth); and (b) the major constraints that have limited the export potential of potatoes, by looking into tariff (tariff scalation policies) and non-tariff constraints, such as for example how countries face considerable hurdles in the form of food health standards and technical regulations to access international markets. The latter is extremely important, because it has hampered the international trade of potatoes, and potato products - only around 6 percent of output is traded.

PhD. Andre Devaux
MSc. Miguel Ordinola

Exploiting Potato Diversity for Food Security, Nutrition and Competitiveness of Small-scale farmers: Lessons from Peru

Farmers in the Peruvian highlands have traditionally grown thousands of different potato varieties, which have been selected over centuries for their adaptation, productivity, culinary and nutritional attributes. Until recently, research and development programs have promoted the adoption of improved potato varieties and external inputs. Over the last decade, together with government initiatives, the International Potato Center (CIP) has worked to enhance the use of native potato varieties, promoting their adaptation to local environments, capitalizing on their nutritional value, and developing new products to raise the image of locally grown produce and allow farmers to supply high-value markets and boost their incomes. CIP and partners have developed an approach that fosters innovation for inclusive value-chain development in Andean rural areas. This approach helps to link small scale farmers to new urban markets by taking advantage of potato biodiversity and tapping new market opportunities. This approach involves three types of innovation:

1. Commercial innovation: development of a new image for native potatoes, business models and market opportunities for small-scale farmers, which stimulate native potato consumption and raise farm-gate prices;
2. Institutional innovation: development of coherent policies to enhance potato visibility and consumption; and
3. Technological innovation: increasing productivity of the potato crop, in support of commercial development and food security.

This value chain approach has also been replicated in the Andes and other parts of the world. It has also been combined with other approaches that address chronic malnutrition challenges facing rural populations, such as dietary deficiency of micro-elements – mainly iron and zinc. To this end, CIP has promoted innovation for sustainable agriculture intensification through the selection and use of native and improved potato varieties with higher contents of micronutrients as well as expanding dietary diversity. This presentation will provide an overview of the approaches developed, results at the level of households and the potato, lessons learned from these experiences integrating production, value-chain and nutritional approaches in Peru, and their potential value in other contexts.

Plenary 4:

Summary and Strategies for Moving the Potato Forward

Dr. Marcelo Huarte

Potatoes have been a model of innovation in comparison to other crops. Potato's own biological features, the growers that cultivate it, research institutions and processing companies are the main sources of innovation. The continuous improvement has been scientifically based and easily deployed to serve a permanently demanding private industry and a willing consumer. It is in this framework that the effects of climate change have to be forecast and prevented, and this interaction will pose challenges for future developments. 70 % of the poor communities of the world live in rural areas and therefore the introduction of varieties and other technologies must guarantee sustainability and food security.

The world is facing a nutritional crisis: about three billion human beings in each of its 193 countries have low quality diets. In the next twenty years malnutrition in its diverse forms will pose serious threats to global health. Population growth combined with climate change and the competition of agriculture for natural resources will cause serious stress on food systems, especially in Africa and Asia, where 2 billion additional people will be living by 2050. At the same time, increasing urbanization, notably fast in those areas, will affect hunger and nutrition in complex ways, both positive as well as negative (Global Panel on Agriculture and Food Systems for Nutrition, 2016). More than half a million additional deaths due to diet related causes will occur by 2050 if we compare with a scenario without climate change, and most of these deaths will happen in low and medium income countries. Both direct and indirect effects must be considered when developing climate-sound policies, e.g. in relation to the increase in energy costs.

It looks like there are no important consequences of climate change on the adequacy and quality of diets. However, direct consequences of climate change on diets include increasing temperatures, volatile rains and greater incidence of extreme climatic phenomena, which together will affect agricultural productivity and meat production. Increase in gas emissions with greenhouse effects are associated with the increase in global temperature which has been demonstrated as responsible for crop yield reduction in tropical areas where hunger is more important.

The most recent and more impact yielding technologies on the potato crop that may contribute to mitigating climate change are listed below.

- Precision agriculture including precise decision support systems, "decision agriculture", with fertilizer, disease and yield mapping; use of online sensors applied to farm machinery and storage, innovative planting designs (beds and checks), drip irrigation expansion, sub-surface irrigation with controlled drought and combined with center pivots; automatization and robotics applied to farm labor and combined with the use of drones, strip soil preparation and roads for spraying and irrigation; autonomous weeders and roguing; all connected with an "internet of things". All these technologies

are expected to increase yields, reduce costs, replace hand labor, increase stability and improve quality, improving the potential of each region.

- Use of novel molecular tools applied to disease resistance, stress tolerance and to increase genetic transformation efficiency: CRISPR/Cas9 or gene edition, use of plant embryo cells to increase growth plasticity, RNA silencing, marker assisted breeding, cisgenics, new true seed variety development techniques, etc. These technologies avoid transgenic opponents' arguments and may increase breeding speed.
- Use of biological products that will profit from native soil microbioma and the increase of N use efficiency (NUE) will allow a more sustainable agriculture. Biological products' market increase has been exponential.
- Among traditional agrochemical products, an increase of the use of micro emulsions with ultra- low surface tension to increase wetting (less than 10 nm drops), higher thermostability, higher area interphase and the ability to dissolve liquids that normally don't mix; products with asymmetric catalysis as innocuous antiviral agents and new products with lower environmental and human risks.
- With regards to economic aspects, potato production under contract with increasing backward integration, customized selling strategies, automatized quality control, specialized finance for small growers, direct supply to bars and restaurants, corporative planting or pool planting, hand labor replacement, territory ordination for increased sustainability and efficiency.
- Significative changes are expected in regulatory aspects regarding consumer trends, present applicability of norms, protectionism, and global commerce policies. Both withdrawal and increase of GMO and agrochemical regulations are expected; commercial barriers among countries should be withdrawn, especially those tariff-related barriers that prevent free but controlled movement of potato; European, US and other countries subsidy polices and protectionism should be revised and reduced: potato doesn't need government paternalism. Sanitary risk evaluation among countries is a must to increase international potato commerce.
- A battle between the backers of GMO and opponents of identification and tagging will probably occur sooner than expected, especially at the society and consumer level. Organic potatoes are increasing steadily, surpassing other horticultural crops; carbon and water footprint is increasingly included in the packaging of all forms of potatoes marketed; nutritionists are expected to increase their information related to the quality of carbohydrates provided by potato and their effect on human health.
- Megatrends will be guided towards the ethics of the potato business and increase the involvement of large companies in social responsibility issues and the implementation of agricultural and industrial best practices. Environmental impact mitigation through the rational or restricted use of agrochemicals is today already an obligation in urban agricultural belts. Water use for agricultural purposes will become more and more competitive with human consumption, and therefore there is an important role in the development of tolerant varieties. Improvements in education in general and in potatoes in particular will be continuous and with a growing demand.

MSc. Lieve Van Elsen
Mr. Leoncio Pichihua Quito

Applying the Business Model of Social Entrepreneurship, to Strengthen Potato Producer´s Organizations in Ecuador and Peru

Applying the Business Model of Social Entrepreneurship, to Strengthen Potato Producer´s Organizations in Ecuador and Peru.

Trias is an international NGO which has been working for more than 50 years on economic development through fostering entrepreneurship in 14 countries in Africa, Latin America and Asia. We are rooted in Belgian business associations and farmers unions whose expertise we tap into for our strategies and operations. We connect and empower entrepreneurs. We work worldwide with more than 100 farmers' organizations, cooperatives and business associations and reach out to more than 2 million family farmers and small-scale entrepreneurs. Inclusion of women and youth are at the core of our business.

Trias South-America has developed an innovative Business Model of Social Entrepreneurship to strengthen producer organizations and cooperatives. This model contains two important pillars: organizational management and business management. The model promotes innovative processes and actions with the aim to achieve sustainable organizations from a social, economic and environmental point of view.

The Business Model of Social Entrepreneurship has been applied in a number of organizations in the potato chain in Ecuador and Peru, including CONPAPA Chimborazo, AGROPAPA Tungurahua and COOPAGROS.

The model consists of six building blocks:

1) Organizational Strengthening: capacity building and leadership, set-up of a cooperative organization model with clear role definition, management tools.
2) Quality production: certified seed potatoes, improved productivity, field promotors, and farmer field schools.
3) Services for farmers: technical assistance, microfinance, agro-inputs.
4) Marketing strategies: Market diversification, business plans, client relation management,
5) Added value to the potato chain: mechanization and processing (washing and packaging), production of native potato chips.
6) Relations – networking: partnerships with different stakeholders, including public and private sector alliances, expressing the voice of farmers.

Important results we achieved:

- Professionalization of 3 organizations and 1455 farmers with improved productivity (average production of 20Tn/Ha)
- Increased offer to markets with better and fairer prices for the producers, by adding value: chuño, native potato chips, washed & packed potatoes
- Successful sale of 850Tn/year potato, with turnover of $450.000/year for 2 organizations (Conpapa and Agropapa)
- Better recognition of 3 organizations by local government
- Improved negotiations and relations with private sector

TECHNICAL SESSIONS

TECHNICAL SESSIONS

Technical session A:
Climate Change and Potato Agri-food Systems

Chair : Dr. Peter VanderZaag
Co-chair : Dr. David Ramirez

Climate change will constrain the capability of agrosystems to provide 60% more food and 3 times more water to feed the increasing population which is predicted to reach 9.2 billion by 2050. The increase of atmospheric temperatures, higher occurrence of extreme events like droughts and flooding, displacements and new incidences of pest and diseases, and the disruption of food markets, among others, are current effects of climate change which will be exacerbated without appropriate water and land management. Under this scenario, the reduction of vulnerability, the improvement of adaptive capacity, and the increase of resilience and transformability of agrosystems reorienting policies in response to climate change are crucial to mitigating its likely effects. In this thematic session we will revise, share and discuss the current scientific topics related to the improvement of prediction capacity, building evidence and resource management in agrifood potato systems around the world to cope with climate change. Perspectives like precision agriculture, climatic smart genotypes, modeling for the analysis of yield gap, environmental footprint and response analyzes of potato systems under different climatic scenarios, and policies to enhance resilience have been topics published in recent years and this thematic session will address these topics.

Technical session B:
Trends in Potato and Consumption and Market

Chair : Mr. Ron Gall
Co-chair : PhD. Guy Hareau

Potato has a prominent role to play in meeting the world's food production needs in the future, both as a commercial and high value crop in developed countries, and as a food security crop in developing countries. Better understanding of the trends and the drivers of demand is needed to help public and private sectors make informed decisions about investments along the value chain and in the food system. Opportunities for promoting potato consumption with innovative products will also enhance the crop contribution as one of the most important food crops in the world. The session aims at discussing new knowledge, methods and approaches that can improve understanding in themes such as:

- Communication and marketing for promoting potato consumption;
- Global, regional and national trends in potato supply and demand;

- Potato emerging markets: niches, trends in developing countries;
- Trends in production of table potato and processed products: innovative products;
- Trends in organic potato production and markets;
- Future role of potato as a food security crop;
- Value chain development;
- Culinary innovations (gastronomy).

Technical session C:
Potato Variety Development and Biotechnology

Chair : BSc. Ghislain Pelletier
Co-chair : PhD. Marc Ghislain

This session will highlight the most recent progress on potato crop improvement from an industry and public-sector perspective. It will cover various topics such as the development of new varieties with tolerance and/ or resistance to biotic and abiotic stress, adaptation to climate change, biofortified potatoes, the potential of genetically-engineered potato varieties using trans / cisgenics and gene editing, regulatory and consumer acceptance barriers for the use of biotechnology, inbred line development for hybrid variety development, and the recent development in omics technology for accelerating potato variety development. We anticipate the presenters will address the justification for crop improvement in the context of climate change, reduction in the use of chemical inputs, nutritional improvement of the potato, reduction of post-harvest losses, and increase of income for potato farmers.

Technical session D:
Potato Pests and Diseases

Chair : Mr. John Jamieson
Chair : PhD. Jonathan Jones
Co-chair : PhD. Jan Kreuze

Pests and diseases are among major constraints to potato production worldwide. Global trade is already significantly exacerbating the spread and impact of pests and diseases worldwide, but changing climates will further alter and contribute to the emergence of new pest and disease threats as well as to increased infestations and yield losses This technical session will address the significance of climate change, highlighting advances and new approaches in all aspects of potato pest and disease management including monitoring, diagnostics, advanced predictions of risks through modeling, population dynamics and epidemiology, decision support systems and integrated pest and disease management.

Technical session E:
Potato Variety Development and Biotechnology

Chair : Mr. David Thompson

Co-chair : Dr. Marcelo Huarte

Basic and applied information for high yielding, environmentally sustainable and economically profitable potato crops is presented in this session. New research and technology that may have a positive impact on the potato industry is presented, keeping in mind that growers and agronomists deal with crops that require high investment and skill to produce in a sustainable way. Special interest is given to precision farming, soil preparation under conservational premises, models for fertilizer and irrigation scheduling, variety specific management techniques, quality management certification issues, digital farming, rational pesticide application and other technologies oriented to maximize yield and quality in an environmentally and economically sustainable way. The nine oral presentations reflect modern and innovative aspects related to potato crop management. Five of them consider water supply in relation to yield, efficiency of fertilizer uptake and modelling of crop growth. Aspects of ecophysiology, fungicide and growth regulators utilization are considered in both field and aeroponical crops. Most presentations relate those agronomic aspects with tuber quality for processing. Presentations come from Argentina, Belgium, India, Indonesia, The Netherlands, Peru, and three from the United States.

The seventeen posters selected for this World Potato Congress/ALAP also have a strong innovative characteristic relating to many aspects of crop management, such as soil management, irrigation, fertilizer application, microbial activity under different soil management practices, greenhouse management for prebasic seed production, and deployment of national varieties in small farmer's fields. Poster presentations come from Brazil (5), Canada, Colombia (2), Iran, Italy (2), Latvia, Peru, United Kingdom and Uruguay.

Technical session F:
Post harvest and Processing Technology

Chair : PhD. Nora Olsen

Co-chair : PhD. Daniel Caldiz

Potatoes are grown worldwide to supply different markets and needs. They are grown by a range of producers from small growers in the Andes to large agricultural companies in the north hemisphere. However, no matter who grows the crop, different varieties need to be stored for variable periods of time and under different conditions. If the crop is not properly managed during the post-harvest period, most yield gain in the field could be lost during storage. Then, suitable storage conditions and management are a must in order to supply the market and processing companies, with tubers of the right quality to be

consumed directly, or processed into chips, crisps, flakes and other by-products. This session will deal with: (a) factors and processes related to post-harvest and storage management, under different environments and with different purposes; (b) processing technologies that could range from very simple processes to state of the art technologies, such as new peeling, cutting and other implements, defect detection, and camera vision systems, among others.

Technical session G and H:
Potato Biodiversity and its use in Breeding, Nutrition and Health

Chair : PhD. Daniel Caldiz

Co-chair : Dr. Alfonso del Rio

Potato is the world's 4th most important food crop (after maize, wheat and rice) in terms of production and area cultivated. Reports indicate that the nutritive value of potato per unit of land is 2 or 3 times that of cereals and that it provides more calories, vitamins and nutrients per unit of land than other staple crops. These top four crops supply a greater part of the world's diet than the next 26 ranked crops combined. Potato biodiversity in the form of cultivated potato varieties and landraces, along with their wild relatives, offer a valuable, unique, and diverse source of genetic variation. This has historically provided various traits which have been used for advances in potato breeding and in basic sciences. In fact, these important sources of genetic variation have played critical roles in creating modern varieties with enhanced adaptation to emerging diseases, pests, changing environmental stresses (e.g., due to climate change) and changing consumer preferences and needs (e.g., enhanced nutritional benefits). Therefore, initiatives to foster dialogue and to integrate global efforts are encouraged to identify what's next in potato research so that we may be able to outline new strategies to better manage and use potato biodiversity in the face of new challenges.

WORKSHOPS SESSIONS

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Workshop session I:
Late Blight Global Challenge

Chair : PhD. Ivette Acuña

Co-chair : PhD. Jorge Andrade

Late blight is the main biological constraint for potato production worldwide, especially in developing countries. In this workshop, we will present the latest findings in pathogen population and disease management. Experiences with regional late blight networks (such as EuroBlight and LatinBlight) will be presented and links among them will be discussed to identify key challenges for research and development to fight this disease. In addition, considering that Phytophthora infestans originated in America and co-evolved with potato and other Solanaceae, this workshop will be an opportunity to present and discuss the current situation of the pathogen and disease management in Latin-America.

Oral presentation:

1. **The Euroblight approach to pathogen monitoring to tackle the global challenge of potato late blight management**

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Plant pathogen populations evolve in response to selection pressures imposedby our cropping systems, management practices and other factors such as the weather. Populations of the late blight pathogen, Phytophthora infestans, have a history of dramatic and rapid change that has had serious impacts on potato and tomato production on a global scale. In Europe, the Euroblight consortium has been tracking such changing populations for several years using standardised genetic markers and a reference database to allow comparisons on national and international scales. Our surveys of late blight infected crops by many collaborators (commercial and academic) from 2013-2017 have generated almost 7000 geo-tagged and genotyped samples from across Europe. The data indicates a mixture of population structures; some areas are dominated by a handful of key clonal lineages whereas other areas to the north and east of Europe are more genetically diverse (see mapping interface at www.euroblight.net). The population is dynamic, as indicated by the widespread increase of the EU_13_A2 clone from 2005 to 2008 and, in the last 2 years two new clones (EU_37_A2 and EU_36_A2) that are becoming established. These changes in the P. infestans population continue to challenge Europe's IPM strategies on sustainable use of plant protection products. The Euroblight approach to collecting and sharing data is increasingly important beyond Europe. The goal is a common interface across potato growing regions of the world bringing with it a shared approach to these disease management challenges on a global scale.

2. Best Practices to manage potato late blight

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The European Union has published a Directive (2009/128/EC) establishing a framework for Community action to achieve the sustainable use of pesticides by reducing the risks and impacts of pesticide use on human health and the environment and promoting the use of Integrated Pest Management. This involves an integrated approach to the prevention and/or suppression of organisms harmful to plants through the use of all available information, tools and methods. Eight important principles are described in this Directive which must be considered when setting-up Integrated Pest Management.

Phytophthora infestans is the most important pathogen in potato cultivation and liable for Integrated Pest Management. EuroBlight, a European network of scientists, advisors and representatives from agrochemical and potato breeding companies meets every 2nd year (www.euroblight.net) to coordinate and discuss late blight research. The EuroBlight network identified 11 Best Practices that reduce the development of late blight. The four Best Practices that significantly reduce the impact of pesticides will be presented. 1: Reducing the primary inoculum sources of late blight by practices that minimize the effects of dumps, infected seed potatoes, volunteers and soil borne inoculum. 2: Using varietal resistance to reduce the dependency of pesticides against late blight. 3: Fungicide choice and spray timing must match with disease risk, weather conditions and growth stage of the crop for maximum efficacy. 4: Decision Support Systems integrate all relevant information regarding the pathogen, the crop, the weather conditions and the fungicide characteristics to recommend on spray timing and product choice.

3. Genetic population structure of Phytophthora spp. causing late blight on potato and tree tomato crops in central and southern Colombia

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In Colombia, late blight (LB) is considered one of the most limiting diseases on potato and tomato production. In addition, the pathogen has been associated with large outbreaks on semi-domesticated plants such as tree tomato (Solanum betaceum) and other Solanaceous plants. Recently, a new Phytophthora species, P. betacei, was described infecting tree tomato crops in Southern Colombia. The aim of our studies were to describe the prevalence of LB disease in tree tomato crops and to characterize the Phytophthora isolates obtained from tree tomato and potato crops. SSR markers showed a significant population structure between populations of Phytophthora isolated from potato and tree tomato crops confirming that they belong to different species. In the case of the P. infestans isolates, all belonging to the clonal lineage EC-1, a total of 128 genotypes were detected with high levels of diversity in all localities. Analysis of molecular variance attributed most of the variation to differences within host genotypes than among them, thus suggesting that host cultivars do not structure the populations of the pathogen. Furthermore, the lack of structure according to host cultivar was confirmed by all the analyses, including Bayesian clustering analysis, suggesting that there are no significant barriers to gene flow for P. infestans among potato cultivars. According to geographical origin, the populations of P. infestans were also not structured and most of the variation among the isolates was attributed to differences within localities. These data provide comprehensive information for developing an appropriate management strategy against LB disease in Colombia.

4. Late blight management in developing countries

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We describe the strategy that the International Potato Center is applying to support farmers to manage potato late blight in developing countries. Clones with genetic resistance are the cornerstone of this strategy and are distributed to countries where late blight is the main biotic constrain for potato production. Pathogen population studies provide information on the genetic makeup of the pathogen that has direct effect on disease management, such as mating type and fungicide resistance. We illustrate this by providing examples from Peru and Sub Saharan Africa. Information about the pathogen and the host is then integrated with weather information using a decision support system adapted for low-scale farmers to help them to decide which fungicide spray and when. We describe the validation process to adapt this DSS to local conditions and new studies that are being conducted to evaluate its impact and its readiness to be disseminated. Training to farmers on the basics of late blight (symptoms, causal agent, effect of genetic resistance, fungicide use, etc.) is achieved with the support of training materials and methodologies that had been rigorously tested. We conclude by providing perspectives on disease management in developing countries, including the use of machine learning algorithms for disease diagnostic and disease management.

5. Implementation of early warning systems for Late Blight in Latin America

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Late blight is the most important Solanaceae crop disease in Latin America, causing productive losses and affecting food security. A group of researchers have constituted the Tizon Latino network (https://tizonlatino.wordpress.com/), with the objective to share knowledge and protocols about the pathogen, the disease and its management, to achieve a sustainable control. Early warning systems are an excellent alternative as a decision support system (DSS) for integrated pest management, allowing a more efficient use of fungicides. These systems use different information and grade of complexity, according to the decisions makers. Some of them do not require technology like Hand-held DSS (HH-DSS) developed by the International Potato Center (CIP) to be use by small stakeholders in the Andes, it is based in farmer observation of the weather and crop management, demonstrating similar performance than Simcast. Also, there are slightly sophisticated systems, but easy to use by farmers, for example, Late blight DSS in Chile, available since 2007, utilizes weather data to do the warning, information is delivery to the farmers through a web page, SMS and e-mail. A survey shows that 42% of the farmers applied fungicide based on DSS information, using 50% less spray compared to a schedule application. In Argentina, an impact study about use DSS, shows both 33% monetary saving and 26% fungicide spray reduction, in potato production using DSS. Warning systems are useful tools to develop integrated pest management, but the most important and fundamental is considering what and how the information is delivery to the final users, it need to be simple and easy to understand.

Workshop session J:
In-situ Conservation Challenges

Chair : PhD. Severin Polreich
Co-chair : PhD. Stef De Haan

Sub-Session 1: On-farm conservation of cultivated potato diversity

Potato landraces remain an essential component of Andean production and food systems. Ecological and social change abounds; yet Andean farming systems have remained surprisingly resilient and smallholder producers continue to manage high levels of diversity as part of their livelihood strategies, thereby providing important ecosystem services to humanity. On the other hand, highland communities are increasingly risk prone as they have to struggle with climate change, land fragmentation and increased pest pressure. The aim of this sub-session is to highlight the importance of and threats to contemporary family farming in the high Andes and its contribution to landrace conservation in light of global change. Different dimensions will be discussed, including spatial, genetic, social and benefit sharing components.

Sub-Session 2: In-situ conservation of wild potato species

The in-situ conservation of potato crop wild relatives remains an underattended component of regional conservation strategies. The conservation of the potato's wild relatives is passive and little is known about the influence of land use and climate change on divergent evolution and population ecology. Active management in terms of monitoring, management and gap filling is still in its infancy. However, there is increased recognition of the need to establish observatories for active management. The aim of this sub-session is therefore to explore and elucidate options for research on, and management of, in-situ populations.

Workshop session K:
Value Chain for Small Farmers and Culinary Innovations

Chair : PhD. Andre Devaux
Co-chair : MSc. Andrés Casas

Ensuring food security in Peru, and more globally, requires actions to improve productivity and to upgrade food value chains. This workshop will inform and discuss the implications of rapidly evolving markets and evolving demand from consumers for agricultural products, the consequences for smallholders and the actions required from decision makers to support value chain development.

The first part will be dedicated to the potential of the gastronomic culture as an engine for national socio-economic progress, by highlighting the value and special characteristics of native products to promote them through programs of a social nature. Chefs from the recognized restaurants, Central in Peru and Gustu in Bolivia, will share their experiences of culinary innovation and social collaboration with rural families.

The second part of the workshop will be dedicated to small-scale farmers' access to market, first considering high-value market niches linked to organic certification and the promotion of short staple food value chains. The second presentation will explore the limitations and opportunities of different value chain interventions, including native potatoes, that aim to address poverty through improved linkages between businesses and rural smallholders in Peru.

Through comments from specialists and a final discussion, a reflection on the value chain approach to family farming in Peru and its relevance in other contexts will provide some lessons learned and challenges on inclusive value chain development.

ORAL PRESENTATIONS OF THE TECHNICAL SESSIONS

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Technical session A:
Climate Change and Potato Agri-food Systems

1. **Assessing risk of potato crops in southern Chile under projected climate scenarios using the SUBSTOR-Potato model**

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The aim of the present study was to assess the yield of potato in southern Chile under projected climate scenarios. The study had two steps, i) the crop simulation model SUBSTOR-Potato (in DSSAT 4.7) was calibrated with the cultivar Patagonia-INIA and ii) application of the model to assess the impact of climate scenarios on potato yields. Experimental data collected during 2016-2017, under irrigated conditions, was used to calibrate the genetic coefficients of the cultivar Patagonia-INIA. Tuber yields from 2005-2015 and 12 locations were used to evaluate the model under rainfed conditions. For the model application, a seasonal analysis (30 years of weather) was performed for a factorial experiment under rainfed conditions including six planting dates (from August to October) and seven climate scenarios (baseline and six future scenarios). The six future scenarios (30 years of daily data generated for 2040-2070) were the product of three Global Circulation Models and two Representative Circulation Pathways (RCP 4.5 and RCP 8.5). Cultivar coefficients for Patagonia-INIA were identified (G2: 2000, G3: 24.6, PD: 0.8, P2: 0.5, TC: 20). The evaluation of the model showed that SUBSTOR-Potato predicted potato yield well for the Patagonia-INIA (0.93 Willmott index, 0.75 R2, 24% nRMSE, and 0.61 modelling efficiency). The analysis of variance for the seasonal analysis reveals that dry tuber yield was significantly ($P<0.001$) affected by the scenarios, planting date and its interaction. The present study highlights the necessity to develop strategies to improve potato production systems in Southern Chile.

2. **Sustainable potato agriculture to challenge climate change in the Andes through supplemental calcium nutrition and breeding for frost tolerance**

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Collaborative research in Peru sought to challenge negative impacts of climate change by fostering sustainable potato production. Two approaches were used: first calcium amendments to increase crop yield and, second to enhance frost tolerance in native potatoes. All the multi-year, multi-location experiments and field trials were conducted in the Andean and Altiplano regions of Peru. The results showed that gypsum (Calcium Sulphate), a very affordable and locally available source of calcium, had positive effects on yield and tuber size. Crop yield was significantly increased in about 30% of the more than 1200 native cultivars assessed; gains in yield varied by cultivar, ranging from 10 to 100% over the controls. Breeding efforts for enhancing frost tolerance also started at the US Potato Genebank. These aimed to introgress extreme frost tolerance and acclimation capacity from wild potato species *S. commersonnii* (cmm) into Peruvian native landraces. Seeds of the seven breeding families generated were sent to Peru where, after multi-year and multi-location selections, evaluations and field tests, a number of promising genotypes were identified. They exhibited not only a good level of frost tolerance but also equal or better yield when compared to local cultivars. A couple of elite selections with good hardiness, attractive tuber shape and productivity are now in the process of being released as new varieties by the Peruvian National Program (INIA) in Puno. Likewise, INIA-Cusco has used these selections as parental lines to successfully introduce frost tolerance to their own potato breeding materials.

3. The impact of climate change on future potato yield and water use efficiency in South Africa and possibilities for adaptation

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In South Africa, potato is grown throughout the year in a range of environments. Climate change is expected to increase temperatures, the incidence of heat stress and dry spells, but lower the risk of frost in some areas. Increased atmospheric CO_2 is expected to enhance photosynthesis and reduce water use of potato. However, the impact of these factors on yield and water use efficiency (WUE) are non-linear and interacting. A simulation study was conducted to assess the impact of climate change on future yields, WUE and possibilities for adaptation in all production regions of the country. Climate predictions between 1960 and 2050 were obtained by downscaling global circulation model outputs, which were used as inputs for a crop model (LINTUL-POTATO) to calculate potential yield and evapotranspiration. Simulation results showed that in most regions potato will benefit considerably from increased CO_2 levels through higher yields and reduced water use, assuming other inputs are optimal. However, when the crop is grown in hot periods, this benefit is counteracted by more heat stress and higher evapotranspiration, leading to lower yields and WUE. This especially applies to interior regions of the country, where expected temperature increases are most severe. In most regions, potato growers will likely respond to climate change by advancing planting to avoid heat stress. Despite the fact that potato is a heat-sensitive crop grown under relatively warm conditions in South Africa, the impact of climate change on yield and WUE is expected to be positive in most regions.

4. A second climate smart agricultural revolution in the Andes for the 21st Century

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Climate Smart Agriculture (CSA) is defined as agricultural practices that sustainably increase productivity and system resilience while reducing greenhouse gas emissions. Evidence from lake cores in the Cuzco area indicates a revolutionary change in agricultural practices in the 12th Century with a hard band of sedimentation probably resulting from erosion linked to building of terraces and temporary slope instability. Wari and Inca empires reconfigured the complex of state institutions and hence were able to introduce extensive terracing and agroforestry; thereby intensify production as part of a pan Andean agricultural revolution with maize and potato-based cropping systems at its heart. Dynamic management of intraspecific diversity and farmer seed systems have typically provided socioecological resilience to regional change processes. Yet, evidence is mounting for recent climate change related impacts on a narrowing spatial distribution of potato landraces, and on increased damage from pests and diseases. Current cropping practices fail to provide adequate soil and/or water management, and biodiversity loss is threatened. The paper argues that this calls for no less than a second climate smart agricultural revolution in the 21st century. This will require comparable institutional change to that during the Inca Empire. This can be based around a citizen science driven innovation agenda with the construction of a virtual Green Terrace around the Andes, real-time agrobiodiversity monitoring, conservation agriculture, adaptation of innovative and sustainable pest and disease management technologies, and soil carbon sequestration to securely provide nutritious and healthy food and environmental services.

5. Climate smart potato for mid-elevation agro-ecologies in tropical Africa

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Potato is the smallholder cash crop of the future for the densely populated African highlands, with a high potential for raising their livelihoods. However, scenarios show that climate change can be a major threat to potato production systems in Africa. For several countries, particularly in the tropics and subtropics, yields are expected to decline by 20–30%. In many of the drier potato growing regions this will cause water and heat stress, leading yields to decline. To adapt potato to these challenges, breeders and researchers from the International Potato Center prioritized their breeding and selection strategies focusing on resilience to the most likely future abiotic and biotic stresses. In

evaluation for tolerance to drought over three seasons (2014-2016) at five locations between 1,300 and 1,700masl with an average precipitation of only 295mm (range from 210 - 414mm - optimum 500mm), 15 clones yielded significantly higher than the existing varieties. Since three of those clones have been officially released as varieties (CIP392797.22, CIP398208.704 and CIP398190.200) in Kenya. Tolerance to drought and heat was expressed without yield losses at 15-20% less precipitation and 2-3 C° higher temperatures compared to climates favorable to potato production. Additionally, a series of adaptive participatory trials have been conducted in sub-Saharan African countries such as Tanzania, Rwanda and Ethiopia. This offers a reduced risk of losses due to climate change and offers farmers in mid-altitude an opportunity to integrate potato into their agro-food system to diversify production for improved food supply and income generation.

6. Physiological markers of tolerance to drought conditions in potato varieties (Solanum tuberosum L. Phureja Group). Knowing the physiological mechanisms of adaptation to climate change

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The potato crop is important worldwide, due to its contribution to food security. However, its yield is affected under drought conditions, one of the most important types of stress intensified by global warming. In this research, the physiological, biochemical and yield responses of four varieties of *S. tuberosum* L. Phureja Group under water deficit conditions were determined. Plants of varieties Colombia, Milagros, Paola and Violeta were subjected to two water supply treatments: water deficit applied at tuber initiation for 16 days, and continuous irrigation. The Colombia variety presented the highest susceptibility to the drought condition, due to the rapid decrease in the relative water content and stomatal conductance, the highest electrolyte leakage, the lowest values of F_v/F_m ratio, the highest yield decrease and therefore, the highest value in the drought susceptibility index. The results suggested that the Milagros variety is the most tolerant, because after 16 days of water deficit there was no decrease in yield and the variety obtained the lowest value in the drought susceptibility index. This may be due to the early increase in proline content that allowed it to make an osmotic adjustment and gradually decrease stomatal conductance. Therefore, less damage was observed to the cell membranes and photosynthetic apparatus due to the higher antioxidant activity. Knowing the tolerant varieties of potatoes under drought conditions, as well as the physiological mechanisms that promote this tolerance, allows us to generate breeding programs focused on obtaining plant materials that can be adapted to the climate conditions of the near future.

7. Assessment of the tolerance to low temperatures of native potatoes (*Solanum spp)*, in simulated conditions in La Molina, to mitigate climate change

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In the agro-ecological areas of the Peruvian Andes several adverse weather events occur that place agricultural production at risk. Frosts produce major losses in the potato crop. The high variability of native potatoes in the Peruvian highland constitutes the genetic basis to identify varieties with characteristics to withstand frost. This research was developed with the aim of identifying accessions of native potatoes with a tolerance to low temperatures in simulated conditions. Thirty accessions of the Communal Native Potato Germplasm Banks of the regions of Cusco, Puno and Apurimac were tested with four treatments T1: -4°C, T2: 0°C, T3: 4°C and T4: room temperature during a period of 2.5 hours. Prior to being tested at low temperatures, the phenological condition was recorded and the color of the stem, the thickness of the upper layer of tissue of the leaf, the number of stomas per area, the water content and the content of chlorophyll were evaluated. All accessions under study showed tolerance to temperatures of 0°C and 4°C, and only two of them showed tolerance to temperatures of -4°C, which were characterized by having a thicker upper layer of leaf tissue , a lower number of stomas per area, a lower water content, anthocyanin pigments in the stem and a higher content of chlorophyll. The methodology used can be taken into account to analyze the entire germplasm bank of native potatoes. The results can be used by plant breeders to develop varieties with a high genetic value.

Technical session B:
Trends in Potato Consumption and Market

1. Launch, growth and challenges of native Andean potatoes as we take them world-wide

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This essay discusses the history of native Andean potatoes in Ecuador, some of the reasons for its success world-wide when transformed into snacks, and the challenges ahead. In August 2010, with the support of CIP, we signed a contract between INIAP, CIP, Agropapa, and Inalproces that properly gave birth to the native Andean potato industry in Ecuador. The 2 varieties selected were Puca-Shungo and Yana-Shungo. Under our KIWA brand, these 2 varieties are exported today to over 30 countries, and the product has won several awards for innovation at major food shows around the world including Anuga, SIAL, and Gulf Foods.

More than anything, it shows the results of hard and collaborative work between development organizations such as CIP and IADB, the public sector represented by INIAP, farmers associations, universities like Stanford, and our company Inalproces. Working towards a shared common goal, we have been able to double productivity in the fields and increase income by at least 40% for farmers living at 3,000 meters above sea level and even higher. Moreover, these potatoes are the single best alternative in terms of cost-benefit for low-income farmers living above 11,000 feet above sea level (3,000 masl).

Our goals in the next 2 years are to increase productivity by a further 20% and double overall production. We finish by addressing the many challenges ahead including changes in climate in the Ecuadorian Andes mountain-range, that have killed 80% of our harvests both in 2014 and 2017.

2. Potato preferences in the Ecuadorian Highland

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Farmers, traders and consumers from three Ecuadorian highland regions were interviewed to obtain information on their main selection criteria in order to identify the ideotype of potato.

The Ecuadorian Highland was divided into three regions according to geographical location: north, central and south. There were 500 interviews. For each zone and actor, the preference criteria were established, the relative frequency was calculated per actor group and region and a correspondence analysis was carried out.

There were differences among areas and chain actors for potato preferences. Farmers in all regions were concerned about agronomic aspects; consumers were interested in tuber quality and processing traits, while the traders were interested in the marketability of potatoes. Preferences among women were more related to quality and processing characteristics, while men preferred agronomic traits and marketability of potato. The selection must be performed depending on the trait with a specific actor and differentiated by gender.

The preferred ideotypes in the northern and central regions of Ecuador were quite similar: round tuber shape, red or pink skin color, shallow eyes, mealy consistence and fast cooking, while in the south the ideal potato should have a yellow skin color and mean depth of eyes. The ideal potato should be resistant to late blight, be high yielding and early maturing. Furthermore, good taste, yellow flesh and suitability for several cooking applications were preferred.

The ideotype of potato was affected by the preferences criteria and was influenced by the region. This information will be useful for the development and success of new potato varieties.

3. Release, adoption, and diversity of improved potato cultivars in Asia

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In combating hunger and malnutrition in a world of climate variability and change, knowledge about the release and adoption of improved varieties is crucial to understanding the impact of crop-genetic research and to guiding future research efforts. However, large gaps exist in national statistics for all major crops, including potato. The objective of this research is to fill the gaps by creating consolidated release and adoption databases and to assess the International Potato Center's (CIP) impact in Southeast, East, and South Asia. In following an established methodology, between 2014 and 2016 a total of 350 experts attended one of 23 expert elicitation workshops in 7 different countries. We found

that a total of 491 improved varieties have been released between 1951-2014, of which 210 varieties are adopted in 2014. Releases continue to rise over the years suggesting increasing investment in crop-genetic research. CIP contributed considerably to crop-genetic improvement in Asia: 34% of total released and 30% of total adopted improved varieties are CIP-related. Regarding area of adoption, 97% out of 7.6 million ha planted to potatoes in 2014-2016 are planted to improved varieties. This is due mainly to the strong breeding programs in China and India. In other countries, such as Nepal and Bangladesh, 20% of area is still planted to landraces. A total of 1.4 million ha (19%) are planted to CIP-related varieties with the highest impact in China (1.25M ha). We conclude that breeding is important for a food secure world but may also reduce cultivar diversity.

4. **Adoption and impacts of Cooperation 88 in Yunnan, China: a multi-dimensional analysis**

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Cooperation-88 (C88) is a late blight resistant potato variety that was formally released in China in 2001 and has become popular in China's Yunnan Province. The International Potato Center (CIP) and Yunnan Normal University collaborated to produce the variety, which is one of CIP's most successful varieties. C88 is popular due to its high quality and taste, and it is used commonly in China's expanding potato chip processing market. This study examines the adoption of C88 in Yunnan Province, its value chain, and economic impacts. The analysis indicates that C88 is still popular with 16.8% of the potato area in Yunnan devoted to this variety in late spring 2015. To examine factors affecting household decisions to adopt and the intensity of their adoption, village adoption, household adoption, and household intensity of adoption were assessed. A village's proximity to a metropolitan county was the most important factor explaining adoption and intensity of adoption. Households in villages closer to a metropolitan county disadopted at higher rates than those farther away. To quantify the economic benefits of C88 adoption, an economic surplus analysis was conducted. Total surplus changes ranged from US $2 to 3 billion, depending on model assumptions, indicating significant economic benefits to consumers and producers in Yunnan.

5. **Market governance mechanisms in the native potato value chain in the Peruvian highlands: a case study in the Cusco region**

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Small-scale farmers in the Peruvian highlands contribute to considerable agricultural diversity developed over time, employing traditional methods to produce a large range of non-commercial potatoes. The crop has been demonstrated to provide significant nutritional benefits and matches emerging market demand. However, to date, farmers receive little benefit as their production is generally sold to intermediaries and consumer information generally does not reach farmers.

Market governance is a term used to describe formal or informal drivers conveyed in price-driven organisations. Despite attempts by farmer organisations in Peru to increase productivity and enable competitiveness in local markets, they still remain far from market-orientation and very little is known about market governance mechanisms. This investigation took the form of a single case study with embedded multiple units of analysis. It explored the market governance mechanisms that operate within the native potato value chain. Semi-structured interviews and focus groups with actors from the chain were conducted Qualitative data was coded and analysed using NVivo11. The results identified fourteen (14) components grouped following the Global Value Chain governance theory. The components influence the information-sharing and coordination levels along the value chain.

This work discusses the degree of implementation and development of market governance mechanisms, and what farmers believe is needed to achieve a better position in the market. This research confirmed that the native potato industry in Peru is significant and justifies investment to ensure more of the benefit that can be obtained from the market and that this benefit can be created and transferred to farmers.

6. Exploratory analysis of colored potatoes varieties in natura in the northeast of the São Paulo State

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The potato crop makes a relevant contribution to Brazilian agribusiness However, the cultivation and commercialization of colored potatoes is practically non-existent in Brazil. The consumption of these type of colored potatoes can contribute to the enrichment of the human diet, due to the abundance of antioxidant substances they contain. The present study aimed to verify the acceptance of new varieties of colored potatoes by the consumer market in the northeast of São Paulo state. To this end, a questionnaire was elaborated referring to the profile of the consumer and the product. Results were analyzed using descriptive statistical analysis to determine the frequency and percentages of the evaluated characteristics. One hundred questionnaires were applied. As for the age group, 48% of the possible future consumers are in the age range between 40 and 60 years, 45% between 20 and 40 years and 8% with an age greater than, or equal, to 60 years. About 90% of the interviewees are unaware of the existence of colored potatoes. Most people (65%) would be willing to pay from 25% to 50% more on the value of the common potato, 19% up to twice the price of the common potato, 11% up to three times the price , 3% four times and 2% would not be willing to increase values. The consumer preference was in descending order for the potato Purple 1, Purple 2, Red 1, Red 2 and Rustic with 32, 30, 21, 13 and 4% acceptance respectively.

7. POTATOISM: How potato symbolism in art and culture advances the Potato Revolution

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For over 20 years as an artist, curator and scholar, I have been a spokesman and champion for the potato by chronicling and highlighting its cultural influence in art and popular culture, and by promoting the potato through artworks, exhibitions, and writings.

In 2000, I established the THINK POTATO Institute (T.P.I.), a potato-centric organization comprising all my *Potatoism* activities; producing events (festivals, dinners, etc.), lectures/workshops, exhibitions, and a collection of nearly 6000 potato artifacts from around the world. These activities have served and continue to demonstrate how the potato intersects and even influences nearly all human endeavors.

In 2003, I coined the term *Potatoism* in "The Dialectical Potato: Potato in Art, Art in Potato." In this paper, I explicated the symbolism of the potato as found in historical works of art and established *Potatoism* as a philosophy and art movement. Since then, I have produced half a dozen international *Potatoism* art exhibitions and inspired the creation of dozens of new potato artworks.

My current potato projects in progress celebrate the potato as a symbol of universality, with the linguistically-focused documentary film, THIS IS HOW I SAY POTATO, and a potato-themed podcast, POTATO RADIO.

By understanding and celebrating the symbolism of the potato as found in art and culture, an important collaboration can be consummated with other established potato disciplines, to engender and promote the Potato Revolution.

Technical session C:
Potato Variety Development and Biotechnology

1. **QTL analysis reveals quantitative resistant loci for Phytophthora infestans and Tecia solanivora in tetraploid potato**

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Late blight, caused by *Phytophthora infestans*, and Guatemalan potato tuber moth, caused by *Tecia solanivora*, are the main problems in the potato crop in Colombia. To understand the genetic basis of resistance to *P. infestans* and *T. solanivora* in potato, this research aimed to identify QTL for late blight and Guatemalan potato tuber moth resistance using the F1 tetraploid population Roja Nariño × 2384.

The severity and incidence of the *P. infestans* and *T. solanivora* infections were evaluated in two crop cycles. The severity, incidence and number of outflow holes were also evaluated in stored tubers. The parents and the F1 population were genotyped using a 12K SNP chip. A genetic linkage map with

a length of 968.4 cM was constructed with 1,287 SNPs using the software *TetraploidMap* and the physical map for potato (PGSC v4.03).

The QTL analysis revealed six QTL linked to *P. infestans* on chromosomes 1, 3, 5 and 8. The most important QTL were qrAUDPC-1 and qrAUDPC-3.2. Additionally, 15 QTL related to *T. solanivora* were mapped on chromosomes 1, 2, 3, 4, 6, 7, 9, 10 and 12. The QTL that most explained the phenotypic variance were qIPC-7, qIPA-2.1 and qOPA-7.1 with a proportion of 11.45%, 12.99%, 10.37%, respectively.

According to our understanding, this is the first study that maps QTL for resistance to *T. solanivora*. Thus, these results may contribute to potato breeding programs, especially in countries where *P. infestans* and *T. solanivora* are an important factor limiting potato production.

2. Candidate Gene Detection for abiotic and biotic stresses and Association Mapping for marker assisted selection of useful potato germoplasm adapted to the stresses caused by climate change

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Numerous candidate genes (CG) for tolerance to abiotic and biotic stresses were derived from known genes in potato and other species and from differential expression analyses in stressed and unstressed controls. Amplicons of these CG were produced and sequenced in around 200 potato accessions. Allelic variation was determined for these CG and the effects of their allelic variants on stress tolerance. Association mapping allowed the detection of significant effects on stress tolerance for several CG, to determine breeding values of the accessions and to design promising crosses for further improvement of stress tolerance.

3. New opportunities to achieve disease-free potato using gene technologies

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The gap between actual and potential yield in the potato crop is estimated at 30-40%, almost entirely due to diseases either directly as crop losses or through poor-quality tuber seeds due to pathogen load. Disease resistance has long been a priority of potato breeding but is slow and difficult because the best sources of resistance often reside in wild species. Genetic gain by conventional breeding for resistance alone will not reduce quickly the impact of disease. Instead gene-based approaches could provide yield jumps in potato by introducing disease resistance. Every year, new disease resistance (DR) genes are discovered and validated in potato by scientists, but incorporation of these genes into farmers' preferred varieties for the developing world is minimal. Plant scientists also continue to

discover genes and mechanisms in plants other than potato that could elevate crop disease resistance and prolong its durability. Pyramiding *Rpi* genes from wild potato relatives in farmers' preferred varieties is successful for controlling late blight disease. Virus resistance is now achievable with the recently cloned Ry_{sto} gene to control PVY. Soon, a major gene for resistance to PLRV will be isolated. Bacterial wilt resistance, a rarely successful biotech objective, has been successfully achieved using EFR, a cell-surface receptor gene. Similarly, promising approaches to nematode resistance are being assessed. Hence, farmers' preferred varieties with DR are at hand, but this requires resources and an enabling policy environment. A 30% productivity increase is attainable which will increase profitability, environmental protection, and sustainable intensification of potato cultivation in developing countries.

4. Potato biofortification: introduction of genetic gains for iron and zinc concentration from a diploid population to advanced disease resistant tetraploid potatoes

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With the purpose of introducing the genetic gains for iron (Fe) and zinc (Zn) concentration at diploid level to tetraploid potatoes, CIP initiated interploid 4x-2x crossing aiming at unilateral sexual polyploidization. A group of top tetraploid parental lines with resistance to major potato diseases such as late blight and viruses (PVY, PVX and PLRV), high yielding, good tuber appearance and relatively high concentrations of micronutrients, were used as female parents and a group of selected diploid (2x) clones from biofortification breeding cycle II, high Fe and Zn concentration and sufficient frequency of 2n pollen, used as male parents. More than 13000 genotypes of 230 different crosses were generated. Ploidy level of each genotype were identified at seedling stage by counting chloroplasts in guard cells of the stomata of leaves. A total 8000 genotypes (69%) were classified as tetraploids. Four selection steps have been carried out. Following ploidy analysis at seedling stage, screening for micronutrient content, yield and resistance to late blight were carried out in six different locations in Peru over the subsequent three clonal generations. Screening to PVY resistance was determined by mechanical inoculation in screenhouse. Presently more than 360 genotypes remain selected with a range 24-45mg/kg Fe and 15-35 mg/kg Zn. Heterotic response for tuber yield was recorded; more than 50% of the population over 30 ton/ha. The fifty tops have been prioritized for dispatching for variety selection to target countries in Latin America, Africa and Asia by February 2018.

5. Practical genome-based approaches to augment breeding new potato varieties

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Increasingly, conventional potato breeding programmes must produce new potato varieties for a wide range of markets, which require different consumer quality traits, diverse disease resistance requirements, and have very different agroecological growing conditions. Poor efficiency at early stage seedling selection, usually only in one environment combined with long breeding cycles, results in low

potential for recurrent selection to stack traits and improve genetic gain. Major advances have taken place over the last fifteen years with the sequencing of the potato genome, leading to an increased array of markers for early stage trait selection and developments towards the use of genomic selection.

As new methods have developed, there has been a dramatic change in the cost of ratio of genotyping and phenotyping, with phenotyping now the cost prohibitive step. Also the development and introduction of new selection methods must have minimal impact on the commercial output of varieties. In the Teagasc breeding programme we have deployed marker aided selection to support the stacking of traits and shorten breeding cycles. We have also developed genomic selection techniques for fry colour and storage traits utilising existing breeding populations and phenotyping capacity. Future goals will include developing predictive selection strategies for environmental adaptation and the use of feature selection to simplify genomics predictive assays. Development and deployment of these new selection strategies will be discussed.

6. Metabolic engineering of glycoalkaloid-free potatoes accumulating useful steroidal saponins by genome editing

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Steroidal glycoalkaloids (SGAs) are toxic specialized metabolites that are found in Solanaceae. Potato (*Solanum tuberosum*) contains the SGAs α-solanine and α-chaconine, which are especially accumulated in sprouts and green tubers and sometimes cause food poisoning. SGAs are biosynthesized from cholesterol. Several biosynthetic genes including *SSR2* [1], two *CYP* genes (*CYP72A188* and *CYP72A208*) [2] and *16DOX* [3] have been identified, and the transgenic potato plants silencing these biosynthetic genes showed SGA-reduced phenotypes. Here we demonstrate our recent results and strategy towards metabolic engineering of SGA-free potato accumulating pharmaceutically useful compounds by genome editing. *CYP88B1*, which is involved in a later step of the SGA biosynthetic pathway with unknown catalytic function, is co-ordinately expressed with the SGA biosynthetic genes. In this study, we applied CRISPR/Cas9 system to knockout potato *CYP88B1*. The *CYP88B1*-knockout potatoes showed no accumulation of SGAs, and furthermore the corresponding amounts of steroidal saponins (protoneodioscin and 25-*epi*-indioside D) were accumulated in the knockout potatoes. These steroidal saponins are pharmaceutically useful steroidal saponins equivalent to saponins from *Dioscorea* spp, which are valuable starting materials for the synthesis of pharmaceutical steroidal drugs such as anti-inflammatory, androgenic, estrogenic, and contraceptive drugs.

7. Hybrid potato shows same yields as commercial controls

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Solynta has achieved a revolutionary breakthrough by establishing a diploid potato capable of inbreeding, thereby allowing the much faster development of new hybrid cultivars that are propagated by clean seeds. Good performing inbred lines have been developed by many rounds of selfings, crosses, and selections. In 2014/15 the first experimental hybrids were generated, followed by the second series one year later. Seed tubers of these first two series of hybrids were produced from seedlings in the field. The seed tubers were used to test the field performance of these hybrids in comparison with commercial cultivars.

The best six hybrids of the first series showed yields that were already close to those of the commercial controls in 2016, while the hybrids of the second series showed a much stronger overlap with the controls in 2017.

The results clearly show that these hybrids already give similar yields to commercial controls. This paves the way to rapidly develop a portfolio of new potato hybrids with added value.

Technical session D:
Potato Pests and Diseases

1. Development and application of biopesticides for management of multiple pests of potatoes

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Potato production in different regions of the world varies with different and unique agronomic and crop protection challenges. In most regions potato production is challenged by potential yield loss from plant pathogens, plant parasitic nematodes, insect pests and competition from weeds that requires extensive use of chemical-based pesticides. Marrone Bio Innovations has been developing a portfolio of sustainable crop protection products with applications in potato production for management of potato psyllid, wireworms, nematodes, and soil and foliar diseases that are based on biologically sourced active ingredients. Active ingredients have been sourced from extract of *Reynoutria sachalinensis*, a unique isolate of *Bacillus amyloliquifaciens*, and two novel bacteria *Chromobacterium subtsugae* and *Burkholderia rinojensis*. Primary targets include *Alternaria solani, Phytophthora infestans*, *Phytophthora eurythroseptica*, *Rhizoctonia solani*, root knot and lesion nematodes, wireworms and *Bactericera cockerelli.* Results from research studies, best use practices and commercial successes will be presented and discussed.

2. Naturally occurring soil-borne Bacillus spp. and Pseudomonas spp. with versatile antagonistic activities against Phytophthora infestans and other potato pathogens

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Potato crop protection has always been a major issue worldwide. The management of late blight in particular remains critical and involves tremendous economic losses. Indeed, its control, resorting to a massive use of pesticides, is a rising concern in environmental and human health matters. The need to find alternatives is crucial and encompasses a large set of potential solutions like adapted fertilizations, reasoned rotations, or the use of resistant cultivars. Accordingly, there is increasing interest in studying microbial agents with proven antagonistic abilities. The present work aims at isolating indigenous bacteria that can be integrated into pest management schemes. A collection of more than 2,800 of *Bacillus*-like and *Pseudomonas*-like strains was isolated from soils and plants associated with potato agro-systems in Belgium. Screenings were performed for antagonistic activities against five potato pathogens *Alternaria solani*, *Fusarium solani*, *Pectobacterium carotovorum, Phytophthora infestans* and *Rhizoctonia solani*. Fifty-two *Bacillus* spp. and eight *Pseudomonas* spp. displaying strong *in vitro* inhibition, particularly against *P. infestans*, were selected. Further characterizations for the production of bio-active secondary metabolites revealed that metabolites such as bacilysin, bio-surfactants and siderophores might explain the activities against late blight. Greenhouse assays and a pilot field trial focusing on *in vivo* antagonistic effect against *P. infestans* allowed the selection of four strains of interest. Among them, one *Bacillus subtilis* decreased late blight severity significantly in field throughout the crop season. Overall, this study showed the potential of using antagonistic indigenous soil bacteria as an alternative to the indiscriminate use of pesticides in potato agro-systems.

3. Isolation and field deployment of novel Rpi genes against Phytophthora infestans

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Genetic variation for *Resistance to P. infestans (Rpi)* genes are found in the genus *Solanum*. *Resistance* gene enrichment and long-read sequencing (SMRT-RenSeq) accelerates cloning of novel functional NLR-type disease resistance genes in plants. We cloned a novel *Rpi* gene from *Solanum americanum* and identified a hotspot for *P. infestans* resistance at the distal end of the short arm of Chr 11. We combined bulked segregant analysis and SMRT-RenSeq to clone *Rpi-amr1e* which confers strong resistance against multiple isolates of *P. infestans*. SMRT RenSeq and association genomics enabled us to clone functional *Rpi-amr1e* alleles from several *S. americanum* accessions, which revealed extensive allelic diversity. Despite 85-90% amino acid identity between these homologs, alleles can still confer *Rpi* function. In one of the lines of *S. americanum,* an *Rpi-amr1e* homolog had translocated to Chr 1. We used the same genetic approach to isolate Ry_{sto} that confers resistance to Potato Virus Y (PVY).

We combined *Rpi-amr1e* with *Rpi-amr3* and *Rpi-vnt1* in a stack of three *Rpi* genes in transgenic Maris Piper in a field trial in Norwich. As controls, we used untransformed plants, and plants transformed

with one *Rpi*- gene. The *Rpi* gene stack gave strong resistance to circulating field races (Pink 6). Our long-term aim is to combine blight resistance, with PVY resistance, resistance to bacterial wilt and resistance to nematodes. We are exploring approaches to introduce such genes to defined genomic locations by homologous recombination using targeted CrispR/Cas9 nucleases. An update on progress will be reported.

4. Phosphite fungicide for protection of potato leaves and tubers against Phytophthora infestans

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Phosphite (Phi) fungicides, such as the commercial products Confine™ and Phostrol™, are effective in potato late blight control. In this study, three emerging strains of *Phytophthora infestans* (US-8, US-23 and US-24) were evaluated for their response to Phi. To assess the efficacy of Phi against *P. infestans* in potato plants, four potato cultivars (Russet Burbank, Shepody, Dakota Pearl and Prospect) were examined under greenhouse and field conditions. Uptake and translocation of Phi in leaves and tubers were evaluated by high performance ion chromatography (HPIC). It was found that Phi was uptaken by leaves within 2 hours. Its translocation from leaves to roots took 3 hours, and its concentration was significantly increased in the roots 24 hours after the Phostrol application. The foliar application frequency of Phi affected the Phi accumulation in potato tubers; more applied during the growing season, more translocated into tubers. Postharvest treatments were demonstrated to be essential for protecting tubers during long-term storage. The infections using the three strains of *P. infestans* on the detached leaves and tubers demonstrated the protective role of Phi against these pathogens. Moreover, potential defense mechanisms related to salicylic acid (SA) and jasmonic acid (JA) pathways activated by Phi were also explored. The results of the study provided key information about how best to use Phi related fungicides to control late blight in potato production.

5. Peruvian potato virome: why we need to know more

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The Andean region, which includes Peru, is the center of potato diversity and therefore likely also the center of potato viruses. Under global warming, the emergence of new viral diseases can be expected due to changes in the population of viruses and their vectors as affected by temperature. Here we report the viruses detected in potato samples collected in five areas in Peru using a small RNA sequencing and assembling approach. The viruses detected with the highest incidence were PVX, PVY, PVS, PVV, and PVB. Other viruses detected with lower incidence were PLRV, PVA, PMTV, PYV, APLV, APMoV, and PBRSV. New strains corresponding to the viruses PVX, PVY, PVV, PVA, PVB, PBRSV, APMoV, APLV, PVS, APMMV, and PYV were identified; as well as several novel viruses in the genera *Potexvirus, Potyvirus, Nepovirus, Comovirus, Tymovirus, Carlavirus, Ilarvirus, Badnavirus, Torradovirus, Enamovirus, Ophiovirus, Polerovirus, Fabavirus, Tobravirus,* and *Pomovirus*. Viruses PVB, PVA and a torrado-like virus (coded as SB26/SB29) were found to be more widespread than expected.

This variability gives a snapshot of the viral diversity in potato in its center of domestication and was higher in Cusco and Junin than in Cajamarca, Huánuco, and Huancavelica. This could be the result of higher variability of domesticated and wild potato species in these regions, but may also imply that there is a greater risk for potato cultivation in Cusco and Junín, considering that greater variation means a greater possibility that new variant viruses could emerge as a result of a changing climate.

6. Bacterial wilt of potato in Sub-Saharan Africa: new perspectives on an old disease

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Bacterial wilt (BW), caused by *Ralstonia solanacearum*, is an economically important disease affecting potato production in Sub-Saharan Africa (SSA). BW has become very widespread in SSA- it was detected in 166 of 228 surveyed farms in Uganda, 128 of 176 farms in Kenya, and 158 of 263 in Ethiopia, resulting in 30-100% yield losses, impacting the food security and livelihood of millions of smallholders. 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. An informal seed system and the use of latently infected seed are the major reasons for RS spread and introduction of *Ralstonia* into their smallholdings. Management strategies to reduce the spread and incidence of BW rely on use of clean seed and good agricultural practices. In Kenya, soil application of Neem kernel cake and Plantmate reduced BW incidence and density in the soil, and latent infection by 70-90% and yielded 30-40 t/ha as compared to 2 t/ha in untreated control. In addition, research has shown that integrated seed quality improvement strategies, combining regular influxes of small quantities of high quality seed with on-farm seed multiplication and positive selection, can reduce BW incidence. Current research is geared towards screening of resistant varieties, improvement in diagnostic tests, evaluation of soil amendments, and modelling disease distribution and risk. Through these efforts, BW management options/strategies can be generated that will give potato stakeholders some new perspectives on this old disease threat.

7. Impact of climate change on potato pests in the Andean region

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Insect pest distribution and population growth potentials are mainly temperature-driven; hence a rise in temperature through global warming may either increase or decrease insect development rates and related crop damages depending on an insect species' optimum temperature range. For better preparing policy makers and farmers and adapting Integrated Pest Management (IPM) to new pest situations, a better understanding is needed to predict potential changes in pest risks on global, regional and local scales. We used process-based climatic phenology models for potato pests and

applied three risk indices (establishment, generation, and activity index) in a geographic information system to map changes in risks for climate-change scenarios of the year 2050 using the Insect Life Cycle Modeling (ILCYM) software developed by the International Potato Center (www.cipotato.org/ilcym). The potato tuber moth, *Phthorimaea operculella,* will progressively increase its damage potential in all regions where the pest already prevails today globally, with an excessive increase in warmer cropping regions of the tropics and subtropics. A range expansion with a moderate increase in its damage potential is predicted for the Andean region; in Bolivia, Ecuador and Peru 44,322 ha, 9,569 ha, and 39,511 ha of potato will be under new risk of infestation. Other pest examples will be presented too. In conclusion, farmers will be confronted with a shift in pest range and, due to higher pest abundance, with greater crop losses. The potential changes in pest risks call for creating better awareness and promoting the inclusion of pest risk adaptation plans at country level.

8. The potato psyllid Bactericera cockerelli (Hemíptera: Triozidae): does it move between hosts?

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The potato psyllid *Bactericera cockerelli* (Hemiptera: Triozidae) is the vector of *Candidatus* Liberibacter solanacearum (Lso), causal agent of zebra chip (ZC) disease. Lso was first reported in Mexico (2009) and has been moving northward across the USA ever since. In 2011, a ZC outbreak caused substantial economic damage to the Northwestern states of the USA which were thought to be ZC free. Four genetically distinct haplotypes of *B. cockerelli* were characterized in the USA representing major potato growing regions geographically (Central, Western, Northwestern and Southwestern). The Northwestern haplotyped psyllids were reported living on a perennial solanaceous weed *Solanum dulcamara* and it was suggested that potato psyllids moved from *S. dulcamara* to potato crops during the growing season. We performed an intense sampling in the potato production area of Washington and Idaho in 2012 and 2013 finding considerable high populations of potato psyllids on *S. dulcamara* and potato crops. However, it was unclear whether psyllids move between these two host plants. We used Nextera-tagmented reductively-amplified sequencing to detect genomic variation of psyllids to infer the psyllid movement. We identified 8,443 polymorphic loci from the psyllid populations collected from potato and *S. dulcamara*. Results of multiple population genomic analyses demonstrated a consistent trend that psyllids from *S. dulcamara* and potatoes formed interbreeding populations, suggesting the likely movement between these two host plants. Meanwhile, a psyllids population collected from potatoes showed distinct genotypes, suggesting another potential host plant serving as host for psyllids invading potato fields.

9. Early warning of late blight using passive spore traps

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A two-year research project (2016-2017) was conducted in Ontario, Canada to determine if passive spore traps would provide an early warning of late blight to better time late blight specific fungicides. The results

indicated that passive spore traps placed in commercial potato fields proved to be a reliable method for detecting spores of the late blight pathogen (*Phytophthora infestans*) at least 15 days before lesions were detected in the field. The traps do not need a source of energy; they are activated by the wind. Filters held in the spore traps retain spores blowing in the air. The filters are changed twice a week and sent to a laboratory where a PCR-based test is used to detect DNA of the late blight pathogen. A positive PCR test indicates the presence of spores in the area. This information alerts growers of the increased risk of late blight and the need to tank mix late blight specific fungicides with broad-spectrum fungicides. Once spores were detected, growers shortened spray intervals and switched to late blight specific fungicides (always tank-mixed with a broad-spectrum product). This avoided an epidemic of late blight.

Technical session E:
Potato Crop Management

1. Deficit irrigation and reduced nitrogen fertilizer use in irrigated potato production systems

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Reducing irrigation water and nitrogen fertilizer use in potato production systems but still maintaining maximum tuber yield and quality will guarantee sustainable potato production. In irrigated potato production, the quantity of irrigation water applied is equivalent to evapotranspiration (ET) replacement. ET is mostly estimated for a wide range of potato cultivars, which often lead to over irrigation of some cultivars and potential leaching of applied nitrogen. Studies were conducted at Colorado State University, USA, to evaluate the response of contrasting potato cultivars to irrigation water applied below the suggested ET and below the suggested nitrogen rate. Treatments for Canela Russet included full ET replacement, 82% ET replacement, and 55% ET replacement. Treatments for Mesa Russet were full ET replacement, 90% ET replacement, and 65% ET replacement. Irrigation treatments for Yukon Gold included full ET, 61% and 83% ET replacement. Full ET prolonged green leaf area duration (LAD) in Canela Russet, but rate of tuber bulking and tuber yield were similar for full ET and 82% ET replacement. LAD was longer and tuber bulking was faster when irrigation water was reduced by 35% in Mesa Russet. For Yukon Gold, LAD was longer with full ET, but tuber bulking was faster, and tuber yield was not impacted with 17% less irrigation water. Nitrogen fertilizer was reduced by 20% when pinto beans were used as a rotation crop. Data from these studies indicate that some potato cultivars can produce maximum yield with below maximum ET replacement water.

2. Increasing nitrogen fertilizer and water use efficiency for potato in Florida

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Shortage of fresh water supply for irrigation of agricultural systems is constraining agricultural growth in many regions around the globe. Hence, alternative irrigation methods have been introduced in Florida to improve agricultural water conservation and to minimize offsite movement of nutrients. The objectives of the study were to evaluate the use of subirrigation drainage tile (SDT), subsurface drip irrigation (SDI), sprinkler and seepage with furrows, and to determine proper N-fertilizer timing and rate strategy for potato. Field experiments under each of the four irrigation methods was setup in a randomized complete block design of three N-rates (0, 56 and 112 kg/ha) applied at planting and two N-rates (56 and 112 kg/ha) at emergence and tuber initiation in 2015 and 2016. In addition, the ^{15}N-isotope was used to evaluate N-fertilizer use efficiency (NFUE) of application timings. Irrigation was managed to maintain similar soil moisture in the 15-cm soil depth for all treatments. Irrigation water applied was 291, 169, 145 and 92 mm for seepage, SDT, SDI and sprinkler, respectively. Tuber marketable yield was 26.0, 28.6, 27.3 and 25.6 Mg/ha for seepage, SDT, SDI and sprinkler, respectively. There was no interaction between irrigation methods and N-treatments. Applying 56, 112 and 56 kg N/ha at planting, emergence and tuber initiation resulted in similar tuber yield than higher N-rates. The NFUE was 18%, 44%, and 64% for N applied at planting, emergence, and tuber initiation, respectively. Overall, SDT, SDI and sprinkler reduce the irrigation water usage with no yield reductions.

3. Infrared radiometry as a tool for early detection of water stress: insights into its use for establishing irrigation calendars in potato

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Assessing water status in plants is crucial for establishing irrigation calendars, maximum stomatal conductance at saturated light (g_{s_max}) being considered an important indicator. However, little is known about the relationship between non-invasive methods liked infrared thermometry and g_{s_max} and how they relate to yield. In this study, g_{s_max} -measured throughout the day- was compared with radiometric temperature comparing well irrigated (field capacity - control) and water restricted (half field capacity) plants in a potted trial, using the UNICA potato variety. In a field experiment, two irrigation timing treatments with pre-established g_{s_max}threshold (0.15 [T1] and 0.50 [T2] mol H_2O m^{-2} s^{-1}) were compared against a control (frequently irrigated) under drip irrigation. Crop water stress index (*CWSI*) based on canopy thermal images was related to g_{s_max}, tuber carbon isotope discrimination (Δ_{tuber}) and dry tuber biomass (DTB). While g_{s_max} showed higher differences among plants under different soil water status predominantly before noon, radiometric temperature differences were mainly expressed from 11:00-15:00 hours. The high correlation found among *CWSI* and g_{s_max} (r=-0.67), Δ_{tuber}(r=-0.74), DTB (r=-0.91) indicated the usefulness of this index to predict water status in potato. The significant yield reduction of T1 in relation to the control (-38.2±10.7%) highlighted that g_{s_max} values > 0.15 must be used to guarantee an optimum potato yield. Findings support the use of *CWSI* values of 0.3-0.4 as thresholds for an appropriate irrigation in potatoes with assessments taken at around 14:00 hours, the time in which plants have accumulated enough radiation allowing an appropriate detection of thermal emission.

4. "WatchITgrow", monitoring potatoes from space

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In collaboration with the Belgian potato trade and processing industry association (Belgapom) Belgian researchers (VITO, CRA-W, ULg) have developed a web application for potato monitoring.

The application, called "WatchITgrow", provides information on the growth and development of the potato crop as observed from satellite images. By monitoring temperature and rainfall, and comparing actual with average values, the production risk or quality losses can be assessed. Crop growth models are used to generate yield forecasts currently for the three main potato varieties grown in Belgium (Bintje, Fontane, Nicola). WatchITgrow can also be used to store and exchange field data. This includes basic information such as the variety, planting date, date of haulm killing, harvest date or more specific information on treatments such as application of fertilizers, pesticides, irrigation, etc.

The web application is available free of charge for the entire Belgian potato sector, from farmers to traders, processing companies, suppliers, consultants, researchers, etc. It allows them to better monitor the potato production in Belgium. This should lead to an increase of production in a sustainable way, which is necessary to support the further growth of the sector.

During the 2017 season more than 300 users registered on WatchITgrow. More than 7500 hectares of potatoes were monitored with WatchITgrow, corresponding to approximately 10% of the total Belgian production area.

More functionalities will be added to the application in the coming months.

5. Eco-physiological yield determinants of potato processing varieties grown in the Argentinian pampas

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This research was performed to compare the eco-physiological yield determinants of four potato processing varieties used by the French fry industry in Argentina. The trial was carried out in the southeast of Buenos Aires province, Argentina (37°87' S, 58°14' W), for the code name varieties: BAL1, BAL2, BAL3 and BAL4. Intercepted radiation, total biomass and tuber yield were assessed during crop growth. The highest tuber dry matter yield was 1400 g m^{-2} for BAL4, which was almost 50% higher than those for BAL1 and BAL2, and 22% higher than that for BAL3. The photosynthetically active intercepted radiation (PARint) in the whole cycle was 658 MJ for BAL4, a value that was 34%, 27% and 10% higher than those for BAL1, BAL2 and BAL3, respectively. Radiation use efficiency (RUE), also varied among cultivars; it was 2.57 g MJ-1 for BAL4, resulting 27%, 16% and 11% higher than those observed for BAL2, BAL3 and BAL1, respectively. Harvest index (HI) varied between 0.82 and 0.88, being higher in BAL2 and BAL3. The length of crop cycle, through its influence on PARint, was the most

important factor determining total biomass and tuber yield. RUE, which varied among cultivars, was the second factor in importance, while HI had the lowest incidence on tuber yield.

6. Reduced efficacy of fluazinam against Phytophthora infestans in the Netherlands

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Potato late blight, caused by *Phytophthora infestans* is the most threatening disease in potato cultivation, the second most important arable crop in Europe. The population of *P. infestans* in Europe has shown sudden changes in composition. Currently it is composed of a wide variety of genotypes, some of which are dominant clonal lines while others are rare or even unique to a year or location. Fungicides play a crucial role in the integrated control of potato late blight. Since its introduction in the Netherlands in 1992, fluazinam has been used in late blight control strategies in ware and starch potatoes. Fluazinam is a protective fungicide with a broad spectrum of activity and is effective against a range of diseases including potato late blight. Fluazinam interrupts the pathogen cell's energy production process by an uncoupling effect on oxidative phosphorylation. It is considered to have a low resistance risk. Reduced efficacy against fluazinam was not detected in *P. infestans* surveys in Europe prior to this report. We discovered Dutch *P. infestans* isolates, belonging to the new *P. infestans* genotype EU_33_A2, displaying a reduced sensitivity to fluazinam in field experiments carried out in 2011 and 2015 in Lelystad, the Netherlands, under high disease pressure. In addition, twenty *P. infestans* isolates, collected during 2007–2014 were tested for their sensitivity to fluazinam using an in-vitro assay. The potential effects of this finding on practical late blight control strategies in Europe, as well as in other potato growing regions of the world, will be discussed.

7. Effects of irrigation regimes on tuber yield and quality characteristics of potato under Mediterranean climate

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Excessive amounts of irrigation water are often utilized for potato production in the Mediterranean basin. Given that water is an expensive and limited resource in semi-arid areas, it is crucial to provide appropriate irrigation management leading to savings in water. With the aim of verifying the effects of irrigation water supply only in certain phases of the growing season in a potato crop in the Mediterranean environment, an experiment was conducted in Sicily (South Italy). The effects of four irrigation regimes (irrigation only at plant emergence, irrigation during the whole cycle, irrigation from tuber initiation up to 50% of tuber growth, irrigation from 50% of tuber growth to the end of tuber growth), on tuber yield and quality, were studied. High tuber yields and good tuber quality can be obtained by irrigating from tuber initiation up to 50% of tuber growth, which compared to irrigation throughout the whole cycle allows savings of roughly 870 m3 ha-1 of irrigation water in one crop cycle, which is a significant amount for the Mediterranean semi-arid areas.

8. **Evaluation of microbial activity in soil under different management methods, with addition of organic material with deep or conventional amendment**

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The conventional system of potato production has proven to be unsustainable due to the high inputs and the high incidence of pathogens that prevent consecutive crops in the same area. The deep tillage system for potato, developed by group PACES (Projecting Agriculture Committed to Sustainability) at the University of São Paulo in Piraicaba, aims to improve chemical, physical and biological properties of soil, making it appropriate for cultivation in tropical conditions. Soil microbial activity is an indicator of the intensity of microbiological processes, which are essential for the maintenance of soil biological quality. This work evaluated the microbial activity of soil under different forms of soil management. The five treatments were: 1. Deep tillage and amendment of *Panicum maximum* 2. Deep tillage and amendment of *Brachiaria brizantha* 3. Deep tillage and amendment of *Zea mays*; 4. Conventional tillage and amendment of *Zea mays*; 5. Control - conventional tillage with no amendment. The samples were collected at depths of 0-20 cm and 20-40 cm and during 5 periods within the potato (*Solanum tuberosum* L. cv. Atlantic) cycle, between May and September of 2013.The treatment with deep tillage and amendment with *Panicum maximum* presented the best potential to keep microbial activity high during the whole potato cycle, but there was no significant difference between the amendment with *Panicum* and *Brachiaria.*

9. Evaluation of benefits and losses of minitubers production as affected by increased potato in vitro plants density under greenhouse conditions

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In a three year study, *in vitro* plants of cultivars 'Monta', 'Prelma' and 'Mandaga' (Latvia) were planted in fertilized peat at four plant densities in three replications each year - 63, 95, 142 and 184 plants per m^2, respectively. Obtained minitubers above 3 g were graded into four weight classes (3.00 – 4.99 g, 5.00 – 9.99 g, 10.00 – 19.99 g, and >20.00 g) and planted in field. Over three years (2014 – 2016) under field conditions, the number of progeny tubers >25 mm and multiplication rate of planted minitubers was assessed for each weight class. The number of progeny tubers (>25 mm) in the first field generation obtained from all minitubers >3 g grown in 1 m^2under each planting density was calculated using assessed multiplication rates and defined as field value of m^2 greenhouse area. Data on cost of *in vitro* plants production and on operational costs of m^2 of greenhouse were added. Analysis of benefits and losses caused by increase of plants density between two marginal values showed 133% rise in total production costs when calculated per useful area, and cost of minituber >3g by 49%. Increase of replantable area was 56%. Field value of greenhouse unit area under highest plants density increased only by 43% due to an increase in number of the lightest minitubers with smaller multiplication rate. The smallest increase of replantable area (42%) as well as field value (28%) was observed for 'Prelma', while 'Mandaga' showed the best performance with 76% and 62% increase, respectively.

Technical session F:
Post harvest and Processing Technology

1. The reality of food losses: a new measurement methodology

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Measuring food loss, identifying where in the food system it occurs, and developing effective policies along the value chain are essential first steps toward addressing the problem in developing countries. Food loss has been defined in many ways, and disagreement remains over proper terminology and measurement methodology. Consequently, and despite its presumed importance, figures on food loss are highly inconsistent. Precise causes for food loss remain undetected and success stories of decreasing food loss are few. We address this measurement gap by developing and testing four methodologies that assess the magnitude of food loss. The methods account for losses from pre-harvest to distribution and include quantity loss and quality deterioration. We apply the instrument to producers, middlemen and processors in potatoes and other seven staple food value chains in six developing countries. Loss figures across all value chains fluctuate between 6 and 25 percent of total production and of the total produced value; these figures are consistently largest at the producer level and smallest at the middleman level. Specifically, in the case of potato, they also show a relative higher level of losses at the middleman level, although substantially lower relative to the losses at the producer level which represent between 60 and 80 percent of total value chain losses, while the average loss at the middleman and processor levels lies at around 7 and 19 percent, respectively.

2. Effect of storage conditions (time and temperature) on some quality parameters of native colored fleshed potatoes and a commercial potato

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Five native colored fleshed potatoes, Michuñe roja (white and pale red), Michuñe azul (white and blue), Cabra (purple), Viscocha (white and blue), Bruja (dark purple) and a non-colored fleshed potato Desiré, were analyzed at harvest and after 2 and 4 months of storage at 4, 12 and 20 °C and 90% relative humidity (RH). Total polyphenol contents (TPC), total antioxidant capacity (TAC), glucose, fructose and sucrose content were determined. TAC showed differences among colored potatoes, with values from 200-500 mg ascorbic acid equivalent (AAE)/100 g fresh weight (FW) and from 150-160 mg AAE/100 g FW on non- colored. Higher contents were registered in potatoes maintained at

12°C with no differences between those at 4 and 20°C. After 2 months, TAC decreased but remained unchanged until the end of storage. TPC were higher about 2 to 3-fold higher on colored fleshed potatoes compared to non-colored ones. Temperature and storage time did not affect the TPC. No differences were observed among genetic materials and storage time in glucose, fructose and sucrose. Temperature only affected glucose levels where the values measured in potatoes stored at 4°C were between 1.3-2.18 mg/g FW, being higher than that measured in potatoes stored at 12 and 20°C (between 0.4 to 1.05 mg/g FW). Potatoes maintained their quality after 4 months when stored at 12°C and 90% RH. Native potatoes were richest in functional compounds constituting an interesting alternative to the non-colored ones.

3. Dormancy models to optimize the storage of various potato cultivars

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A better characterization of potato dormancy helps to optimize storage by 1) reducing the application of anti-sprouting products and, hence, storage costs, and 2) increasing the benefits for human health and the environment. The main objective is to develop statistical models to predict dormancy period using parameters related to growing conditions. To build those models, data were collected from field experiments managed in Switzerland over a period of 25 years, in different locations and with 721 cultivars. The available explanatory variables were the following: cultivar, year, location, potato physiological stages, weather and agronomic data. The harvested tubers were stored at 8°C and 85%RH and the sprouting initiation was measured and used as dependent variable. Data was analyzed as follows: (1) analysis of variance to quantify the importance of explanatory variables on dormancy period; (2) creation of a descriptive model using regressions to study and quantify the effect of the explanatory variables and their interactions on the dormancy. Preliminary results showed that the variable “cultivar” was the most important one, accounting for around 60% of the variation of the dormancy, followed by the variables “year” (20%) and “location” (4%) ($p<0.001$). The regression analysis demonstrated that the combination of cultivar and the sum of temperatures between the emergence and the harvest explain 80% of the variability of the dormancy ($R^2=0.80$; $p<0.005$). The models underline the importance of genetic and climatic parameters to estimate the dormancy period. Our work will be instrumental in optimizing the control of sprouting during potato storage.

Technical session G and H:
Potato Biodiversity and its use in Breeding, Nutrition and Health

1. **Genome wide association mapping to uncover the genetic architecture of morphology in tetraploid Peruvian native potato**

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The global in-trust collection of Peruvian native potatoes housed at the International Potato Center provides the ideal population for uncovering the genetic basis of potato morphology. Historically, the genebank has been curated using morphological descriptors of accessions. We genotyped the collection using a SolCAP SNP array. Of the 12K SNPs on the array, accurate tetraploid genotype calls were made for 9,292 markers. After eliminating apparent duplicates, the panel contains 1417 tetraploid cultivars, although 2535 tetraploid individuals with district genebank IDs were genotyped. These duplicate genotypes with divergent morphological descriptors highlight the limitation of SNP array data in a species with clonal variants.

Despite the limitations, a task for which SNP array data is particularly appropriate is genome wide association mapping (GWAS). We used GWAS in order to identify the genetic basis of the morphological descriptors. The resulting QTL for coloring and patterning across tissues exhibited a range of dominance patterns. Many of the resulting QTLs co-localized near two known color loci, *Developer* and *Pigmented Flesh*. However, the majority of the QTLs are for traits not associated with either gene. *Developer* is a MYB transcription factor, one of seven in the QTL region. We hypothesize a series of diverged homologous MYBs and associated cis regulatory elements may determine color and patterning across tissues in Peruvian native potatoes.

This study highlights an effective use of the fingerprinting data from the global in-trust potato collection, and provides a model for future explorations of functional diversity in Peruvian native potato.

2. **Natural starch digestive enzyme inhibitors from potato peels and their influence on glycemic response**

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Potato processing is a large industry, and it generates, worldwide, 70,000 tons of potato peel waste annually. Most of the peels are not well utilized; a small quality of peel is used as animal feed, but most of it is composted. To utilize peel waste, we focus on generating benefits to human health. We

hypothesized that potato peels contain some molecules interfering with starch digestive enzymes and consequently influence postprandial blood glucose level. Our objectives were to demonstrate the impact of potato peel on digestive enzyme activities in vitro, examine the inhibition mechanism, identify and quantify the inhibitors, and examine the difference in inhibition powers across various potato varieties. Our data showed that the inhibitors are water soluble and influence both α-amylase and α-glucosidase with mixed competitive and non-competitive inhibition mechanisms. The identified inhibitors include micro molecules (i.e., copper and nickel), pectin, polyphenols, and calystegine. Potato peel from different varieties impact starch digestive enzyme activities at different levels. Russet Burbank's peel had the highest inhibition effect than other selected 12 varieties. Our data demonstrated that potato peel significantly decreases digestive enzyme activities and indicate a potential to modulate glycemic response. We have planned an in vivo study to verify our findings. Our research has successfully led to an opportunity to utilize potato peel that will promote agricultural sustainability, increase the profitability of the potato processing industry, and benefit human health.

3. Screening for resistance mechanisms to Myzus persicae in potato wild relatives from Salta, Argentina

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The cultivated potato, *Solanum tuberosum* spp *tuberosum* (L), is the fourth most important food crop in the world. The potato crop propagates vegetatively through tubers as seeds (seed potatoes). Therefore, viruses are a significant phytosanitary problem for the crop. The main vectors of viruses in potato are aphids, especially *Myzus persicae* (Sulzer). Aphids are controlled by multiple applications of insecticides, but *M. persicae* can rapidly develop resistance to different classes of insecticides. An alternative to control *M. persicae* is to use resistant plant genotypes although only a low proportion of wild potato relatives have been used as sources of resistance in breeding programs. Our aim was to find new sources of resistance to *M. persicae* in germplasm of wild potato relatives from Salta, Argentina. Twelve accessions belonging to four wild (*Solanum stoloniferum, Solanum chacoense, Solanum vernei* and *Solanum infundibuliforme*) and one cultivated species (*Solanum andigenum*) were obtained from the INTA-Balcarce germplasm bank (Balcarce, Argentina). Resistance to *M. persicae* was evaluated by a colony-development test. A high level of resistance was found in *S. vernei* and *S. stoloniferum* genotypes, and a moderate level in *S. chacoense* genotypes. One *S. chacoense* genotype developed a strong reaction to the aphids, generating pustules. Then, a preference test with a two-chamber olfactometer was performed to compare the preference of *M. persicae* between the resistant genotypes and *S. tuberosum*. Aphids preferred S. *tuberosum* over *S. chacoense* or *S. stoloniferum*. Currently, we are studying the mechanisms of resistance in the selected genotypes at molecular and morphological level.

4. Towards an increased understanding of genetic relatedness in cultivated potato

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Ex-situ germplasm collections rely heavily on the taxonomy of the crops they preserve for maintenance and characterization of the collections. The International Potato Center (CIP) in Lima, Peru safeguards the global in-trust collection of potato with over 4,350 cultivated potato landraces. Using the SolCAP 12K SNP array, the entire cultivated collection of landraces was genotyped. This material is classified on the taxonomy of Hawkes (1990) (seven species and nine subspecies) while the recent revised taxonomy of Spooner (2014) groups cultivated potato into just four species. According to Spooner, *Solanum anjanhuiri*, *S. juzepczukii* and *S. curtilobum* are distinct species yet, in our data set, they appear similar genetically, forming a single branch in a dendrogram with similar allelic distributions from a STRUCTURE analysis. The lumping of *S. stenotomum* (spp. goniocalyx and stenotomum) by Spooner is in agreement with our data with species boundaries not clearly separated. Interestingly, *S. phureja*, *S. tuberosum* subsp. tuberosum and *S. xchaucha* are very distinct from each other in a dendogram, are composed of unique allelic components distinct from other taxa, and yet are uniform within each taxon. Our data also agrees with Spooner that S. tuberosum subsp. andigenum contains so much admixture, apparently derived from populations outside the cultivated material, that it does not form an individual grouping. With the growing number of genetic and genomic analyses ongoing, we propose that interested parties hold a workshop to discuss these new data in more depth as they relate to the taxonomy of potato.

5. A pan-genome approach to enhance understanding of the potato genome

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Sequences of the genomes from the nine cultivated potato taxa (defined by Hawkes 1990) in addition to the genome of a putative closely related precursor of potato, *S. bukasovii,* have been assembled by combining *de novo* and reference-based methods. The long-term goal of the project is to assemble a pan-genome for use in genomic studies, but also to help understand differences between these taxa to support ongoing taxonomic studies of this important crop. Our studies support the growing understanding that a single genome from an individual, is unable to capture the genetic variability among a group of related species as many genes are affected by Copy Number Variations (CNVs) which significantly contribute to diversity of agronomic traits. Major efforts for potato improvement have been attempted and enormous success has been attained. However, an expansion of available genomic and transcriptomic resources could greatly aid in the exploration for novel traits. Focusing on the genomic resequencing data from four diploid landraces, plus a landrace each from *S. stenotomum subsp. goniocalyx* and *S. tuberosum subsp andigenum* (six genomes in total), structural variation was identified and compared to the current reference genome. The results of a CNV analysis showed that in most of the genomes, the number of the genes affected by deletion events was greater than those affected by duplications. Chromosome 12 is particularly interesting as it appears to have a high number of CNVs per Mb, with genes involved in metabolic processes of polysaccharides, environmental stress tolerance, and response to disease.

6. Diversity, taxonomy, distribution, conservation and uses of the wild potato species in Southern South America

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Solanum L. sect. Petota Dumort. comprises cultivated potatoes and wild conspecifics, which are distributed from the Southwestern United States to the center of Argentina, Uruguay and Chile. Sect. Etuberosum (Buk. & Kameraz) A. Child, group closely related, is located in Argentina and Chile. A new monograph revises diversity, taxonomy, distribution, conservation and uses of all wild species of these two sections of Argentina, Bolivia, Brazil, Chile, Paraguay and Uruguay. Three diploid species (2n = 24) are recognized in section Etuberosum while 27 species of different ploidy, diploid (2n = 24), triploid (2n = 36), tetraploid (2n = 48) and hexaploid (2n = 72) are included in section Petota. In relation to the classical treatment of wild potatoes by Hawkes, in this contribution the names of 36 species, 7 subspecies and a variety have been synonymized, and a subspecies was awarded the rank of species. The monograph summarizes recent morphological and molecular studies, proposes a classification of wild species, and includes complete descriptions, synonymy, illustrations, distribution maps, reproductive characteristics and breeding applications, as well as data from localities and the habitat of each species. This work contributes to the understanding of wild potato diversity of Southern South America and also a synthesis of proposals for ex-situ and in-situ conservation of these valuable genetic resources.

POSTERS OF THE TECHNICAL SESSIONS

Technical session A:
Change and Potato Agri-food Systems

1. **Developing a potato sustainability index through greenhouse gas and nutrient density modelling to support nutrient sensitive agriculture**

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Population growth will continue to drive the demand for responsibly produced foods and nutritionally adequate, healthy and affordable diets. Disentangling the nutrient rich foods to environment nexus enables the development of strategies and policies towards environmentally-friendly production and processing, while supporting healthy, well-nourished and food secure populations.

The quantity of a specific nutrient (nutrient content) found in a food forms an important point of departure for arguments related to the role of that specific food for human dietary needs. In addition, quantitatively presenting this value in the context of dietary quality and, in comparison, to environmental impact, will be a valuable tool to prioritise sustainable and nutrition-sensitive food systems.

To develop a strong quantifiable case for potatoes, energy and nutrient density (ND) of potatoes, in relation to other popular Sub-Saharan Africa foods were mathematically calculated and plotted in relation to their carbon footprint using the NRF 9.3 model and the Carbon Food Scope.

Even though potatoes are commonly consumed as a starch they are classified as a vegetable, contributing to higher ND values compared to other starch vegetables. In this study potatoes obtained a ND score of 11.63 combined with a low GHGE score of 0.33. As potatoes are a minimally processed product that can be consumed as harvested with only at home cooking methods applied, they have very low GHGE values when compared to other staples such as pasta (1.24) and rice (1.53) which have more extensive processing regimes.

2. Regulating flower and tuber formation in potato with light spectrum and day length in Pakistan

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Solanum tuberosum (potato) can reproduce through tubers and seeds. Recent developments have enabled hybrid breeding and propagation from seeds in this crop. This makes potato flowering a new focus of research interest. Tuberization and presumably flowering, followed by seed set, are strongly regulated by environmental cues. A well-studied environmental regulator of tuber formation is day length. Photoreceptors are involved in this photoperiodic control of tuberization, suggesting light spectrum may be an important factor. However, it is not known how photoreceptors control potato flowering. Here, in this study, influence of light spectrum and photoperiod on tuber and flower formation were observed. Three potato genotypes (PRI-Red, Ruby, Sadaf) were grown in climate chambers with Light-Emitting Diode (LED) lighting and additional far-red and blue LEDs under long and short days. Far-red light accelerated tuber formation up to eleven days and blue light slightly delayed it up to four days. Light spectrum does not possess any effect on flowering. Long photoperiods delayed tuber formation compared to short-day conditions in two of the three tested genotypes. Aside from one genotype "Sadaf" which only flowered in long-days, photoperiod does not have any effect on flowering.

3. Sustainability of potato farms in the Lima region

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The potato is an Andean native crop, with wide genetic diversity, that is developed on small farms in Latin America generating rural employment. There is a priority therefore to evaluate the sustainability of the production system according to environmentally friendly agronomic practices. The objective of this research was to evaluate the sustainability of the potato farms and to propose management alternatives to optimize the potato production system under conditions on the central coast of Peru. The levels of social, economic and environmental sustainability of the potato farms were evaluated through Sarandon´s Multicriteria Analysis, using as a tool a survey of 127 farms in the provinces of Barranca, Huaral and Cañete in the Lima region. Later the effect of microbial inoculation on the sustainability of the potato production system was also evaluated. It was determined that the potato producing farms presented a low level of sustainability with a value of 1.76 on the weighted scale of indicators used, and that it is necessary to implement actions that reduce the vulnerability of the potato crop with respect to the conservation of soil life and management of agrobiodiversity, among other factors considered. By inoculating seed tubers with microbial strains, significant differences were obtained in comparison with the control plots in experimental and field conditions, considering that the use of growth promoting microorganisms in potatoes can be a management alternative to increase the level of sustainability found in the potato producing farms in the Lima region.

4. **Social implications of the use of water: quality water as a key factor in the performance of sweet potato cultivation in Cantarranas, Honduras**

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The use of high quality water for the cultivation of sweet potato and the conflicting demand for its uses with the neighboring communities of Cantarras, Honduras is a theme that has been analyzed from the perspective of local economic development, social justice and the management of natural resources. Sustainable human development as a factor of change in communities, especially the less favored ones, benefits directly from the production of sweet potato. The conflict of use of water resources is analyzed within the east basin of the La Tigra National Park focusing on the quality and quantity of water in the dry season. The situation is also examined from the perspective of TACIS agreements and negotiations that emphasise the source of work employment and the conservation of the environment as premises for local analysis.

5. **Yield and physiological responses of potato crop under future climate scenarios of temperature increase in southern Chile**

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The present study assessed the impact of moderately high temperatures (3-4°C above ambient temperature) during tuber bulking on yield and physiological traits of Chilean native (Chona) and commercial varieties of potato (Karú-Desiree) under different water regimes. During two growing seasons, four treatments were applied for 40-days from the beginning of tuber bulking under field conditions: ambient temperature without irrigation (T0H0) and with irrigation (T0H1), temperature increase without irrigation (T1H0) and with irrigation (T1H1). Plots were heated using polyethylene chambers equipped with thermostatic electric heaters. Plots were arranged in a split-plot design with 3 replicates (blocks). The yield increased with irrigation but not with temperature, whatever the genotype. The harvest index, average tuber weight, tuber number and dry matter content varied mainly depending on water availability and genotype. In Chona, T1H1 increased the photosynthesis rate by 30% and the RuBisCo content by 680% compared to T0H1. Karú showed lower concentrations of foliar pigments than Chona which maintained its green foliage for longer time under T1H0 and T1H1 treatments. Proline concentration increased in leaves and tubers of plants without irrigation,

showing that it contributed to osmotic adjustment in potato. The concentrations of MDA and total ascorbate content of leaves varied mainly depending on water availability and genotype, showing that oxidative stress was observed without irrigation. In conclusion, the moderate increase in ambient temperature projected for southern Chile will not adversely affect potato production, however water availability will play an important role in productivity increase under climate change conditions.

6. **Relationship between Guatemalan Moth (Tecia solanivora) adults and elements of climate in the potato crop (Solanum tuberosum L.) in West Sabana de Bogotá, Mosquera, Colombia**

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High levels of pest populations were reported recently in potato crops in Colombia, showing Guatemalan Moth (*Tecia solanivora*) as the most limiting of these. Interdisciplinary approaches are important in dealing with the uncertainty of the behavior of pests and climate conditions. This work aimed to evaluate the effect of climate elements, present in the study zone, on moth adult populations. The experiment was carried out in Mosquera (Cundinamarca – Colombia; 4° 41' 18.84' 'N and 74° 12' 22.67'' W) at 2,560 masl. Three potato crop cycles (cv Diacol Capiro) were established with a monitoring system based on *T. solanivora* pheromone traps. Climatic variables were recorded at a local weather station. Data analysis included Pearson correlation and correlograms. Throughout the study period (2015 – 2017), the fluctuation of *Tecia solanivora* adults exhibited mean positive-correlation with: maximum temperature, day degrees, solar brightness and mean temperature (in order of relevance); and we found mean negative-correlation with precipitation and humidity index (in order of relevance). In climate change scenarios, maximum temperature may be considered the climatic variable of greatest relevance to explain population increase and dispersal of *Tecia solanivora* adults. On the other hand, rain has a negative influence on the adult population of *T. solanivora*, with the greatest number of individuals occurring in conditions of low rainfall.

7. **Evaluation of drought tolerance in native potato (Solanum spp.) under semicontrolled conditions, to mitigate climate change**

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Peru is one of the most vulnerable countries to climate change that causes, among other factors, a loss in water resources availability. This generates a series of climatic alterations, mainly droughts in the Andean highlands, which affect crop production. The search for sources of genetic resistance to water stress is one way to face the challenges of yield increase within this context of changing climate conditions. Lots of native potato varieties grow in the high Andean zone of Peru, with a high potential to mitigate climate change. In this research, 36 accessions of native potatoes (*Solanum spp.)* from southern Peru were evaluated in order to identify drought tolerance under semicontrolled conditions. Three watering conditions were applied 1) watering during the whole cycle with a frequency of three times per week (control), 2) gradual suspension of watering at tuberization onset for 10 days

(mild water stress) and 3) gradual suspension at tuberization onset for 18 days (severe water stress). This screening allowed us to identify 17 accessions that were tolerant to mild water stress and 10 accessions that were tolerant to severe water stress. Accessions A9 and A19 stood out for their resistance to drought, greater biomass accumulation and root architecture. One of the mechanisms that contributes to tolerance is related to less number and stomatal area in tolerant accessions than susceptible ones. The results of this study highlight high-value genetic sources which can be used by potato breeding programs and by conservationist farmers to mitigate the effect of climate change.

8. **Options of potato production stabilization using drip irrigation in the potato production region of the Czech Republic**

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The aim of the trials was verification of drip irrigation use under the conditions in the potato production region of the Czech Republic. The verification was performed with specific field trials at the Potato Research Institute, Havlíčkův Brod (460 m a.s.l., cambisol, annual mean air temperature 7 °C, annual mean total precipitation 652 mm). The trials were performed between 2016 and 2017 with two potato varieties: very early Monika and medium-early Jolana. Irrigation pipes were installed after planting into ridges (4.5 cm below the ridge top). Irrigation was automatically started based on soil moisture measured with moisture sensors. Three variants of irrigation intensity were evaluated, starting at various soil moisture levels – 15 % (low), 20 % (intermediate) and 25 % (high). Uniform irrigation rate was 10 mm. Compared to non-irrigated control, a statistically significant potato yield increase was found in almost all cases. For high irrigation intensity the yield increase was 47.5 % (Jolana) and 49,3 % (Monika) in 2016 and 33.1 and 59 % in 2017 due to drip irrigation. Drip irrigation also significantly increased marketable potato yields in both years. On the other quality parameters any negative effect of irrigation was not detected. Based on the results we concluded that using of drip irrigation could also stabilize potato production in regions where irrigation has not been applied so far.

9. **Early Agroclimatic Warning System Prototype (EAWS-Prototype), for potato crops (Solanum tuberosum) in the municipality of Yacuanquer (Nariño, Colombia)**

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An Early Warning Agroclimatic System Prototype (EAWS-Prototype) for potato crops (Solanum toberosum) was designed and implemented in the municipality of Yacuanquer, department of Nariño - Colombia. Its purpose was to provide a decision-making tool for crop management considering a Climate Smart Agriculture (CSA) approach. The EAWS-Prototype is part of the MAPA Expert System (ES-MAPA), a platform that seeks to improve the adaptation of farming systems to climate change and variability. The ES-MAPA systematizes the most relevant results of the "Models of Adaptation and Agroclimatic Prevention" (MAPA) project, which was implemented in 54 farming systems, in an equal number of municipalities. The ES-MAPA follows a logic that enables the management of agroclimatic risks at three different spatial

scales: departmental, municipal, and local. At departmental level the ES-MAPA characterizes agroclimatic threats. At municipal level it maps the land agroclimatic suitability under events of climatic variability and highlights "productive niches of low agroclimatic risk" under conditions of excess and deficit of soil water. Finally, on a local scale (where the EAWS - Prototype is hosted) it calculates a probable humidity condition in the area using a seasonal climate prediction for one, two and three months. It estimates the effects of this condition on the crop and provides a set of recommended technological options validated by Corpoica as part of the MAPA project. As more weather data and crops information become available, other EAWS will be able to be implemented in different regions in the medium term. The ES-MAPA are available at: http://www.corpoica.org.co:8086/NetCorpoicaMVC/SEMapa/

10. Experience of the first year of the Allin Kawsay Program with potato smallholders in Huanuco

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Agriculture in Peru can be divided into two segments: agro-industry and small-scale agriculture. The former has been the main driving force of success in the agricultural sector, with an impact that has translated into economic growth and the reduction of poverty in recent decades.

The latter however, represents mostly a subsistence agriculture, whereby farmers have only limited access to financing as well as to the new technologies that have revolutionized the agricultural industry. For these reasons, this population has remained at one of the highest rates of poverty.

This paper discusses the results, as well as analyzes and evaluates, the first year of implementing the Allin Kawsay program, developed and subsidized by BASF. This program was developed to improve the quality of life in Huanuco. The Huanuco region is home to the largest producers of potatoes in Peru, and yet, it is also one of the highest regions of extreme poverty. The program focused on knowledge transfer and encouraging smallholders' learning in potato crop management, integrated pest and diseases management and good agricultural practices.

During the first stage of the program, more than 4,000 farmers in 25 communities in Huanuco were trained by Allin Kawsay. Demoplots were made, which resulted in an average increase yield of 35% in first category potatoes compared to the farmers' usual practices and treatments. The Allin Kawsay Program is at the beginning of its second stage, which aims to replicate, based on the Huanuco findings, and expand its program to other regions throughout Peru.

11. Targeted calcium nutrition as a strategy to mitigate the impact of heat stress on potato tuber quality and production in view of global climate change

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Potato is a cool season crop, cultivated in the temperate zone in North America, Europe and the highlands of South America, Africa and Asia. Heat stress is known to reduce potato plant growth

and tuber production. Climate models predict the impact of temperature stresses on plants to be more erratic, severe and unpredictable. Thus, it is important to devise strategies to mitigate the impact of temperature stresses on plants. Our studies conducted, with the cultivated potatoes at the University of Wisconsin, have shown that rhizosphere calcium concentration can modulate the adverse impact of heat stress. Using a controlled environmental facility, precise experiments were conducted to study the response of potatoes to a simulated heat stress. These studies showed that by maintaining a critical level of calcium in the root zone we were able to get over 30% increase in yield under heat stress conditions. Recent studies show that under heat stress foliage and tuber growth can be dramatically improved by enhancing soluble calcium in the root zone. Our field trials have also demonstrated that late season heat-induced tuber necrosis (internal browning) can be reduced by in-season calcium application. Calcium is well known to protect membrane health and act as a powerful metabolic regulator. Thus, our studies provide not only physiological and molecular explanation for mitigation of heat stress impact on potatoes by calcium nutrition, they also provide a simple and practical means to reduce the impact of heat stress on potato production and quality.

12. Effects of climate change on the distribution of Potato Tuber Moth, Tecia solanivora (Povolny) (Lepidoptera: Gelechiidae)

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T. solanivora is considered to be one of the most serious pests of potato tubers in both Central and South America. Losses may be as high as 100%. Furthermore, *T solanivora* is established along the border of Ecuador and Peru (EPPO, 2005). This research determined the geographic distribution of *T. solanivora* in relation to literature sources and the potential distribution of *T*. *solanivora* under current climate conditions and a climate change scenario (A1B-2050) at the global level using the CLIMEX model. The model used physiological parameters of *T. solanivora* and global meteorological data, to build an Ecoclimatic Index (EI), which described the potential area of establishment (EI>30) and occurrence (EI<30) of *T. solanivora*. For the calculation of number of generations/year of *T. solanivora* the CLIMEX model used the algorithm of Baskerville and Emin, based on degree-days of *T. solanivora* from egg to adult. The results showed that *T. solanivora* is currently in 12 countries. The area of establishment (EI>30), for *T. solanivora* in current climate conditions, summed 131 176 554.9 km^2 and in the scenario (A1B-2050), it summed 131 176 081.8 km^2 globally. The potential range (EI>30) for *T. solanivora*, in the (A1B-2050) scenario diminishes in 0.08 % in Africa, 0.06 % in America and 0.03 % in Oceania, but increases in 0.02 % in Europe and 0.01 % in Asia, compared to the current potential distribution. In the scenario (A1B-2050) globally for *T. solanivora* with respect to current climate conditions, there will be an average increase of two generations/year in the tropics and a generation/year in the northern and southern world.

13. Physiological variation, yield and free proline accumulation in potato cultivars (Solanum tuberosum L. Phureja Group) under water deficit

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Climate change increases the risk of drought in many regions of the world. Water availability is one of the main limitations of potato yield due to the high sensitivity of this crop to water deficit. In this work, the effect of water deficit on physiological parameters, yield and free proline in potato plants (*Solanum tuberosum* L. Phureja Group) of cultivars Colombia, Dorada and Ocarina were determined. Plants at tuber initiation were subjected to two treatments of water availability: water deficit applied at tuber initiation for 17 days, and continuous irrigation. The results showed a decrease in the volumetric soil water content (47%) after 5 days of treatment, which caused a significant reduction in the leaf relative water content and stomatal conductance. An increase in chlorophyll concentration was observed in plants under water deficit, due to decreased growth. Also, a higher content of malondialdehyde was found because of lipid peroxidation. Proline content was increased (73 times) in response to water stress. Plants under water deficit of all varieties showed a decrease in leaf area and total dry mass, and a high root/shoot ratio, which caused a decrease in yield. The decrease in yield could also be associated with the fact that the plant increased proline content generating an additional energetic cost. Although the three cultivars evaluated showed sensitivity to water deficit according to the percentage of reduction in yield compared with well-watered plants, the Dorada cultivar was the most sensitive to water deficit and Colombia was the least sensitive.

14. A first insight on the effect of climate change on potato production under Tunisian Highlands conditions

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Climate change affects natural resources, crop yield and incomes of smallholder farmers. Sustaining performing potato production systems might help to reduce these effects in rural areas such as the Tunisian Highlands and provide a good source of income and nutritional foods. In Tunisia, a summer cropping-season is difficult in traditional low land regions due to the limiting climatic factors (hot temperatures and dry conditions). To overcome this problem, a new crop cycle was developed during (2013- 2015): Planting in June and harvesting in October; exploiting the particular climatic conditions in the Tunisian Highlands (mainly high thermal and relative humidity amplitudes). Consequently, new seed multiplication and crop management-systems were developed according to plant behavior, pests and disease aggressiveness. A special regional project was established in 2016 through an agreement between the Tunisian Ministry of Agriculture and the German Ministry for Development (BMZ) to support small farmers. The average yield was improved to attain an average of 32.5 t/ha, with a net

income per hectare of 5600 USD. Aditionally, a farmer association was created for better management of inputs supply and post-harvest commercial flow. The project will be gradually extended to new highlands regions, aiming to reach 1000 ha planting area, 3000 tons of seeds and a production of 25000 tons (equivalent to the October market gap) by 2021, thereby developing a new potato value chain. In the meantime, research is underway to identify the best adapted clones to this new season crop and to understand the climate change effect on potato production and quality.

Technical session B:
Trends in Potato Consumption and Market

1. A consumers' valuation of Frital INTA: an empirical research that applies the experimental Auction Method

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Argentineans' potato consumption is almost 60 kg/*per capita*/year. Potato is produced in different regions of the country although most consumers have little knowledge about the existing varieties and the properties of each one. Despite the existance of a large number of potato varieties in Argentina -Frital INTA, Pampeana INTA, Innovator, Kennebec, so on-, Spunta remains the most commercialized for fresh consumption.

In April 2017, a Vickrey Second Price Experimental Auction was developed to evaluate consumers´ preferences regarding two potato varieties: Frital INTA -produced with a lower agrochemical content- and Spunta -produced conventionally. As in other experimental auction studies, 155 students and employees of the Economics and Social Sciences Faculty of the Mar del Plata National University were recruited. The sample was representative by sex and age, in according with the database of the Faculty. The experiment consisted in 9 sessions of 6 rounds each.

The aim of this research was to study how consumers evaluate differentiated potato, according to information given regarding culinary aptitude, low agrochemical content and packaging.

The Kruskal-Wallis Test shows that significant differences were found between the 9 groups, comparing the bidding prices between both varieties when information was offered orally.

After that participants received information about the Frital INTA variety and presented with new packaging with labeling. They were willing to pay almost 50% more than in the first round. The preliminary results obtained not only show a consumer concern about culinary aptitude and low agro-chemical content, but also an interest in packaging and labeling.

2. Production costs and use of potato seeds in the department of Nariño in Colombia

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A sample of 1,018 households located in 21 potato-growing municipalities was selected for collecting information under the project "Technology and production improvement of the potato growing system in the department of Nariño." A survey regarding the potato crop production system was administered, which provided background information related to the production and use of seeds in Nariño. The data collected revealed that 9.9% of the respondents used certified seeds, 66% employed their own seeds, and 24% used descendants of certified seeds. The biophysical parameters were determined based on semi-structured interviews with seed producers in Nariño and on the collection of secondary information. It was possible to produce maps with the following characteristics: annual rainfall from 800 to 1,600 mm, loam soil texture, 15% slope, altitude between 2,800 and 3,000 m a.s.l, and temperature from 8°C to 15°C. This information was used for establishing potential areas for seed production. Lastly, a seven-year cost forecast was prepared taking into account cash flow estimates. It was established that the financial load makes it impossible to produce significant yields from a single hectare. The forecast suggested that seeds would have to be produced in an area of at least three hectares at an actual cost of USD29,068.50 with profits of USD6,874, and at an internal rate of return of 28%. Data also is useful in determining the parameters associated with the formal business of producing seeds and designing projects to increase the availability of seeds in regional conditions.

3. Visibility: the challenge of the Latin American Potato Journal

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In this work, the "state of the art" of the Latin American Potato Journal, published by the Latin American Potato Association (LAPA), is analyzed as a means of scientific and technical diffusion of the potato crop. . The objectives of the document are: i) to make a current analysis of the journal and its challenges in the world of information and ii) to share the strategy developed for achieving visibility. The journal has a biannual frequency. Original and unpublished articles are accepted in the fields of biotechnology, genomics, physiology, nutrition and fertilization of crops, genetics and plant breeding, entomology, phytopathology, integrated phytoprotection, agroecology, malherbology, geomatics, soils, water and irrigation, postharvest, etc. Since 1988, the LAPA Journal has published 25 issues, 12 invited articles, 170 scientific articles, 25 short communications and 8 reviews, totaling 215 publications. From this total, 29% are from Bolivia, 23% from Peru, 13% from Argentina, 8% from Colombia, 8% from Ecuador, 4% from Venezuela, 3% from Mexico and 4% from Brazil. Countries such as Spain, Costa Rica, Honduras, Panama, Nicaragua, Chile, USA and Denmark have contributed 1% each country. The main publication topics were in phytopathology, entomology, plant breeding, agronomy and physiology, agro-industry,

genetics resources, participatory methodologies and economics, seed production, biotechnology and microbiology. In order to achieve a greater impact, our journal will improve the processes and quality of work, and to ensure its greater visibility, strategy will be indexed to databases and indexers of greater diffusion such as Scielo, REDALYC, Thomson, Scopus, DOAJ, SRI, Springer, etc.

4. **Study on the knowledge and consumption of native potatoes in university students of a private university in Lima, Peru**

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The objective of this work was to study the level of consumption and knowledge about native potatoes in a group of students at a private university in Lima, Peru. A survey of 20 questions was conducted on a cohort of n = 215, related to knowledge and consumption habits of native potatoes. Among the results obtained, it can be seen that the respondents are 90% undergraduate students and 10% graduate. Of the total, 87% consume native potatoes, 84% believe that the difference between native and non-native potatoes is culture, color and nutritional value. The yellow potato was the most known and preferred variety (> 90%), in addition to the varieties “Huayro”, “Yungay” and “Peruanita”. In addition, information was obtained that 58.6% would eat in an industrialized form, 40.5% would consume a precooked and / or crushed portion, and that 90% would prefer to consume the equivalent of two portions of parboiled potato. 80% of respondents believe that native potatoes can resist frost but only 33.3% believe that it is grown in non-Andean places. For the results presented, the students demonstrated preferences for consumption of the native potato, which they buy in the markets and consume cooked and with the skin. We suggest an extended study to determine new market products to be offered, based on the consumption preferences found in this work.

5. **Preliminary study of production sustainability and consumption of Peruvian native potatoes**

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According to FAO, from 1950 to 2016 annual potato production in Peru has risen from 1’364,300 TN to 4’527,600 TN. Initially most of it was native.

Even though in the year 2000 intake per capita was 58.8 kg, by 2008, thanks to different campaigns to promote consumption and productivity, it increased to 85 kg. (Source: MINAGRI)

Information from the GMML (Gran Mercado Mayorista de Lima) specifies that 81% of the potato sold in 2016 was solely the type called “white” - Canchan and Yungay varieties of.

On the other hand, the WHO (World Health Organisation) indicates that from the year 2000 to 2013 consumption of heavily processed foods and high sugar beverages in Peru has risen 107%, showing a tendency toward high rates of chronic malnutrition, obesity, type2 diabetes and chronic diseases.

Since 2008, Le Cordon Bleu Peru has been promoting consumption of native potatoes with the publication of the book "La Papa: del antiguo Perú al mundo moderno".

This preliminary study shows most of the biodiversity of native potatoes is situated above 3000 meters above sea level, but only 28.42% (3000/3500) and 16,9% (3500/4200) of the farmers that harvest at this altitude sell their crops to the market. (source: INEI)

Le Cordon Bleu Peru, Cite Papa, Aders Peru and Centro de la Imagen have joined efforts to promote consumption of native potatoes that have all year-round availability, which include Amarilla Tumbay, Peruanita, Huayro Rojo and the seasonal varieties like Huamantanga, Sumac Soncco, Queqorani, Leona, Wenccos and Huayro Macho.

6. Trading margins in the value chain of CONPAPA – Ecuador

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Avalue chain identifies the various links from production of a product until it reaches the final consumer with a view to seeking financial gain for all the actors. This research looked at the value chains for the commercial potato varieties, Superchola and YanaShuto, from the Consortium producers in Ecuador (CONPAPA). Values of net production margins, gross margins of commercialization and percentages of participation were used for the actors of each link in the chain. It turned out that there are three links in each value chain: partner - producer, the CONPAPA consortium and the national industry. Four value chains were identified. For the first (Yanashuto), the sale price of the producer remains constant throughout the year. In the other three (Superchola), there are two stable sale prices depending on two different times of year. The last link comprises poultry factories, agribusiness and fast food, at national level. They receive the 57.9% that represents the highest net trading margins, as in chain three. The participation rates for each Superchola variety producer, who come from the central area of Quero, vary from 28.5% to 50.0%, at the time of high sale price, representing the highest value in chain two. These percentages reveal the need to implement strategies in order to improve sale prices for producers throughout the year. The Consortium should do so with all the chains.

7. Improved potato varieties in the Center of Origin (Peru): adoption determinants and impacts

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The International Potato Center and Peruvian partners have invested a substantial amount of resources towards the development of improved potato varieties. A household survey conducted in 2013 by

CIP described the diffusion of improved potato varieties in Peru, identifying specific constraints to adoption, and assessing the economic impact of adoption. Results showed that around 60% of the potato area in Peru is planted to improved varieties. Adoption is region specific, time dependent, and relies on informal transmission methods. Yungay, an improved variety released in 1971, is the most adopted variety covering 22% of the potato area in Peru (around 60,000ha). Canchan (1990) and Amarilis (1993), varieties both released as a result of joint efforts between INIA-Peru and CIP, cover 12% and 11% of the potato area respectively. The study finds that adoption of improved varieties is influenced by market access; and information via markets increases the probability of adoption, further helping the diffusion of improved varieties to market oriented farmers. Besides information constraints, household head age, wealth, and social networks were found to affect decisions to adopt and disadopt improved varieties. The impact study indicates that farmers growing improved modern varieties have benefited from increased yields (around 1 t/ha) and market a larger share of their output, earning higher incomes than their comparable neighbors (around 490 US dollars per household per cropping season). Other varieties which are expected to replace the existing ones are UNICA and Serranita. However, seed market and demand will play a significant role in their promotion.

Technical session C:
Potato Variety Development and Biotechnology

1. Potato varietal evaluation and release of nutrient-dense potato variety in Bhutan

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Potato (*Solanum tuberosum L.*) is one of the most widely produced, consumed and traded horticultural crops in Bhutan. Hence, potato cultivation has picked up fast and has transformed the Bhutanese agriculture from subsistence to an emerging market-oriented economy. However, productivity of potato in Bhutan has stagnated over the last decade due to lack of diversity of varieties and degeneration of potato seed quality. Therefore, variety development research was carried out to increase yield and diversity of varieties, and to provide alternative varieties for the growers. The advanced evaluation trial using a mother and baby approach was conducted using suitable CIP-originated potato clones of 399053.11, 394034.7, 394611.112, 396034.268, 397196.3, 392797.22 and 303381.30 and Desiree as the local check (control) at Bumthang and Khangma in 2015. When the clones were assessed against yield and preference ranking, 397193.3 and 392797.22 clones outstood as high yielders and the preferred varieties, and 394034.7 was the least yielder and least preferred clone in Bumthang. The two clones (397193.3 and 392797.22) were significantly ($P<0.05$) high yielders and preferred to

Desiree (control) in both the mother and the baby plots. However, on the organoleptic assessment of appearance, taste and texture; 392797.22 was significantly more preferred over 397193.3. Key results for Khangma were similar to that of Bumthang. Similar patterns were observed in 2014 in both locations. Having fulfilled all the research requirements 392797.22 was released in 2017 as Yusi Maap to address yield stagnation, as an alternate red-skinned variety. In addition to the variety being nutrient-dense, it has moderate resistance to late blight.

2. Host resistance in potato to three Globodera species

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Potato cyst nematodes (PCN) under quarantine in the U.S. and Canada are the pale cyst nematode (*Globodera pallida*) and the golden cyst nematode (*G. rostochiensis*). A new species, *G. ellingtonae* was discovered in Oregon and Idaho in 2008 and is not currently a quarantine pest. In 2006 detection of PCN occurred in Idaho, U.S.A. (pale cyst) and Quebec, Canada (golden cyst). Host resistance can help with eradication and other mitigation efforts. Resistance in potato to the golden cyst nematode pathotype Ro1 is available from dominant gene H1, which has been incorporated into many commercial varieties. Resistance in potato to pale cyst nematode is not as well developed and is unknown for *G. ellingtonae*. This study evaluated 22 potato breeding lines/cultivars for resistance to three *Globodera* species. Resistance to golden cyst nematode was found in many entries. Resistance to pale cyst nematode was also found, but at a lower level. A strong correlation existed for resistance to *G. rostochiensis* and *G. ellingtonae* suggesting a common resistance gene(s) possibly with H1 conferring that resistance. Results will be used to develop resistant breeding populations based on russet-skinned long tuber types predominant in the western U.S. These new cultivars would have resistance against multiple species of *Globodera*.

3. Construction of a cDNA library and amplicon sequencing for the detection of candidate genes for abiotic stress in potato

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Plants growing in natural habitats are exposed to multiple environmental stresses resulting from abiotic factors such as heat, drought, and cold, which have a significant impact on cultivated potato. We have evaluated in two *Solanum tuberosum* varieties (Soprano and Kondor) the adaptation to different abiotic stresses (heat, cold, drought). For this purpose plants of both varieties were stressed for different abiotic stresses, and when they showed symptoms of stress, RNA extraction was carried out and a cDNA library for each sample was constructed.

The objective of this study was to detect and analyse the genes involved in the responses to abiotic stresses in *Solanum tuberosum.* The assay generated transcriptome sequences from both varieties, and a total of 5.579.655 reads and 8420 putative candidate genes were generated. 4.027 of the candidate genes were polymorphic and presented a different number of patterns defined by a varying number of SNPs.

Many of the generated candidate genes showed differential expression, since the candidate gene was present in the stressed plant, but not in the control plant. The application of this methodology and method of analysis allows us to detect numerous candidate genes or specific alleles/allele combinations, which are differentially expressed in specific samples after the application of different abiotic stresses. This will be useful to identify superior alleles which can be used in Marker Assisted Selection for resistance and tolerance to abiotic stresses.

4. Development of durable resistance to late blight in Indonesia

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Development of late blight resistant potato cultivars by classical breeding is continuously under threat due to the rapid evolution of the late blight pathogen *Phytophthora infestans*. In the US, new cultivars Jacqueline Lee and Defender are now susceptible to certain strains of *P. infestans*. To evaluate if the three *P. infestans* resistance Rpi-gene stack the USAID FtF BPP wants to put in cv. Granola will be suitable for Indonesia it is important to first understand the genetic diversity of strains present in Indonesia. Isolates of *P. infestans* were collected on FTA cards from cultivars Atlantic and Granola growing in Pangalengan, Indonesia. Twenty-two isolates were extracted and analyzed using microsatellite markers. A comparison of allele sizes in Indonesian isolates compared to US and European standards, showed that Indonesian isolates clustered into 3 groups which were different to those of the US and European isolates. Indonesian groups were most closely related to the US isolates. Isolates were also tested for the presence of *P. infestans* avirulence effectors *Avr-blb1*, *Avr-vnt1*, *Avr-blb2*, Avr2 and *Avr3a.* Potato resistance genes *RB*, *Rpi-vnt1*, *Rpi-blb2, Rpi-mcq1* and *R3a* recognize these effectors. For resistance to be expressed in the plant, the effectors need to be present in the *P. infestans* strain, and the resistance genes need to be present in the plant. Results showed that one strain of *P. infestans* was missing the *Avr-blb1* effector. Therefore, any new Indonesian potato cultivar containing the *RB* gene alone will be susceptible to this strain.

5. Lanosterol synthase-like is involved with differential accumulation of steroidal glycoalkaloids in potato tuber-flesh and leaves

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The potato steroidal glycoalkaloids (SGAs) are toxic secondary metabolites whose total content in tubers should be regulated. The SGA pathway branches from the mevalonic/isoprenoid pathway. We showed a correlation between high SGA levels and high expression of *3-HYDROXY-3-METHYLGLUTARYL COENZYME A REDUCTASE* (*HMG1*) and *SQUALENE SYNTHASE 1* (*SQS1*) in potato tissues and potato genotypes varying in SGA content, and in *HMG1* and *SQS1* overexpressing transgenic lines. Overall data suggested coordinated regulation of isoprenoid primary metabolism and SGA secondary metabolism.

Cycloartenol synthase (CAS) and lanosterol synthase (LAS) are phylogenetically related enzymes that are positioned at the branching point between the isoprenoid pathway and the sterol/steroids pathways. Cycloartenol is the accepted precursor leading to cholesterol and phytosterols, and in potato, to SGA biosynthesis, while the LAS role in sterol homeostasis was not clear. Recently we identified and characterized a potato *StLAS-like* gene using a transgenic approach with targeted gene expression and metabolic profiling of sterols and SGAs. This allowed us to suggest a model for maintenance of sterol homeostasis by diverting precursors between the biosynthetic branches of the phytosterols and the SGAs. *StLAS-like* expression was detected only in tuber flesh which may explain the differential accumulation of SGAs in commercial cultivars – low in tubers, high in leaves. In leaves, to maintain phytosterol homeostasis, an excess of intermediates may be diverted into SGA biosynthesis, whereas in tuber flesh these intermediates are catalyzed by the tuber specific *StLAS-like* instead, resulting in low levels of SGA.

6. Disease resistance in potato – from marker discovery to applied breeding

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Potato breeding programs strive to combine numerous traits in a single variety in a breeding process that typically takes 10-15 years from first crossings to the variety release. While traits such as yield, taste, shape and dry matter content are the most important characteristics of a potato variety, lack of disease resistance often results in high yield losses and makes the variety undesirable because of the additional management costs. The principle genetic determinants of resistance to several important diseases of potato have been discovered in past decades. Therefore, molecular markers can be applied in the early stages of the breeding program to discard the individuals that lack important disease resistance traits. Due to the savings obtained from planting fewer individuals, more resources can be instead invested in performing more crosses, which is expected to result in a higher likelihood of combining traits and thus faster genetic gains. Molecular markers involving polymerase chain reaction and subsequent visualization using electrophoresis are available for some traits. However, these traditional markers are both expensive and low throughput and therefore not suitable for rapid screening of a large number of samples. For forward selection, the genotyping system needs to be adapted to a high throughput and low-cost format that allows for rapid and accurate identification of resistant progenies. This presentation summarizes the molecular markers for disease resistance being used in CIP and discusses the benefits and challenges of modernization of the breeding program.

7. "Morada-Cica", a new variety of potato resistant to *Phytophthora*

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The Research Center for Andean Crops (CICA) at the National University of San Antonio de Abad of Cusco (UNSAAC), has been making genetic improvements from their superior collection of germplasm since 1995. Research concluded in 2016, with the last phase financed from UNSAAC Canon funds with the project: " EX SITU CONSERVATION OF NATIVE POTATO AND THE RELEASE OF VARIETIES FOR REGIONAL AGRICULTURE"

The progenitors used in the improvement were; *Yungay x Yana Maqt'illo x Wallata.* The progeny of these crosses, after 13 cycles of selection, agronomic and morphological characterization and evaluations with farmers in agro-ecosystems in Cusco, has allowed us to obtain the cultivar ***MORADA-CICA***. This tetraploid genotype of Andigena progenitors grants a broad limit of climatic tolerance and adaptation to different inter-Andean valleys and high Andean areas of Peru.

The cultivar achieves average yields of up to 40 t / ha, in farmers' plots. It has high culinary quality, with dry matter exceeding 25%, yellow flesh and light oxidation when frying. It shows resistance to *Phytophthora infestans*, tolerance to *Rhyzoctonia solani*, *Spongospora subterranea;* tolerance to leaf chewers *Epitrix spp, Diabrotica sp., Tequus sp*, and poor preference of larvae in tuber damage of *Premnotrypes latithorax* and potato moths *Phthorimaea operculella* and *Symmetriscema tangolias.*

8. Combining ability estimates from line xtester mating design in potato tetraploid (Solanum tuberosum L.)

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The objective was to evaluate the effects of general combinatorial ability (GCA) and specific (SCA) of 10 tetraploid potato clones (lines), by means of the cross line by tester (LxT). In the period 2010 to 2012, 10 clones (L) were crossed with three testers (T) of broad genetic base (cultivars improved) obtaining 30 trial crosses , which were evaluated in two localities in Pasco Huariaca (2941 m) and Paucartambo (2950 m) in Peru. Evaluations were performed in a randomized complete block design with two repetitions, considering as a factor "A" the lines and Factor "B" the testers. Variables were: total yield of tubers (RTUB), area under the curve of the development of late blight (AUDPC) and the number of tubers selected (NTUB). An analysis of combined variance of LxT was performed. It was found that the LxT interaction was significant ($p<0.01$) for the three variables under study, indicating that the non-additive effects were the most important. The results found show that the best tester for its high values of GCA for the variables under study was Perricholi (T_1); with values of 1.6, -176.8 and 2.1 for RTUB, AUDPC and NTUB, respectively. Between the lines, best tester for RTUB were L_1 and L_2, for AUDPC the lines: L_1, L_2 and L_5 and for NTUB, the lines L_1, L_3 and L_4. The best crosses for their ACE values, for RTUB were: L_5xT_3, L_2xT_2 and L_5xT_1, for AUDPC were: $L_{10}xT_2$, L_5xT_3, L_3xT_2 and for NTUB were: L_5xT_3, L_2xT_2 and L_3xT_2

9. Correlations of potato tuber traits between the seedling generation and the first field generation, as a function of pot and plot size

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This study aimed to calculate correlation coefficients of potato tuber traits between the seedling generation (SG) and the first field generation (FFG) and their implications on selection. The work was carried out at Embrapa Temperate Agriculture, Pelotas-RS, Brazil. Three pot sizes [small(S)= 0.25 kg; medium(M)= 0.80 kg; large(L)= 2.40 kg] in SG, and three plot sizes (1, 2 and 3 plants) were tested, using ten progenies. The experiment was arranged in a split-plot design with three replications. In both generations, tubers of each plant were evaluated for yield, number, skin texture, stolon insertion depth, eye depth, eyebrow prominence, shape, flatness, curvature, pointed ends, and appearance. Coefficients were significant for yield, number, shape, pointed ends, and skin texture, but correlation was strong only for yield for L pot x L plot, moderate for M pot x M plot, and S pot x S plot; for number, moderate for L pot x L plot, while for other pot and plot sizes they were weak; for shape, moderate for L pot x L plot, and M pot x M plot; and for other traits, coefficients were low or not significant. These results suggest that in SG, using L pots, selection could be applied for yield at strong intensity, and for number and shape at moderate intensity; while using M pots, selection could be applied for yield, number and shape, but at moderate intensity; and using S pots, selection could also be applied at moderate intensity, but only for yield.

10. Breeding and development of Globodera-resistant potato varieties with long tuber shape and russet skin for production in the western United States

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Two species of potato cyst nematode (*Globodera rostochiensis,* and *G. pallida,*) have been identified in the U.S. and are under quarantine regulations, with a third newly identified species (*G. ellingtonae*) not categorized as a quarantined pest. Management of *G. rostochiensis* in the state of New York includes the use of resistant potato varieties, but resistance to *G. pallida* is not present in the primary varieties grown in the state of Idaho, where *G. pallida* was identified in 2006. The primary market class of potato grown in Idaho and the western U.S. is characterized by varieties having long tuber shape and russet skin. Potato varieties commercially available having *G. pallida* resistance typically have round tubers and white or yellow skin making them unsuitable for producers in the western U.S. Hybridizations have been conducted between *Globodera*-resistant breeding clones and varieties with russet-skinned germplasm. Progeny from an Eden x Western Russet family display *Globodera* resistance (derived from Eden) and the desired long tuber shape and russet skin (derived from Western Russet). Sources

of *Globodera* resistance being utilized in our program, the use of marker-assisted selection, and our progress in developing russet-skinned germplasm having long tuber shape with resistance to the three *Globodera* species is described.

11. Evaluation of twenty-one potato (Solanum tuberosum) genotypes for cold tolerance using methodologies of visual Scale and electrolyte leakage

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Frost is an abiotic factor that causes irreversible damage in potato crops worldwide. Many efforts have been made to prevent damage caused by low temperatures, primarily by searching for genotypes that are more tolerant. However, this process requires continuous effort and research since many genotypes are not yet characterized for this trait. During this study, 21 genotypes of *S. tuberosum* were subjected to low temperatures to determine their tolerance or susceptibility to this condition. These genotypes were obtained from INIAP´s breeding program (Ecuador), with high potential to find candidates for frost tolerance. Damage produced by extreme cold conditions (-18° C for 12,5 min) were evaluated using two methodologies: visual scale and electrolyte leakage. A completely random experimental block design with three repetitions was used to assess damage levels among all genotypes using both methods. The results obtained from the two methodologies were similar, indicating that the level of damage can be assessed by any of them irrespectively. In summary, cultivar Superchola was found to be the most tolerant (low damage) followed by the genotype named 39-90-75-26, while the most susceptible genotype (highly damaged) was the cultivar Estela. In further research, the most tolerant genotypes can be studied for their genetic mechanism, with the aim to include them in potato breeding programs to develop commercial varieties tolerant to frost damage.

12. Cryopreservation of Andean potato shoot tips monitored by differential scanning calorimetry

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At the potato genebank of the National Institute of Agricultural Technology (EEA Balcarce - INTA), three potatoes landraces of *Solanum tuberosum* subsp. *Andingena,* maintained under slow growth in vitro conservation, were selected to reinitiate long term conservation by cryopreservation employing a modified droplet vitrification protocol. The effect of dehydration at different times with plant vitrification solution 2 (PVS2) on the potato landraces was studied. The protocol involves excision of about 1 - 2 mm shoot tips in MS medium from in vitro plants, the transferal of shoot tips to loading

solution and dehydration in PVS2 for 20 and 30 min before rapid cooling in liquid nitrogen (LN). Samples of cryopreserved shoot tips and cryoprotecting solutions were analyzed under Differential Scanning Calorimetry (DSC) equipment to investigate their thermal activities and detected ice formation during the droplet-vitrification process. Thermograms evidenced diverse responses from the three potato varieties towards cryopreservation according to the different dehydration times.

13. Breeding for potato late blight resistance in Ecuador: historical review

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Late blight is the main disease that affects potatoes in Ecuador. Breeding efforts for obtaining improved potato varieties with resistance to late blight have been conducted mainly by the Instituto Nacional de Investigaciones Agropecuarias (INIAP). These initially consisted in the selection of material from local, introduced germplasm from Colombia and crosses, resulting in a late blight resistant variety, INIAP-Santa Catalina, being released in 1965 , was. Later on, in 1974, a recurrent selection method was used to increase late blight resistance, and INIAP-Gabriela and INIAP-Esperanza were released in 1982 and 1983 respectively.

In collaboration with the International Potato Center (CIP), advanced potato clones were introduced and some varieties were released: INIAP-Suprema in 1999 and INIAP-Papapan in 2000. Most of them had monogenic resistance which was effective when the varieties were released, but defeated later.

Later on a strategy for quantitative resistance breeding against late blight was implemented, and as result INIAP-Fripapa, INIAP-Rosita, INIAP-Raymipapa, INIAP-Victoria were selected. Other strategies explored were mutation breeding, but no improved varieties have been developed by this technique.

Other approaches included the introduction of genes from wild species to obtain varieties with late blight resistance. From crosses performed among INIAP-Gabriela and Superchola, with hybrids between the landrace Yema de Huevo (*S. phureja*) x *S. pausissectum*, INIAP-Natividad and INIAP-Estela were obtained. To date, 21 varieties have been released by INIAP. The most recentis INIAP-Libertad, a late blight resistant variety coming from CIP germplasm released in 2015.

14. Potato breeding for resistance / tolerance to late blight and low temperatures in Ecuador

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Potato is affected by biotic and abiotic stresses which in recent years have become more severe due to the effects of climate change. In Ecuador late blight and low temperatures have become serious limitations causing losses of up to 100%. Therefore, it is necessary to develop new varieties adapted to these stresses, taking advantage of the existing natural biodiversity.

The objective of this research was to identify potato accessions with resistance/tolerance to these two constraints. In addition the information will be a contribution to the identification of candidate genes related to the development of molecular markers and models which will speed up the breeding of potatoes adapted to climate change. Two trials for low temperature and late blight evaluation were established in two locations in the Ecuadorian highlands. Twenty-nine improved and native potato varieties were evaluated under a randomized complete block design with three repetitions. Yield, cold damage and severity of late blight were evaluated. The information was analyzed by means of variance analysis and a correspondence analysis.

Large variation was established for all traits. Based on the response to low temperatures, and resistance to late blight and yield, the correspondence analysis identified varieties with better behavior to be: the improved INIAP-Fripapa, INIAP-Catalina, INIAP-Victoria and the natives Calvache, Coneja Negra and Jubaleña. These varieties can be promoted for their cultivation in areas of climatic risk and within a breeding program. These materials are being analyzed for the detection of candidate genes.

15. Early selection of potato clones for processing quality

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The potato crop in subtropical and temperate conditions of southern Brazil represents an opportunity for the development of new cultivars with wide adaptation and tuber processing quality, because of the high variation between subtropical (spring and autumn) and temperate (summer) growing conditions. The objective of this work was to evaluate the selection efficiency in the first clonal generations of potato clones for chip processing quality, and adaptation for subtropical and temperate conditions of southern Brazil. Minitubers of 43 families combining tuber processing with adapted parents were produced in the greenhouse. Selection for short dormancy resulted in 403 (4.3%) clones. Selection for tuber appearance and maturity in the field resulted in 120 clones, which were evaluated during summer (temperate) and spring and autumn (subtropical) growing conditions. The correlation estimations among environments, and the genetic gain from selection for the evaluated traits, confirm that the diversity of growing conditions affects both the wide adaptation as well as tuber yield and processing quality. Early selection based upon environment averages s is a feasible strategy for the identification of potato clones with tuber processing potential combined with short dormancy of the tubers, plants with early maturity and broad adaptation to the subtropical and temperate growing conditions of southern Brazil.

16. Understanding the inter-related genetics and physiology of Zn and Cd accumulation in northern European cultivated potato

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Zinc is an important micronutrient, and Zn bio-fortification has become an objective of potato breeding programmes targeting developing countries. Varieties accumulating high levels of tuber Zn can also exhibit a tendency to accumulate undesirable levels of cadmium when grown in soils with high levels of Cd. Thus, selection for high tuber-Zn accumulation could potentially lead to inadvertent selection for high tuber-Cd accumulation when such varieties are grown in Cd contaminated soils. In order to gain a greater understanding of the physiology and genetics of these characteristics, we identified two tetraploid varieties, one of which accumulates high levels of tuber Zn, and high levels of Cd (in Cd-enriched soil), and one which accumulates low levels of tuber Zn and Cd. To elucidate the accumulation patterns of both metals, we performed time course and reciprocal grafting experiments to track their concentration in different tissues throughout the growth cycles of the varieties. In addition, we generated a segregating population using the two varieties, and mapped quantitative trait loci (QTLs) for both Zn and Cd accumulation in the parents using the SolCap 8303 array. The QTL mapping experiment revealed partially overlapping genetic control of tuber Cd and Zn concentration in the cross, involving both maturity and non-maturity related mechanisms. The physiology experiments indicated that tuber accumulation of both metals is heavily influenced by foliar biomass. We conclude that maturity-related foliar biomass is a major influence on the accumulation of both metals and propose a potential mechanism governing Cd and Zn accumulation in these genotypes.

17. Genotypes of potato F1 (andigenas x cultivars) selected in second cycle for resistance to Tecia solanivora (Povolný) and tolerance to *Phytophthora infestans*

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The losses generated by Guatemalan moth, *Tecia solanivora* and by the pathogen *Phytophthora infestans*, are significant in potato production in Colombia. However, at commercial level, there is still no cultivar with characteristics of combined resistance to *T. solanivora* and *P. infestans*. The objective of this study was to evaluate 174 F1 potato genotypes from crosses of nine native varieties x eight commercial cultivars, selected in 2016. The materials were taken to field arranged in a randomized complete block design, with three repetitions, in order to evaluate percentage of severity of *P. infestans*, and later calculation of the area under the curve of progress of the disease (AUDPC). Then, during the harvest season, the incidence percentage of *T. solanivora* by genotype was estimated. Additionally, percentage of incidence, severity and biological development of *T. solanivora* was evaluated under storage conditions, using a complete randomized block design in a free choice test and artificial moth infestation. Through analysis of main components, cluster and data from previous trials, genotypes were selected with high yield, late blight tolerance, and / or some degree of moth resistance under field and storage conditions. Of the seven groups that the analysis yielded, 30 genotypes were selected with the best responses to the variables evaluated, under the thresholds: rAUDPC ≤ 0.3; total yield ≥ 0.5 kg / plant and moth incidence <16%. The selected genotypes may be the basis for a potato breeding program in Colombia.

18. New potato cultivars (Solanum tuberosum L.) with resistant to late blight [Phytophthora infestans (Mont.) De Bary] and drought for Bolivia

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In the season 2015-2016, six experimental plots planted with six potato cultivars were implemented in the production areas of Colomi and Anzaldo (Cochabamba), Tarabuco and Lampacillos (Chuquisaca), Betanzos (Potosí) and Colquencha (La Paz). The objectives were to i) evaluate the resistance to late blight (*Phytophthora infestans*) and drought; ii) evaluate the phenotypic stability of the cultivars. The experimental plots were housed in the field in an experimental design of rows and columns with 12 repetitions. The response variables evaluated were blight severity, degree of wilt, degree of recovery and yield. Pinker and Cholita Rosada cultivars were resistant to *P. infestans* and had high yields. Pafrita and Puka Huaycha displayed moderate performance. Pafrita and Pinker cultivars were resistant to drought and Cholita Rosada recovered from this factor better. The native cultivar Huaycha obtained the lowest yields in all localities.

19. Molecular characterization of a collection of Solanum tuberosum L. Phureja group and S. tuberosum L. Tuberosum group obtained from sexual seed using Random Amplified Microsatellites

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Molecular characterization of 313 genotypes of *S. tuberosum* Phureja group and 35 of *S. tuberosum* Tuberosum group (obtained from sexual seed from a native potato collection) was performed using PCR (polymerase chain reaction) and four RAMs markers. The results analysis was carried out with TPFGA software, using a binary matrix, where the presence of the band is one (1) and the absence zero (0). Cluster analysis was performed using the coefficient of Nei -Li (1978). The Phureja group matrix generated 180 loci, of which 100 % were polymorphic. The bands obtained ranged from 125 to 1900 bp. The most polymorphic primer was CA with a heterosis unbiased of 0.217. The average genetic diversity was 0.186 and the classification analysis (dendrogram) established 6 groups. The analysis for the Tuberosum group showed a total of 119 loci, of which 99.16% were polymorphic. Also, the bands obtained ranged from 125 to 1900 bp. As in the Phureja group results, the most polymorphic primer was CA with a heterosis unbiased of 0.32 and a total genetic diversity of 0.288. The classification analysis (dendrogram) showed 32 nodes and 6 groups. The diversity observed in this work was low compared to that described by Pérez (2004) with Andigenum potatoes (0.81). However, it was similar to those found by Navarro et al. (2010) with 19 genotypes of potatoes which reported a diversity of 0.23. Finally, it is concluded that in this analysis the presence of duplicates was not detected.

20. Breeding of potato cyst nematode resistant varieties in Japan

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In 1972, the golden potato cyst nematode (GPCN) was reported in Japan for the first time. The expanse of the total infected area has reached 10,000 ha and it has been increasing. Since then, the introduction of GPCN resistance has been a top priority and is now a prerequisite for new potato varieties in Japan. A single dominant gene, *H1*, has been widely used to confer resistance to GPCN in Japan. Screening for GPCN resistance is performed by cultivation in infested fields or using the plastic cup method. In addition, marker-assisted selection (MAS) using DNA markers linked to the *H1* gene has also been carried out in combination with an inoculation test. To date, more than 40 GPCN resistant varieties have been developed.

In 2015, white potato cyst nematode (WPCN) was also found in several fields in Japan, and the total infected area has reached 680 ha. Although attempts to develop WPCN resistant varieties had started before the onset of WPCN infestation, WPCN resistant varieties have not yet been developed in Japan; therefore, we accelerated the development of WPCN resistant varieties. At the beginning, we screened our germplasms for two WPCN resistant loci, namely, *Gpa5* and $GpaIV^{s}_{adg}$which are useful for the breeding of WPCN resistant varieties. We improved DNA markers for both loci and selected several germplasms which were positive for these markers.

21. Generation of high-quality potato seeds through environmentally controlled conditions (CETS System) in Andean native varieties

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Lack of quality potato seeds limits chances of reaching good crop productivity levels in Latin America. This situation has urged the need of exploring and introducing alternatives to challenge this problem. We examined an existing technology for generating disease-free, high-quality potato seeds developed by the US-based company CETS. It utilizes environmentally-controlled growth chambers called phytotrons to create the conditions for propagating potato plants and producing tuber seeds. The phytotron supplies photoperiod, temperature, humidity levels, water, etc. which are set up and controlled by computer software. Plants are thus capable of developing in an accelerated way; they produce tuber seeds in 60-70 days after planting, offering a chance of up to 6 harvests every year. This system is commonly used for commercial seed production of US varieties but has been never tested in Latin American

varieties. Therefore we examined the effectiveness of CETS technology for 10 potato varieties from South America as they encompassed the eight identified cultivated species. Results showed that plants of every native variety effectively completed their phenological and physiological phases within the expected timeframe for this technology. Numbers of tuber seed production were variable. In some cases tuber yield was extremely high (i.e., *Solanum ajanhuiri*) but in others was moderate as in *S. phureja*. In summary, production of high-quality tuber seeds of native potatoes was possible with phytotron technology. Besides being an option for crop production, this offers possibilities in other important areas such as protection and conservation of biodiversity, and potato breeding and research.

22. Marketable tuber yield stability of fourteen advanced potato clones (Solanum tuberosum L.) of pigmented pulp in Cutervo, Peru

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This paper analyzed marketable tuber yield stability for fourteen advanced potato clones with pigmented pulp and two commercial varieties (Amarilis and Canchán) as witnessed in two potato producing locations in Cutervo, Peru, for two years. Combined analysis of variance and the AMMI (model of main additive effects and multiplicative interaction) was used with the objective of analyzing the interaction genotype-environment and marketable tuber yield stability. The combined analysis of variance indicated the clones CIP302281.17, CIP 302298.42 CIP302298.44 showed superior performance, averaging 1077.68, 1044.33 and 986.43 g/plant-1 marketability. The AMMI analysis revealed that the environment, genotype and genotype-environment interaction, explained, 14.42%, 26.92% and 58.66% of the total sum of squares in the marketable yield of the clones, with the greater part being contributed by the genotype- environment interaction. When decomposing the sum of the square of the genotype-environment interaction, the first two main components captured 50.23% and 31.28% of the total variability. In addition, the clones CIP 302285.27, CIP 302304.15, CIP 302290.13 and CIP 302295.32 demonstrated low interaction with the environment, indicating greater marketable yield stability in environments evaluated.

23. Marker-assisted selection of Russian potato varieties and breeding clones

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Two hundred and forty Russian cultivars, foreign varieties involved in their pedigrees, hybrids and selected clones of wild progenitor species *S.stoloniferum*, *S.demissum* have been involved in MAS with DNA markers detecting cytoplasm types (Hosaka, Sanetomo, 2012) and markers of major R-genes conferring extreme resistance to PVY and PVX, resistance to late blight and to *G.pallida*.

Tested varieties had only sterile cytoplasm types: T(46,4%), D(43,4%), W/gamma(9,7%). About 30% of varieties with T and D sterile cytoplasm types had a high pollen fertility, indicating possible presence of functional alleles of nuclear fertility restorer genes.

Varieties with W/gamma cytoplasm showed different levels of tetrade sterility (36–100%) and possess diagnostic markers of *Rysto* and *Ryfsto* genes indicating that *S. stoloniferum* was involved in their maternal pedigree. Such association was demonstrated before (Song, Schwarzfischer, 2008) for the European varieties gene pool.

Diagnostic markers of *Rpi-sto1* gene have been detected in four varieties having *S.stoloniferum* in their pedigrees, but only two of them possess W/gamma cytoplasm.

New CAPS-mtDNA-markers of locus *rps14/cob* were developed by us to allow differentiating W/gamma type. These markers divided 25 varieties with W/gamma cytoplasm into 14 mitotypes absent among tested 38 accessions of Mexican polyploid species. This might be explained by restructuring of mt-genomes during interspecific hybridization. All varieties and hybrids with alpha and beta mtDNA types have the same one mitotype. New CAPS-mtDNA-markers provide novel information in maternal pedigree analysis.

The joint use of DNA markers associated with R-genes and with male sterile cytoplasm could increase the efficiency of gene pyramiding programs.

24. Combined use of quantitative genomics and bulked segregant analysis to identify genes regulating starch content in potato tubers

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In potato (*Solanum tuberosum* L.) tuber starch is a major storage compound. Tuber starch is not only the agronomically important carbohydrate, but starch biosynthesis is also the model pathway to study source-sink interactions. Potato tubers are strong sink organs. Sucrose, being the major product of transitory starch degradation in leaves, is exported via the phloem to potato tubers. In our recent study (Śliwka et al. 2015, TAG 129:131–140), we have mapped QTL for tuber starch content (TSC) on seven potato chromosomes: I, II, III, VIII, X, XI and XII. The most important QTL spanned a wide region of chromosome I (42.0–104.6 cM) with peaks at 63 cM and 84 cM, which explained 17.6% and 19.2% of the phenotypic variation, respectively. In addition, our study is the first one to report QTL for sucrose content in potato leaves. QTL for sucrose content in leaves were located on seven potato chromosomes: I, II, V, VIII, IX, X and XII. The most prominent QTL for leaf sucrose content in 5-week-old plants was detected on chromosome I (0–15.6 cM) and had a significant effect, both after night and after light. In the present project, UMO-2015/19/B/NZ9/00776, RNA-seq technology was used for selection of genes displaying differential expression between RNA pools, prepared from tubers of parents and F1 individuals, of a diploid potato population based on contrasting levels of tuber starch content.

25. Somatic hybridization in potato breeding

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Somatic hybridization is an alternative method for creating new breeding materials. In our work, this method was applied in two directions, for both intraspecific and interspecific hybridization. To combine the ability of a good yield and capability for industrial processing, dihaploids of *Solanum tuberosum* were used. To enrich *Solanum tuberosum* by resistance genes, *Solanum pinnatisectum*and *S. bulbocastanum* were employed. Both wild species are tuber-bearing diploids with high level of resistance to *Phytophthora infestans*. Progeny was obtained from each combination. While the somatic hybrids of *S. pinnatisectum* + *S. tuberosum* and somatic hybrids of dihaploids *S. tuberosum* flowered sufficiently and their sexual offspring was obtained, the somatic hybrids of *S. bulbocastanum* + *S. tuberosum* bloomed rarely and sexual progeny has not been gained yet. Somatic hybrids *S. pinnatisectum* + *S. tuberosum* and some individuals of their progeny displayed moderate or high level of resistance to *P. infestans* in laboratory tests and also in the field experiment. This work demonstrated the possibility of somatic hybrids to be sexually crossed with *S. tuberosum* cultivars, and also proved the opportunity to pass resistance to *P. infestans* from wild species to somatic hybrids and also to cross generation.

26. Population structure of potato breeding germplasm from Embrapa-Brazil assessed with single nucleotide polymorphism (SNP) markers

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Embrapa, the Brazilian Agricultural Research Corporation, coordinates a national potato breeding program. Aiming to reveal the genetic structure intrinsic to the germplam used by the Brazilian breeding program, a diversity panel, composed of 155 accessions, was genotyped with 8303 single nucleotide polymorphism (SNP) markers (Infinium 8303 Potato Array). The allelic dosage of each SNP for each genotype was estimated using the fitTetra package. Of the 8303 SNPs, 6086 (73%) presented good quality and were used to examine the population structure within the diversity panel. The population structure showed the division of the germplasm among three populations: I) diploid genotypes, from Phureja group; II: germplasm from Atlantic introduction within the chip processing market class; III) germplasm introduction from Europe, and the cultivars and advanced breeding clones from potato breeding program of Embrapa, including genotypes for fresh market class and French fry processing. Considering an adhesion coefficient ≥ 50%, of the 155 genotypes evaluated,

two were in the subpopulation I, 34 in the subpopulation II and 107 in the subpopulation III. These results are the basis for studies of genome wide association (GWAS), and to guide the crossing blocks in the breeding program.

27. Genetic improvement for Colorado potato beetle resistance in cultivated potato using wild Solanum relatives

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Colorado potato beetle (CPB), *Leptinotarsa decemlineata* (Say), is an economically important pest of cultivated potato, *Solanum tuberosum*. The insect can defoliate an entire field causing 30-50 % yield losses. While neonicotinoid insecticides have been used for control, there is increasing concern about effects on non-target insects, negative environmental impact and development of resistant CPB populations. CPB resistance from wild *Solanum* relatives of *S. tuberosum, S. oplocense* (renamed *S. brevicaule*), *S. chacoense* and *S. pinnatisectum,* was transferred to *S. tuberosum* through sexual or somatic hybridization. Backcross progenies carrying CPB resistance were identified and used to enhance potato germplasm for breeding. Analysis of foliar metabolites using liquid chromatography-mass spectrometry (LC-MS) untargeted metabolite profiling demonstrated differences in glycoalkaloids associated with resistance. *S. oplocense* had increased levels of the glycoalkaloid dehydrocommersonine and decreased solanine and chaconine. *S. oplocense*interspecific hybrids with variation in CPB resistance in the field were analyzed using LC-MS and results confirmed that increased dehydrocommersonine was associated with resistance. In contrast, CPB susceptibility was found associated with a novel solanidenol-chacotriose glycoalkaloid with the same molecular mass as solanine. A genetic mapping population was created using *S. oplocense* hybrid clone 13213-07 crossed with *S. tuberosum cv* Shepody. This mapping population of 94 individuals was genotyped with a genome-wide set of several thousand single nucleotide polymorphism loci generated with genotyping-by-sequencing. Phenotyping was done using foliar metabolic profiling with LC-MS to quantify levels of dehydrocommersonine and the solanidenol-chacotriose glycoalkaloid. Marker trait association was performed using bulk segregant analysis.

28. Parametric stability and genotype by environment interaction analyses for tuber yield and specific gravity in diploid potato (Solanum tuberosum Group Phureja)

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Phenotypic expression depends upon the genotype, the environment and the differential response of the genotypes when assessed under different environments. This is known as Genotype by Environment Interaction (GEI). Eight univariate parametric methods were evaluated for stability

analysis and two multivariate methods to determine the GEI. For this, eight advanced potato genotypes (*Solanum tuberosum* Group Phureja) and two commercial controls were used in 11 locations during two consecutive semesters. The variables measured were total yield and specific gravity. A combined analysis of variance across the environments was performed. Parametric stability statistics were estimated and after the correlation coefficients measured between them. Significant differences were found between the genotypes and their GEI. The level of association among the statistic values obtained was measured using the Spearman correlation coefficient. The genotypic mean for tuber yield and specific gravity was significantly correlated to parametric stability statistics P_i (r = 0.98), AMMI1 (r = 0.63), and SREG1 (r = 0.92). Due to the high correlation with the mean, the amount of information they provide and the fact that they are easily interpreted, multivariate AMMI and SREG analyses are preferred over univariate methods. The average and stability parameters of the trait, allow us to determine that the genotypes UN-59, UN-50, UN-52 and UN-4 are superior for yield and UN-64 is superior for specific gravity.

29. Gene expression biomarkers for prediction of nitrogen-related yield and specific gravity in potato

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Gene expression in potato foliage associated with crop response to fertilizer nitrogen (N) treatments was examined for application as a sufficiency predictor of N. Genome-wide transcriptome sequencing identified genes responsive to potato N sufficiency. Sampling of leaf tissue was performed at four time points during the day (0800, 1100, 1400 and 1600 h) on two sampling dates (48 and 63 days after planting) for three potato cultivars (Atlantic, Shepody, Russet Burbank). There were four replicate plots. The terminal leaflet of the last fully expanded leaf was sampled for 20 plants per plot and pooled for each replicate. RNA was extracted and genome-wide gene expression was quantified using transcriptome sequencing. A total of 63 genes were identified which were responsive to N fertilization across cultivars and sampling dates, but were not affected by time of day of sampling. The expression of these genes was evaluated in potato plants grown in seven field trials at four sites in two different years with different cultivars and N treatment rates and sources. A total of 439 samples of 20 leaf disk pools were collected. RNA was extracted and quantified using Nanostring nCounter. Gene expression predictive of relative yield (yield per plot/ maximal yield for trial), specific gravity and total N uptake was analyzed using regression analysis and supervised machine learning algorithms. The result of the field experience indicated that tuber yield and N uptake responded to applied N rate.

30. Frying quality of elite potato clones in the south of Brazil

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Potato production in the southern part of Brazil occurs in two main annual crops, autumn and spring. The objective of this work was to study the frying quality of two elite clones in the Rio Grande do Sul state. Field trials were conducted during autumn and spring in 2017 at Embrapa Clima Temperado, Pelotas-RS, Brazil. Two elite clones (F50-08-01 and F183-08-01) from the Embrapa potato breeding program, were compared to two commercial cultivars (Asterix, a French-fry variety, and BRSIPR Bel, a chipping variety) in relation to specific gravity, glucose content, and chip color. ANOVA revealed significant differences among genotypes for the three characteristics, and significant GxE interaction for specific gravity and glucose content. Regarding the frying color, the two elite clones had lower scores (darker color) than 'BRSIPR Bel', but they did not differ from 'Asterix'. In relation to specific gravity, in autumn, the clone F183-08-01 was outstanding, whereas in the spring, the two elite clones were statistically superior to both commercial varieties. Regarding glucose, in the autumn, the contents were higher than in the autumn than in the spring. In autumn, both elite clones had lower glucose content than 'Asterix', but higher than 'BRSIPR Bel'.

31. Local breeding to develop potato varieties with increased resistance against limiting production factors in Costa Rica

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Costa Rica produces more than 3000 ha of potatoes annually. Up to 45% of production costs correspond to pest and disease control. Late blight and leafminer are the most constraining biotic factors in potato production in Costa Rica. Indiscriminate use of chemicals has led to selection of resistant populations and potential negative environmental impact. Genetic resistance is the best option for pest and disease control, and might reduce the costs of applying pesticides and their environmental impact. Potato breeding allows the development of varieties with high resistance or tolerance to many pests and diseases. However, in tropical countries like Costa Rica, growing conditions are more favorable to biotic and abiotic stressors than those in countries where potato varieties are traditionally bred and selected: Therefore the importation and evaluation of materials from other countries has been ineffective. A local potato breeding program was initiated more than a decade ago at the University of Costa Rica, which has been focused on the generation, through sexual crossing, of hybrids with combined resistance to late blight (horizontal resistance)and leaf miner as well as other important agronomic traits such as high yield and tuber quality. Through years of field evaluation in different potato growing regions of Costa Rica, new genotypes have been selected. One of them, named Elbe-UCR, was released for commercial production at the end of 2015. Elbe-UCR shows a very high resistance to late blight and leaf miner, as well as, high yield, high dry matter content and good processing quality.

32. Enhancing capabilities for potato and sweetpotato research in China and Asia-Pacific: the case of CCCAP

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China is the main potato and sweetpotato producer in the world. Potato is one of the main sources of calories and nutrients for the Chinese population. There is a constant need in China for new potato varieties, adaptable to their targeted environment, easy to produce, and accepted by consumers. The International Potato Center (CIP) has been involved in China since the 70s, releasing highly successful varieties like Cooperation 88, UNICA and TACNA. The collaboration between CIP and the Chinese government has deepened with the establishment of the CIP-China Center for Asia Pacific (CCCAP). This research campus is part of CIP and has as its centerpiece 48 state-of-the-art, fully equipped laboratories. CCCAP's main goals are to (a) establish a potato and sweet potato genebank in China and enhance the regional germplasm exchange and study, (b) develop effective support services to provide assistance to local and regional breeding teams, and (c) serve as a global training and meeting hub for scientists. High-level roundtables with leading Chinese potato scientists have produced a list of research priorities for CCCAP. These are: drought resistance, late-blight resistance, biofortification, diploid potato breeding, and soil-borne disease resistances. Regarding breeding tools, the priorities are germplasm, bioinformatics (breeding software, GWAS, big data, genotyping), and standardized & multi-environment phenotyping. Future research plans for CCCAP are outlined. Future challenges for food systems from population growth and climate change will need to be addressed on several fronts, with strong focus on innovative technologies as well as strong and fluid collaborations.

33. Development of new diploid varieties resistant to powdery scab in Colombia

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In Colombia, powdery scab has been reported in all producing regions. In some potato fields, only root symptoms are detected, whereas in others, only tuber symptoms are reported. However, crops with both symptoms are common. Crop rotation is not a common practice for disease control, and chemical control is not very successful. Potatoes planted in Colombia are highly diverse and Phureja Group is the diploid potato used. A plant-breeding program was established to obtain new Phureja varieties with (a) high resistance to late blight, (b) high resistance to powdery scab, (c) presence of antioxidant substances inside tubers, (d) high tuber yield, and (e) good characteristics for potato chipping. Firstly, parents with resistance to powdery scab in both roots and tubers were searched for. 115 genotypes were evaluated at six sites with high natural soil inoculum (between 1.3×10^6 and 4.1×10^6 sporosori/g of soil). Severity of root and tuber symptoms was assessed using severity scales. Approximately 100 genotypes were resistant to root and tuber *Spongospora* diseases. This shows that Phureja Group is an important source of genes for resistance to powdery scab and root galling. Hand crossing and open pollination methods were used to obtain new genotypes. During four growing seasons, genotypes were selected by all trait objectives of the plant-breeding program in field conditions. Four multi-environment experiments were carried out in naturally infested fields between 2013 and 2014. Five new varieties were registered: Milagros, Paola, Paysandú, Primavera and Violeta, the last three with high antioxidants in tubers, and resistance to late blight.

34. Obtaining new potato varieties with late blight resistance and adaptation to climate change, using participatory varietal selection

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The potato crop in Peru is the main source of income and food in high Andean areas. To achieve the adoption and dissemination of new varieties, it is necessary to apply special methodologies such as participative varietal selection, which involves value chain actors taking into account gender equity, in order to prioritize the selection criteria. One way to deal with the adverse factors of climate change is to promote varieties that are genetically resistant to late blight, tolerant to frost, drought, heat, etc. This was the objective of this study. From 2016 to 2017, three potato advanced clones and two variety controls were evaluated in 8 field trials, located in Huánuco, Junín and Huancavelica, using Randomized Complete Blocks with three replications. The best selection criteria at flowering were: resistance to late blight, abundant foliage and tolerance to drought; and at harvest were: high yield, uniform tuber size and health. At flowering, clones CIP396034.268 and CIP393079.4 were selected. With regards to gender, male participants selected the clone CIP387096.2, while women selected the Canchan control variety.

At harvest time, participants selected clones CIP396034.268, CIP393079.4 and CIP387096.2, in first, second and third place respectively. Both men and women selected the same clones, but in a different order. The control varieties ranked fourth and fifth.

Organoleptic evaluation, considering appearance, flavor and texture selected the Canchan control variety and the clones CIP387096.2 and CIP393079.4. Clone CIP 387096.2, with the name INIA 326 SHULAY, was released as a new Peruvian variety in 2017.

Technical session D:
Potato Pests and Diseases

1. Characterization of physiological races of Phytophthora infestans (Mont.) de Bary in Spain

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The oomycete *Phytophthora infestans* is the main pathogen of the potato, which causes great losses in the production of this crop, constituting a threat to food security. A survey was carried out in the main potato-growing areas in Spain, obtaining a total of 52 isolates, to determine the aggressiveness and complexity of *P. infestans.* This was the first monitoring study of this pathogen in Spain. Characterization through the spectrum of virulence with differential cultivars has identified

17 physiological races; the most complex race being a group of isolates from Cadiz, with 11 virulence genes, and with mating type *A2*. The results presented in this work may constitute the beginning of future research into a greater number of isolates to deepen the knowledge of resistance genetics, and to be able to continue with the breeding programs against this pathogen.

2. Monitoring black dot and silver scurf in commercial potato crops from plantation to shop shelf

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Disease development for silver scurf and black dot was evaluated by monitoring commercial potato crops over three years (2016-18) using an existing qPCR assay and visual rating at different stages from plantation to shop shelf. The preliminary results of 2016 und 2017 show a diverging development of the two diseases. The development of black dot severity was mainly from plantation to harvest, with soil inoculum as an important factor. No correlation was found between seed tuber inoculum and disease severity at harvest. During storage, no or only a small increase of disease severity could be observed. Potato lots which were clean at harvest stayed clean until the shop shelf. No soil inoculum was detected with qPCR for silver scurf. Already low levels of silver scurf on seed tubers led to important disease severity at harvest. In contrast to black dot, disease severity for silver scurf increased during storage independently of disease severity at harvest.

3. Globodera Alliance (GLOBAL): risk assessment and eradication of Globodera spp. in U.S. potato production

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A transdisciplinary team of researchers including nematologists, plant breeders, pathologists, extension specialists, and economists are working together to tackle the ongoing threat of *Globodera* spp. to U.S. potato production. This collaborative effort is known as GLOBAL (GLOBodera Alliance). The outcome of this research will yield a model management approach to protect the U.S. potato industry from current and future introductions of these nematode pests, and will improve U.S. agriculture, food security, and stakeholders' economic interests, knowledge base, and participation in decision-making. Ongoing research is directed towards 1) development and implementation of effective early warning tools for *Globodera*, including improved detection and diagnosis methods, 2) use of genomic approaches

to characterize pathogen virulence and host resistance for development of resistant cultivars, and for detection and identification of effector genes and genetic variability in *Globodera* across its geographic range, 3) identification and deployment of potato germplasm conferring resistance to three species of *Globodera* in economically viable potato varieties, 4) coordination with stakeholders and policymakers to co-develop science-based agricultural approaches to deal with the threat of *Globodera* and implement sustainable, environmentally sound agricultural practices for potato production in the context of *Globodera* risk management, and 5) increasing the number of scientists, extension specialists, and educators with the skills and knowledge to effectively address the problem of *Globodera* species.

4. Potential source of tolerance and resistance to zebra chip disease in potato genotypes

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Zebra chip (ZC) is associated with the bacteria '*Candidatus* Liberibacter solanacearum' (Lso). Lso is transmitted by the potato psyllid *Bactericera cockerelli* Sulc (Hemiptera: Triozidae). While ZC reduces yield and tuber quality at harvest, Lso continues to negatively impact potatoes during cold storage. Currently, the only available control measure for ZC is frequent insecticide applications to reduce psyllid population, which is an unsustainable and costly approach. Planting ZC-resistant, or tolerant, genotypes is expected to contribute to an improved production sustainability as a component of an integrated management approach. However, to date, no resistant cultivars are identified. Our objective is to identify sources of resistance/tolerance to ZC in selected potato genotypes, of which some appeared promising in previous studies. Evaluations were not only limited to field, but were also conducted post-storage. To simulate early- and late-season infection scenarios, using Lso-infected potato psyllids, plants were inoculated 78, 12 and 4 days before vine-removal. After harvest, tubers were placed in cold storage. The relationship between Lso titer (qPCR) and symptom severity was used to compare relative susceptibility (and tolerance) to ZC among genotypes. The lack of a significant relationship between the two variables confirmed variability among genotypes. A07781 siblings, derived from *Solanum tuberosum* and *S. berthaultii*, presented relatively greater tolerance, with two genotypes also offering low susceptibility to Lso (A07781-3LB and A07781-4LB). A07781 siblings also exhibited greater ZC tolerance post-storage. Hence, this genetic line would contain genetic source(s) of ZC resistance to be incorporated into a breeding program.

5. A temperature responsive transmission model for the potato yellow vein virus-Trialeurodes vaporariorum- potato pathosystem

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Management of viral diseases can be improved if supported by predictive models that can accurately forecast disease spread. Potato yellow vein virus (PYVV; Genus *Crinivirus*, Family *Closteroviridae*) is transmitted in a semi-persistent manner by the greenhouse whitefly *Trialeurodes vaporariorum*. Although several approaches exist for modeling insect pests, climate responsive predictive models for virus epidemics have not yet been developed. To address this challenge, we initially developed a temperature-dependent phenology model for the vector using ILCYM software. Next, the efficiency of virus transmission (by adult whiteflies) was determined through controlled laboratory experiments at different temperatures (15-25 ºC). Non-linear equations were developed to estimate the probability for virus transmission by the insect vector as a function of temperature. Results show efficient transmission occurs over a narrow range between 12 and 18 °C, which is different from the optimum temperature for insect development. The transmission probability function interacts with the prediction of the insects phenology produced by the life cycle model of *T. vaporariorum*, thereby generating a fully climate-responsive model for virus spread and transmission. GIS risk maps produced by the model reflect the current occurrence of the virus but also predict new areas at high risk of invasion that have successfully been targeted for surveillance.

6. Phenology of the potato psyllid, Bactericera cockerelli (Hemiptera: Triozidae), and "Candidatus Liberibacter solanacearum" in commercial potato fields in Idaho, USA

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Zebra chip disease is an emerging potato disease in which tubers are produced with striped necrotic patterns that make them unmarketable. Zebra chip is associated with the bacterium "*Candidatus* Liberibacter solanacearum," which is transmitted by the potato psyllid, *Bactericera cockerelli* (Šulc) (Hemiptera: Triozidae). First found in Idaho during 2011, zebra chip now contributes to increased production costs each season via additional insecticide sprays. To clarify the extent and severity of the zebra chip threat in Idaho, we sampled potato psyllids in commercial potato fields across the state over six growing seasons (2012-2017). All life stages of psyllids were sampled using a combination of methods (yellow sticky traps, vacuum samples, and leaf samples), and adult psyllids were tested for the presence of liberibacter by polymerase chain reaction. Abundance of potato psyllids initially increased gradually over each growing season, then exhibited a sharp late-season rise and a sharp decline as most fields were being harvested. Abundance of psyllids was higher at warmer, lower elevation sites, but infestation onset did not differ between growing regions. Fewer psyllids were collected in vacuum samples than in sticky trap samples. Nymphs and eggs were found only late season and during years with high abundance of adults. Overall incidence of liberibacter was similar among all years but one. The results presented here clarify our understanding of the seasonal phenology of potato psyllids and liberibacter in Idaho potato fields and will aid in developing integrated management strategies against this important pest of potato.

7. Identification of regulated genes differentially, of resistant and susceptible potato varieties during infection by *Globodera pallida*

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Globodera pallida, also known as "potato cyst nematode", is one of the pathogens with the highest attack incidence in the potato crop. It not only decreases crop productivity, but also has a high impact on food security. The search for potato varieties with resistance genes to this nematode is an alternative for managing this disease. In the present work, we performed infection tests by inoculating stage 2 juveniles (J_2) of *G. pallida* in potato roots from Maria Huanca and Chimbina Colorada varieties, provided by the International Potato Center (CIP), which classified as resistant and susceptible to *G. pallida*, respectively. Infected roots were evaluated at 24 and 72 hours post - inoculation by measuring, under microscope, J_2 quantity that entered the root. In addition, RNA extraction from infected roots was done in order to perform RNA-sequencing. Using bioinformatics programs, genes were identified and transcripts expression related to defense were also quantified in both varieties. The results showed 100 candidates genes related to *G. pallida* resistance that were expressed differently between varieties Maria Huanca and Chimbina Colorada. To conclude, the resistant variety María Huanca may posess a superior mechanism of resistance against the juvenile infective nematode (J_2) compared to the Chimbina Colorada variety.

8. Finding and use of late blight resistance genes from potato relatives

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Resistance to late blight caused by *Phytophthora infestans* (Mont.) de Bary is an important goal of potato (*Solanum tuberosum* L.) breeding efforts. The pathogen is fast-evolving and can quickly adapt and infect new resistant cultivars of the host. Therefore, new strategies of using late blight resistance (Rpi) genes to improve durability of resistance are being developed. They are all based on access to multiple broad-spectrum Rpi genes.

In our research, three genes: *Rpi-phu1* from *S. phureja* from the International Potato Center (CIP), *Rpi-rzc1* from *S. ruiz-ceballosii* and *Rpi-mch1* from *S. michoacanum* from the Vavilov Collection (Saint Petersburg, Russia) were identified and introduced into a potato pre-breeding program. The genes were mapped and markers used for marker-assisted pyramiding of the genes. We also mapped and used the *Rpi-Smira1* gene from the cultivar Sárpo Mira. Spectrum and durability of provided resistance is monitored in the Polish population of *P. infestans* in virulence detached leaflet tests. The effect of pyramiding is tested both in the laboratory and in field tests. Using qPCR we test the expression of the *Rpi-phu1* gene and the corresponding effector during the host-pathogen interaction for better understanding of virulence/avirulence.

The search for new resistance sources is continuing within the Vavilov Collection accessions. The research was funded by the G2P-SOL project (Title: Linking genetic resources, genomes and phenotypes of Solanaceous crops) which has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 677379.

9. Effect of acquisition access period, retention time and inoculation access period on transmission efficiency of potato yellow vein virus by *Trialeurodes vaporariorum*

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Potato yellow vein virus (PYVV) (*Crinivirus/Closteroviridae*), is a reemerging plant virus, spread throughout all Colombian potato producing areas. Information on PYVV transmission characteristics by *Trialeurodes vaporariorum* (natural vector), such as acquisition access periods, retention time and inoculation access periods has not been reported yet. In the present study, these characteristics were evaluated. Assays were based on the ability of the adult greenhouse whitefly (*T. vaporariorum*) to acquire and transmit the virus: Symptomatic potato plants were the source used to obtain viruliferous whiteflies used to infect recipient plants (plants of *Solanum tuberosum* Grupo Phureja variety Criolla Colombia, PYVV-free). For each characteristic, different time periods were evaluated (0-48h). Expression of symptoms and PYVV capside protein RT-PCR of asymptomatic plants were used to indicate PYVV infection. The virus could be retained for up to eight hours, but transmission efficiency decreased with an increasing retention time. The results indicate that greenhouse whitefly required at least six hours of inoculation access period to successfully transmit PYVV to recipient plants with an increase in transmission efficiency over the time. Furthermore, whitefly adult density was evaluated. The transmission efficiency with different groups of whiteflies, (1, 5, 10, 30, 50 and 100 adults) was estimated. At least ten adults are needed to transmit the virus; PYVV transmission was positively related to the number of whiteflies used for inoculation. These results are congruent with semi-persistent virus transmission. These findings are of importance for understanding the transmission biology of greenhouse whitefly vector and devising management strategies for the disease caused by PYVV.

10. Reproductive fitness of *Meloidogyne hapla* on eleven potato cultivars

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The northern root knot nematode (*Meloidogyne hapla*) is an important soil borne pathogen of potato in the northeastern United States, which may result in yield reductions or crop damage in severe infestations. Knowledge of reproductive efficiencies of *M. hapla* on different potato cultivars may support informed nematode management strategies and mitigate the need for control tactics such as nematicides. The reproductive fitness of *M. hapla* was evaluated on eleven potato cultivars commonly grown in New York State, USA, in a replicated pot trial conducted in the greenhouse. Plants were

inoculated with one of three population densities (500 or 1,500 second-stage juveniles per pot, or a non-inoculated control). After 65 days of growth, *M. hapla* reproductive fitness was assessed for each cultivar by determining the total final population (eggs and second stage juveniles), *M. hapla* per gram fresh root, and reproduction factor (final / initial population). Virulence of *M. hapla* on each of the cultivars was also assessed by visually scoring galling severity on the roots. Data were analyzed and significant effects investigated for individual factors and interactions. Potato cultivar had a significant effect on virulence and each element of reproductive fitness assessed. Results of this study will be used to inform disease risk prediction models of *M. hapla* in potato.

11. Resistance of potato cultivars as a determinant factor of potato virus Y (PVY) epidemiology

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Potato virus Y (PVY) is considered the most economically damaging virus for seed-potato production. PVY isolates are usually divided into three historical PVY strains, namely PVY^{C}, PVY^{O} and PVY^{N}. More recently, recombinant strains named $PVY^{NTN}$and $PVY^{N\text{-}Wi}$ appeared in Europe and North America, rapidly spread into seed-potato production and gradually replaced historical strains. This progression can be explained by several factors, including the differential susceptibility of cultivars to PVY strains. This research presents the results of a Swiss survey of PVY strains conducted in 2012 in which the progressive increase of the prevalence of $PVY^{N\text{-}Wi}$was observed. The occurrence of PVY strains in the two main potato cultivars grown in Switzerland, cv. Agria and cv. Charlotte, is described through the 2012 survey and one additional PVY strain survey conducted in 2014. Both surveys were completed with a mechanical-inoculation assay. The inoculation assay showed that cv. Agria is susceptible to $PVY^{N\text{-}Wi}$ and resistant to PVY^{NTN}, whereas cv. Charlotte is susceptible to both strains. The inoculation assay also showed that the expression of symptoms on cultivars is strain-dependent, with a lower expression of symptoms for plants of cv. Agria inoculated with $PVY^{N\text{-}Wi}$. These results stress the major role of the resistance profile of cultivars to explain the balance of the PVY strains in potato crops.

12. Factors of expression of Rhizoctonia stem canker in potato plants as an integrated management risk assessment

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Rhizoctonia stem canker of potato caused by the fungus *Rhizoctonia solani* is responsible for yield losses due to stand losses before and after emergence. Crop management decisions based on available information can be used to prevent disease. A survey was conducted among 500 farmers to assess risk factors associated with disease expression, including seed health, crop rotation, variety, planting date, fertilization, irrigation, chemical treatment, storage facilities and use of best agricultural practices. In order to predict the potential risk of disease, field experiments were conducted to evaluate Rhizoctonia risk based on chemical control, variety susceptibility, date of planting and seed

and soil inoculum, during the crop seasons from 2014-2017. The risk assessment was determined based in the experimental results, literature review and farmer crop management practices. The importance of each factor was rated using a 1 to 4 scale, where 1 is low risk and 4 is high risk. The risk of management practices was rated using a 1 to 10 scale, where 1 is good and 10 is bad. For this assessment, the highest risk for disease expression will be 40 (4*10). For example, seed is an important factor in Rhizoctonia disease expression (rate 4) and the decision to use a bad quality seed has a high risk (rate 10). On the other hand, lowest risk will be 1 (1*1) (storage facility*good storage facilities). Risk assessment and management recommendations are available for self-evaluation by farmers as a decision support system at http://enfermedadespapa.inia.cl.

13. Development of an immunochromatographic test kit for the presence of *Clavibacter michiganensis* subsp. *sepedonicus*

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Clavibacter michiganensis subsp*. sepedonicus* (Cms) is one of the most important potato pathogens. As the cause of bacterial ring rot in potato, it is already on the list of quarantine facilities with zero tolerance and is subjected to official control. The occurrence of ring rot is associated with serious consequences for potato producers, and often causes problems for potato producing companies.

The most effective way to control the disease is through application of healthy seed potatoes and rapid elimination of disease outbreaks. Both cases need sensitive and specific diagnostic tools for detection of the pathogen. Detection and identification of this pathogen is very difficult, mostly because of the many limitations of currently used diagnostic methods. Early and appropriate detection methods are necessary for the production, processing, and distribution of plant material. Therefore, it is necessary to develop innovative solutions solving presently known methodological difficulties and allowing for simple, fast and specific detection of Cms.

Therefore, the aim of this research was to develop a new immunological diagnostic test for the detection of Cms bacteria. In the construction of the test, we applied highly specific anti-Cms antibodies and colloidal gold nanoparticles as one of the most sensitive markers used in diagnostics.

Our preliminary results confirmed high efficacy of the solutions in rapid detection of the Cms bacteria.

14. Resistance of potato varieties to golden cyst nematodes (Globodera rostochiensis Woll.) isolated from the south of Chile

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The golden nematode *Globodera rostochiensis* is a quarantine pest affecting the potato crop. The damage caused is related to population density and susceptibility of varieties employed. In Chile, there are potentially resistant varieties that carry resistance genes such as *H1* and *GroV1*. With

the objective of determining the level of resistance of nine potato cultivars against isolates of *G. rostochiensis* obtained from recently infested areas in southern Chile, an experiment was performed in pots under growth chamber conditions. The varieties Innovator, Yagana-INIA, Atlantic, Patagonia-INIA, Cardinal, Puyehue-INIA, Asterix, Karu-INIA and Desiree were inoculated with 24 cysts per pot. A complete randomized design with four replicates was employed. In parallel, the presence of molecular markers associated to genes conferring resistance to golden nematode was assessed by PCR reactions. The variables evaluated were relative susceptibility, multiplication of cyst and juvenile viable per cyst after four months post inoculation. The number of cysts per pot was affected by variety. (ANOVA, $p < 0.01$). The most susceptible cultivar was Desiree, where the number of cysts incremented ten levels, followed by Patagonia-INIA and then Innovator. The most resistant cultivars of this assay were Asterix, Karu-INIA, Yagana-INIA, Cardinal and Atlantic. In such varieties the number of cysts was not incremented with respect to inoculation. All these varieties were holders of the *H1* gene. These results are the first reports of resistance for golden nematodes for Karu-INIA and the first antecedents of reaction of varieties to isolates of *G. rostochiensis* from southern Chile.

15. Physical and chemical factors of soil affecting the biology of the potato cyst nematode (Globodera spp.) in Colombia

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The potato cyst nematode (*Globodera* spp.) is a phytoparasite identified in Colombia since 1970, which in recent years has become important due to an increase in its incidence and severity in potato producing areas. Corpoica carried out research aimed at identifying the physical and chemical characteristics of soil that can stimulate the presence and development of *Globodera* spp. in the main potato producing departments. The methodology consisted in identifying a representative sample of crop fields from a database collected during the years 2013-2014 with the objective of taking new soil samples. The samples were transferred to the research center, where physicochemical characterization, and identification and quantification of populations of *Globodera* spp. were made. The information was analyzed by cluster and correlation analysis. It was observed that the infested area increased 34% during 2016 compared to the 2013-2014 sampling. Likewise, in the farms with the presence of *Globodera* spp., an increase in the population was observed in 51% of the samples analyzed. The variables: sand content, porosity, calcium and phosphorus, have a strong relationship with the presence of *Globodera* spp. This information was found in the samplings from the years 2013-2014 and 2016 in all departments. The analysis of the data by department showed the importance of some particular variables in the soils in each department that either stimulates or not the biology of the nematode. The obtained results can lead to the development of specifically targeted local nematode management strategies.

16. Current distribution of the potato bacterial wilt pathogen Ralstonia solanacearum in Peru

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Here we report the occurrence of bacterial wilt caused by *Ralstonia solanacearum* (Rs) in potato fields in the central (Huanuco) and northern (Cajamarca, Ancash, Piura and Amazonas) highlands in 2016-2017. In total, 547 samples of potato stems showing bacterial wilt symptoms were collected from 56 fields between the altitudes of 2111 and 3742 meters above sea level (masl). The bacteria were isolated using modified Kelman's medium, the taxonomic identification of *R. solanacearum* was verified by species specific PCR, and the diversity of isolates was determined by biochemical test and phylogenetic analysis based on the partial DNA sequence of the endoglucanase gene. Aggressiveness of 25 strains *of R. solanacearum,* selected based on the phylogenetic analysis, was determined by inoculating potato, tomato, eggplant and tobacco. *R. solanacearum* was found in 33 fields up to 3350 masl and in 217 out of 547 samples. The rate of infected potato fields out of those sampled, and with wilted samples, was 81% in Piura, 80% in Huanuco, 60% in Amazonas, 55% in Cajamarca and 13% in Ancash. This suggests that the wilt symptoms observed in the field are also caused by other pathogens besides *R. solanacearum.* Differences in aggressiveness among the strains were found on tobacco, but not on the other plants tested. Biochemical characterization revealed that most strains (98%) were biovar 2A, and the remaining were biovar 1. According to the phylogenetic analysis, all strains belong to phylotype IIB sequevar 1, a group specially adapted to potato in cold and temperate areas.

17. Phosphonate fungicides enhance host resistance to late blight in potato

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Late blight has been a major constraint in potato production in Eastern African highlands and has proven to be one of the most yield limiting factors for smallholder farmers of the region. Moreover, the recent occurrence of metalaxyl resistant strains of *Phytophthora infestans* and negative impacts on health of widely used mancozeb products complicate the situation further. Applications of phosphonate products have been shown to be effective against oomycetes in several studies. Phosphorous acid inhibits oxidative phosphorylation in the metabolism of oomycetes. In addition, some evidence suggests that phosphorous acid has an indirect effect by stimulating the plant's natural defense response against pathogen attack. The presented study therefore assessed, over 6 seasons, the potential for late blight control with products based on phosphorous acid neutralized with potassium together with the different levels of host plant resistance to late blight of varieties grown in Kenya. Results reveal that phosphonates are as efficient as other chemical treatments in controlling the disease with high levels of host plant resistance resulting in higher or same yield levels compared with the chemical control. However, with increasing varietal susceptibility, disease control and yields were significantly lower compared with the chemical control.

Phosphonates, in a package with at least moderate host plant resistance, can therefore be recommended as an alternative to chemical late blight control which is safe to human health, and with reduced risks of a buildup of pathogen resistance.

18. Fungicides sensitivity of Phytophthora infestans isolates to systemic fungicides in potato-growing regions of the central highlands of Colombia

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Late blight caused by the plant pathogen *Phytophthora infestans* (Mont.) de Bary is the most devastating disease on potato worldwide. Chemical fungicides are often used to control the disease. Although the sensitivity of *Phytophthora infestans* populations to certain fungicides is maintained in natural populations, resistance events have often been detected in the current *Phytophthora infestans* populations. Here, we have monitored the occurrence of resistant isolates of *Phytophthora infestans* to the most common systemic fungicides used for the control of potato late blight in the central highlands of Colombia: Mefenoxam, Cymoxanil, Fluopicolide and Dimetmorf. *Phytophthora infestans* isolates were collected from 33 sites in different potato-growing areas between 2016 and 2017. Isolate sensitivity to each fungicide was tested based on mycelial growth and sporulation using *in vitro* assays. Overall, all fungicides tested were less effective to control mycelial growth than sporulation. Results for each fungicide showed that 289 isolates were significantly sensitivity to mefenoxam with low levels of EC50 (94.1%, n=307), whereas Cymoxanil was the most ineffective fungicide with only 7 isolates categorized as susceptible (3.5%, n=194). We also reported naturally resistant *Phytophthora infestans* isolates to Fluopicolide with EC50 values greater than 10µg mL^{-1}. Resistance to this fungicide was found on 78 *Phytophthora infestans* isolates (21.9%, n=356). Finally, only 28 of all isolates tested were classified as resistant to Dimetomorph (11.3%, n=249). The importance of effective monitoring and evaluation of *Phytophthora infestans* fungicide resistance, as well as the implications for developing integrated late blight management strategies for Colombian potato crops are discussed.

Technical session E: Potato Crop Management

1. Development of PCM, a web-based potato yield and tuber size forecasting system for applied use

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Potato yield models have not generally been adopted in commercial practice despite the potential value of forecasting yield and tuber size. The web-based Potato Crop Management System (PCM) described in this paper has overcome some of the barriers to adoption and the number of registered crops is increasing. PCM uses crop measurements to parametrise the model and forecasts are updated

using ground cover from images input via smartphone. A RESTful application programming interface (API) allows the model to be executed autonomously from databases holding crop and meteorological information. Web-based interfaces are used to collect data and an API can provide output to user-friendly dashboards.

Yield estimates were on average within +/-1 % of sampled yields although the variance for grower reported yields was generally greater. Yield forecasts inform logistics, procurement and crop management. Forecasts of tuber size distributions are used to determine the most suitable defoliation and harvesting dates to optimize marketable yield. The system also provides a platform for ongoing crop improvement through analysis of canopy data, yield and tuber size.

2. Chlorophyll content and chlorophyll fluorescence response of potato under different nitrogen rate

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A field experiment was conducted in Sicily (south Italy) to assess chlorophyll (Chl) content and Chl fluorescence parameters response of potato crop in relation to nitrogen rate and cultivars, and to detect relationships between Chl content, Chl fluorescence parameter and tuber yield. The experiment included five nitrogen rates (0, 100, 200, 300, and 400 kg ha^{-1}) and three cultivars (Arinda, Daytona, and Ninfa). Chl content and Chl fluorescence parameters (initial fluorescence, F0, maximum fluorescence, Fm, variable fluorescence, Fv, Fv/Fm, Tmax) were measured on five sunny days between the appearance of the fifth and sixth leaves and the onset of plant senescence. A positive linear relationship was established between nitrogen rate and Chl content, Fv, and Fv/Fm. Nitrogen rate up to 100 kg ha^{-1} also had a positive effect on Fo, Fm and Tmax. Arinda had the highest Chl content, whereas Rubino had the lowest Tmax. Tuber yield was significantly correlated with Chl content, which in the present study seems to be the unique tool able to detect, under field conditions, differences among cultivars in response to nitrogen supply.

3. Potato productivity and greenhouse gas emissions under varying nitrogen management in Southern Alberta, Canada

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Nitrogen fertilization in potato (*Solanum tuberosum*) is a key driver to both crop productivity and greenhouse gas (GHG) emissions. A reduced nutrient use-efficiency in potato crops typically leads to detrimental outcomes from agronomic, economic and environmental perspectives. Moreover, new market and customer trends increasingly question current production systems with regards to the intensity of their environmental footprint. This field study evaluates options of N management that can sustain or improve the overall performance of the Russet Burbank potato production system in Southern Alberta, Canada. The use of an alternative N granular form (ammonium sulfate nitrate - ASN)

and a nitrification inhibitor (2,4-dimethylpyrazol succinic acid - DMPSA) was compared with common N sources such as regular urea and polymer-coated urea (Environmentally Smart Nitrogen™ - ESN) in two irrigated sites (Lethbridge and Brooks), each with four replicates. Compared to conventional N formulations, ASN could potentially deliver higher N availability per added N unit to the crop, while the additive DMPSA is expected to prevent N losses and improve timely N availability. In these experiments, we measured the emissions of the potent greenhouse gas nitrous oxide (N_2O) from hills and valleys in potato crops throughout the growing season using the chamber method. Plant N uptake and use-efficiency were quantified. Tuber harvest and grading were also documented. Data is being analyzed and results will be discussed. In addition to agronomic responses, the presentation will encompass GHG baseline, environmental GHG footprint, and N use-efficiency.

4. Potassium acetate as source of potassium fertilizer enhances potato tuber yield and quality

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Potassium (K) fertilizer is comparable to nitrogen in the quantity needed for a successful potato crop production. Earlier studies conducted indicate that the source of potassium fertilizer applied can influence potato tuber yield and quality. A new potassium-based fertilizer, known as Bio-K® has been introduced. This fertilizer is a combination of an inorganic salt reacted with an organic acid to form potassium acetate (KA) fertilizer. A study was conducted at Colorado State University, U.S.A., to evaluate the response of Russet potato to potassium acetate as source of potassium fertilizer and to its application time. Potassium acetate was compared to Potassium Chloride (KCl) in this study. Treatments included (i) pre-plant application of potassium acetate; (ii) pre-plant application of potassium acetate, followed by foliar application of potassium acetate; (iii) foliar application of potassium acetate; (iv) pre-plant application of potassium chloride; and (v) pre-plant application of potassium chloride, followed by foliar application of potassium acetate. A control treatment was included where no K fertilizer was applied. Using KA as source of K fertilizer and applying it pre-plant increased total and marketable tuber yield by 8% and 12%, respectively, compared to the control treatment. When compared to KCl as source of K fertilizer, KA applied pre-plant, and as foliar application, increased total and marketable tuber yields by 15% and 8%, respectively. Data from these studies indicate that potassium acetate as source of K fertilizer and proper timing of its application can improve tuber performance of Russet potato.

5. Conservation farming practices for potato production in the Sandveld region of South Africa:a four-year review

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Conservation farming embraces crop production systems involving the management of surface residues in which tillage plays a critical role. The trial was performed in the Sandveld region of South Africa over the period from 2013 to 2016 and evaluated three tilling systems, conventional mouldboard, rip and a paraplough treatment with a combination of three cover crop treatments. The

cover crop treatments were black oats, rye and a rye and small grain combination established after potato harvest**.** The paraplough treatments showed no negative influence on free living nematode numbers when compared to the conventional and rip tillage treatments. Significantly higher levels of respiration were found in soils where the paraplough was utilised, up to 8.062 mg/kg/h. The yield between the different tillage treatments was not negatively influenced by the paraplough and was significantly higher in the first and fourth year in comparison to the other two tillage treatments with 61.2 t/ha and 35.36 t/ha respectively. Black oats planted as cover crop had the lowest dry mass production throughout the four year cycle of the trial ranging from 42.00 to 187.16 g/m^2. Percentage cover ranged from 9.5% to 91.0%. The highest values of soil carbon were achieved in the paraplough treatments throughout the duration of the trial. Soil compaction at the depth of 60 – 80 cm showed that the paraplough led to the lowest soil densities. The first cycle produced favourable results and it would be of great significance if these results could also be obtained in the second cycle.

6. Influence of the deep soil preparation associated with succession of maize in the production of potato tubers

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Potato cropping in Brazil is marked by a constant need to migrate to new areas due to a high incidence of soil diseases and soil preparation is done by conventional tillage, using plow and harrow. There is limited research done on sustainable systems for potato production in Brazil. Therefore, deep soil preparation for potato cropping succeeding maize may be a viable alternative for producers attempting to reach and maintain high levels of potato tuber production without having to relocate to new cropping areas. The objective of the present study was to compare the production of potato (*Solanum tuberosum*) cv. Atlantic in two types of soil preparation (i.e. conventional and deep tillage) with the average national production. The experiment was conducted over ten years (2006-2016) in Piracicaba (São Paulo - Brazil). The treatments were: corn, deep tillage soil preparation (0.70 m depth), and conventional tillage soil preparation (0.20 m depth before planting the potato crop). For statistical analysis a randomized block design was adopted with six replications. Before harvesting the tubers, the means of treatments were estimated in tons per hectare. Data were subjected to analysis Student's t-test to assess statistical significance using the software SAS. A comparison was made between treatments and the average national production of potato. Deep soil tillage did not differ significantly from the national average, but when compared to conventional tillage, it showed increases of 35.9% in productivity. Thus, the studied system has potential to end potato nomadism.

7. Shoot growth and tuber yield of potato crop as affected by plant growth regulator and nitrogen supply

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The use of plant growth regulators in potato combined with nitrogen (N) fertilizer management may be an alternative to reduce shoot growth of plants and increase tuber yield. Thus, the aim of this study was to evaluate shoot growth and tuber yield of Agata potato cultivar submitted to N and plant growth regulator applications. The experiment was conducted in a potato production field in Brazil. A randomized block design was used in a 2x4 factorial scheme, with four replications. Treatments were represented by two levels of N supply (Recommended = 120 kg ha^{-1} and High = 240 kg ha^{-1}) combined with four prohexadione calcium rates (0, 50, 100, and 200 g ha^{-1}). Prohexadione calcium rates were divided into two applications at 15 and 25 days after emergence (DAE). Only plant height, tuber mean weight, and tuber yield smaller than 23 mm were affected by rates of prohexadione calcium. Plant height evaluated at 45 DAE decreased up to 198 g ha^{-1} of prohexadione calcium, while tuber mean weight and tuber yield smaller than 23 mm increased up to 118 and 123 g ha^{-1}, respectively. Yield of tubers smaller than 33 mm was higher under high N supply, but the number of leaves and tubers per plant and yield of larger tubers was not affected by treatments. In both levels of N supply the increase in plant growth regulator rates reduced shoot growth without affecting yield of larger tubers.

8. Tuber yield of Agata potato cultivar in response to nitrogen fertilizer management

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Nitrogen (N) supply at the appropriate time increases potato yield (*Solanum tuberosum* L). The objective of this work was to evaluate the tuber yield of cultivar Agata under different management with traditional N fertilizer and with the N application during the tuber bulking stage. The experiment was conducted in the field in a randomized complete block design in a 4x4 factorial scheme, with four replications. The forms of N fertilizer management were: **M1** = 160 kg ha^{-1} N at planting; **M2** = 80 kg ha^{-1} N at planting; **M3** = 40 kg ha^{-1} N at planting and 120 kg ha^{-1} N at hilling (10 days after emergence); **M4** = 80 kg ha^{-1} N at planting and 80 kg ha^{-1} N at hilling; combined with the rates of 0, 20, 40, and 80 kg ha^{-1} N applied in the tuber bulking stage. Tuber number per plant was increased linearly with N rates at tuber bulking stage. Total and marketable tuber yields were not influenced by treatments. Yield of tubers > 45 mm was affected by management x rate interaction. N rates applied in the tuber bulking did not affect the yield of M1 and M4 managements, but increased linearly in the M3, and reduced in the M2 to the rate of 45 kg ha^{-1} N. In the M3 management, the application of 80 kg ha^{-1} N at tuber bulking stage increased the yield of tubers > 45 mm.

9. Effect of vermicompost of sewage sludge on potato plants (*Solanum tuberosum* L.)

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The accelerated generation of residual sludge requires action for its disposal and recycling. An alternative is the addition to the soil, which improves the structural properties and increases fertility. However, these residues contain heavy metals, that in high concentrations cause alterations to the functions of organisms as oxidative stress. An alternative is to treat them with the vermicomposting technique that generates a stable, innocuous and suitable product for application to crops.

The objective of this work is to evaluate the effect of vermicompost elaborated with residual sludge and horse manure on the growth, productivity, and antioxidant activity in plants of *Solanum tuberosum* L cultivar Citlali. The evaluations were made on agricultural soil with 0, (T0), 20 (T20), 40 (T40) and 60 (T60) tons ha-1 of vermicompost. This was elaborated using young earthworms of the species *Eisenia foetida* at reproductive age (developed clitelium), with a length of between 3 to 5 cm. The vermicomposting process was stabilized at pH 7.2, electrical conductivity of 1.1 dSm-1 and 50.5% organic matter in approximately 60 days. The growth (length, fresh and dry weight), antioxidant activity (total phenolic compounds, enzymatic activity of peroxidases and DPPH) was quantified according to the content of photosynthetic pigments and number and weight of tubers. The results show that there is an increase in growth and productivity at a higher dose of vermicomposts compared to controls, as well as differences in antioxidant activity and photosynthetic pigments.

10. Nitrogen reduction of nutrient solution on minitubers seed potato production in an aeroponic system

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Aeroponics is the latest technology used to improve the production of basic seed potatoes in the world. As it is a recent technique some challenges still need to be overcome, such as the determination of an optimal nutrient concentration and the nitrogen (N) management of nutrient solution, focusing on increased tuberization, aimed at high yields. Nitrogen affects the abscisic-acid/gibberellin (ABA/GA) ratio on potato plants and therefore tuberization. It is well known that an excess supply of nitrogen can stimulate GA biosynthesis, promoting stem elongation and not favoring tuber formation. However, little information is known about appropriate nitrogen reduction amounts, especially for different climate conditions and potato cultivars in the aeroponic system. Thus, the objective of this work was to verify the effect of nitrogen concentration reduction in nutrient solution on the shoot growth development and seed potato production of two cultivars (Agata and Asterix) in an aeroponic system. The reduction of nitrogen did not affect the accumulation of biomass by the plants of the cultivar 'Agata' but increased the yield of minituber by 17% (73.3 mg L^{-1}) when compared to the control treatment (141.2 mg L^{-1}). For 'Asterix', the nitrogen reduction affected the biomass accumulation, but not the minituber yield. These findings suggest a cultivar specificity in relation to nitrogen management (reduction) in plants grown aeroponically.

11. Yield evaluation in three varieties of potato using two methods for late blight Phytophthora infestans control, in three localities of Colombia

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Previous research carried out in Peru and Ecuador resulted in the development of a tool for decision making on late blight control by small farmers in potato crops (CIP disks). In this work we present the first step of the validation process for a future use of the CIP disks in Colombia. Three locations: Mosquera (Cundinamarca), Turmequé and Toca (Boyacá), were chosen to carry out independent experiments to evaluate the disks with varieties that differ in their resistance to *P. infestans*: Pastusa Suprema (resistant), Ica Única (moderately resistant) and Diacol Capiro (susceptible). In each experiment, three treatments were evaluated: T1 (Control using CIP disks), T2 (Positive control: Mancozeb, in Mosquera, and farmer management, in Toca and Turmequé) and T3 (Negative control – without any control strategy applied). The experimental design was a randomized complete block design with four replications. The weight of harvested tubers was not different in T1 and T2. This result implies that the use of the disks could be a powerful tool. The disease pressure was high enough to guarantee that the average weight of tubers in T3 was significantly lower than the rest of treatments. The exception was the Pastusa Suprema plots in two localities, where not significant differences ($p < 0.05$) were observed between treatments. This result could possibly be due to the resistance of this variety to the pathogen. Some adjustments to the use of the disks as a tool for decision taking in managing potato late blight are necessary.

12. Effect of foliar application of Mg+Mn gluconate on chlorophyll contents and tuber yield in yellow diploid potato (*Solanum tuberosum* Group Phureja)

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Foliar fertilization based on magnesium (Mg) and manganese (Mn) gluconate is a new trend complementary for nutrition of the diploid potato (*Solanum tuberosum* Group Phureja), considering its importance in the photosynthetic process and its low mobility in the plant and the soil. The objective was to evaluate the effect of foliar fertilization with different levels of Gluconat Mg+Mn® on yield and quality traits in yellow diploid potato cv. Criolla Colombia. A randomized complete block (RCB) design with three repetitions, was used to determine the effect of five levels of Gluconat Mg+Mn® (0, 150, 300, 450 y 600 ml/ha), in Mosquera, Cundinamarca. The assessed variables were chlorophyll contents (CC), tuber yield (TY) and economic viability. The plants treated with Gluconat Mg+Mn® showed a higher CC. The higher efficiency was obtained with the 400 ml/ha dose, being 23% higher compared to the control with 23 ton. ha^{-1}. The economic review showed that the gluconate application at doses of 400 ml/ha increases the profitability up to 40% compared to the control. We can conclude that the foliar applications of Gluconat Mg+Mn® in doses of 400ml/ha^{-1}, increase the yield in Criolla Colombia cultivar. The Gluconat Mg+Mn® is a great alternative for improving nutrition management, due to its higher absorption and the rate of release of metallic ions into mesophyll cells, correcting the typical bronze bud in yellow diploid potatoes, due to the deficiency of these elements, and positively affecting performance through better photosynthetic efficiency.

13. Production and multiplication of national potato varieties in family farming systems

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Potato is the main vegetable in terms of production volume at national level in Uruguay. Two agricultural cycles are carried out every year, in autumn and in spring. Small-scale family potato farmers represent 80% of production and cover only 10% of national area. The current system of seed multiplication allows for 2 crops in 2 years, involving the conservation of seed tubers for 6 months. An alternative scheme for family farmers has been proposed, based on the use of national short dormancy varieties. With proper management, it is possible to obtain 4 crops in 2 years. In order to support the inclusion of family farmers in a multiplication scheme of national varieties and to identify the main management factors to be improved, the monitoring of seed production was carried out in 2016. Farms were visited every 15 days to assess crop growth and health, and support decision making. Total yield was estimated and classified into categories. Critical management factors discussed with farmers were crop design and density, emergence, harvest and post harvest management. We found harvest date is a bottleneck for family farmers, where delays in harvest are frequent. The delay of the spring harvest prevents using these seeds for the autumn crop since they would not reach an adequate sprouting state. In spite of the fact that national varieties have short dormancy, for this scheme of seed multiplication, the spring harvest date is a key factor to ensure a proper sprout status for the next planting season.

14. From farm-saved seed to quality declared planting material – a case study from Ethiopia

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Until 2012 around 99% of seed potatoes planted in Ethiopia were derived from the informal seed system, characterized by farmers using farm-saved seed or bought in local markets mostly of poor health status. Numerous initiatives have invested in improving the production of early generation seed and establishing decentralized seed production systems. These efforts have greatly increased the availability of quality seed. However, in the absence of an official seed certification system, the sustainability of these initiatives is questionable. An official seed certification scheme is largely impractical in a situation such as in Ethiopia where seed is being produced by a large number of farmers, often operating in remote areas. To address this issue, CIP and its local partners conduced a pilot study to test the semi -formal Quality Declared Planting Material (QDPM) protocol over a period of four seasons. The system builds on and improves existing informal seed systems and constitutes an intermediate step towards a fully-fledged seed certification system. The pilot study had strong involvement of local research and extension bodies and included 14 seed producer cooperatives. A total of 135 fields were inspected, out of which 116 met the seed quality requirements. The benefits of using QDPM seed became clearly

apparent with an average yield increase of 63% compared to farmers' seed (25.7 vs 15.7 t/*ha^{-1}). As a result, QDPM has been ratified by the Ethiopian government as a legal seed quality control standard in March 2015 – however it has been renamed Quality Declared Seed.

15. Response of sseed tubers containing dicamba and glyphosate residues

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The use of herbicides near seed potato farms is concerning to seed potato growers as potato seed tubers have been reported to be affected by glyphosate or dicamba when the mother plants have been exposed to glyphosate or dicamba. The objective of this study was to determine the effects of planting 'Russet Burbank' potato seed tubers from mother plants that were exposed to dicamba (4, 20 and 99 g ae ha^{-1}), glyphosate (8, 40 and 197 g ae ha^{-1}) and the combination of dicamba and glyphosate during tuber initiation the previous growing season. Daughter tubers were planted back near Oakes and Inkster, North Dakota, USA in 2016 and 2017, at the same research farm they were grown the previous year. The highest rates of dicamba (99 g ha^{-1}), glyphosate (197 g ha^{-1}) and the combination caused 17 to 72% reduction in emergence and 23 to 57% reduction in total yield when compared to the non-treated check. Dicamba applied at 20 g ha^{-1} reduced yield 11 to 33%. Dicamba and glyphosate can reduce emergence and total production when residues are carried over in seed potatoes. 'Russet Burbank' was more susceptible to dicamba than glyphosate.

16. Soil microbial diversity of native potato under conventional and non- conventional tillage: taxonomic and functional approach using whole genome sequencing

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The inadequate agricultural management practices of the most diverse ecosystem on earth are producing erosion and change and/or loss of the soil microbial diversity.

The main goal of this study was to identify the taxonomic and functional aspect of the microbial diversity present in soil samples collected in agricultural fields of native potatoes under conventional and non –conventional tillage from Huancavelica, Peru. To fulfill this goal, we used whole genome sequencing.

Our preliminary results showed that the majority of the sequences can be attributed to *Bacteria* (21.05%), *Archaea* and *Eucarya* (0.3% and 0.2%, respectively), and 78% showed no similarity with any known sequences for both types of soil management. The functional analyses found 90 proteins associated with the Gene Ontology - nucleobase-containing compound metabolic process - in conventional tillage; and 95 proteins associated with Gene Ontology: - phosphate-containing compound metabolic process - in non –conventional tillage.

Our results are the first attempt to determinate the taxonomic and functional profile of microbial diversity present in the agricultural soil of native potatoes. It also represents the beginning of a new area of research at The National Institute of Agricultural Innovation (INIA for its acronym in Spanish) with the aim of finding new ways to know our genetic resources.

17. Feasibility improvement of emergence of buds and yield indices of different cultivars of minituber potato influenced by different composition of planting bed and cultivation methods in greenhouse conditions

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In order to evaluate the effect of different cultivars, substrate combinations and types of cultivation on bud emergence and yield of mini-tubers, an experiment was conducted based on completely randomized design with three replications in the greenhouse at the Seed and Plant Certification and Registration Institute (SPCRI) in 2012-2013. Three factors were considered: three cultivars (*Agria, Sante , Satina*) , different substrate combination of planting at six levels: Peat moss+Sand (1:1 by volume), Coco peat+Perlite+Sand (1:1:1), Peat moss + Perlite (3:1) , Peat moss+Sand+ Perlite (1:1:1) , Coco peat + Perlite + Peat moss (1:1:1), Coco peat+Sand (3:1), and type of cultivation in beds at two levels (pot and direct planting). Results indicated that the effect of cultivars and different substrate combinations were significant at ($P<0.01$) on the number of day to bud emergence at the soil surface, total production of mini-tubers, total tuber number in standard size and tuber dry weight per plantlet. Peat moss+sand bed (1:1) showed high total number of mini tubers, tuber number in standard size and tuber dry weight per plantlet with the average of 8, 6.66 tubers and 4.41 g respectively. *Santé* cultivar had the highest number of tubers and number of tuber in standard size with 8.80 and 7.91 tubers, respectively. The highest number of tubers with a mean of 6.95 tubers and number of tubers in standard size with a mean of 5.96 tubers was obtained in direct planting in bed. The results showed that *Sante* cultivar had the best performance in direct cropping in Peat moss+Sand bed.

Technical session F:
Post harvest and Processing Technology

1. The response of potato (Solanum tuberosum) to vacuum impregnation

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Potato ranks as the fourth food in worldwide consumption, due to its nutritional quality and high energy. Therefore it is a promising candidate for the development of functional food using different engineering techniques. One of these techniques is vacuum impregnation (VI), which exploits the porous microstructure of food matrices to incorporate physiologically active compounds (PAC) or components to improve quality. The objective of this work was to evaluate the response to the VI of some potato slices with an isotonic sodium chloride (NaCl) solution. The system was subjected to three different levels of vacuum pressure (P) (15, 19, 23 "Hg) for 3 minutes (t_1), and subsequently the local barometric pressure (85,3 kPa) was restored to 4 min period (t_2). The response variables were: fraction and volumetric deformation at the vacuum stage (X_1; g_1) and the process end (X; g) with effective porosity (εe). The main result was X and X_1 presented statistically significant differences ($p < 0.05$) due to the effect of the applied pressure. In general, it can be concluded that the potato has availability of intercellular spaces, which makes it possible to include components of interest in its structure, for the design of new nutritionally balanced, healthy and/or functional products.

2. Effect of different cooking methods on phytochemical concentration of pigmented potato cultivars

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Potato is one of the best sources of phytochemicals in the human diet. However, thermal processing usually reduces the concentration of some bioactive compounds. The present study was focused on evaluating the effect of four common cooking methods (baking, boiling, microwaving and steaming) on total phenolic, anthocyanin and carotenoid concentrations of four purple and red fleshed potato cultivars. Purple Peruvian and Rouge de Flandes showed high total soluble phenolics and monomeric anthocyanins (TMA), whereas Morada was characterized by a high carotenoid concentration (TC). The comparative analysis of raw and cooked tubers showed significant losses of phenolics, anthocyanins and carotenoids, but these reductions were higher after boiling and baking. Steamed and microwaved tubers retained the highest phytochemical levels. Differences in the composition of tubers, sample preparation and extraction processes and chemical assays explain the great variability of effects that have been reported.

3. Innovation and research advances for more efficient and sustainable storage

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Year after year, the need to preserve a more standardized tuber quality during storage remains a necessity. At the same time, the constraints required by regulatory directives and energy supplies are also increasing. In order to solve the different thermodynamic, physiological and biochemical parameters linked with storage, a lot of innovations have been and are on the way to being developed, to maintain or to engage the storage chain more efficiently and sustainably. Highly accurate inside and outside sensors provide digital supervision integrating data in sophisticated software for improving the stability of potato quality. Humidity, CO2 and temperature are the main parameters to be controlled. If artificial cooling has frequently been usedto replace ambient air when outside conditions are too warm, it needs now to contend with a more expensive energy supply and the attendant greenhouse gas effect. Adaptations and new solutions are proposed to keep storage economical and sustainable. This also includes sprouting management, for which new treatments have been regularly appearing on the European market for a few years, some of which have a natural profile.

4. Potential of hyperspectral imaging for potato cultivars classification based on their processing aptitude

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There has been a significant increase in the use of hyperspectral imaging systems within the agrofood sector in recent years. A reason for this lays in the main benefit these systems provide compared to conventional spectroscopic technologies, as they are capable of not only identifying but also locating different chemical compounds in the samples analysed. In this study, we have focused on the use of such systems in combination with chemometric analysis to determine the aptitude for processing of different potato cultivars, as either suitable for boiling or frying. The dataset used was composed of 20 different potato cultivars with the two aptitudes described above. Among them, 9 cultivars were already classified as suitable for frying and the remaining 11 as appropriate for boiling. A total of 80 tubers, 4 of each cultivar, were scanned with a setup for hyperspectral imaging acquisition sensitive to the 900-1700 nm range. Once this step was completed, data were processed using both a K-Nearest Neighbour classification technique and a Partial Least Squares Discriminant Analysis using the PLS_Toolbox software working under MATLAB. The result obtained indicated that hyperspectral imaging and a KNN analysis seem suitable to be used for classifying potato cultivars according to their processing aptitude, with more than 76% of correctly classified samples. In contrast, the combination of HSI and PLS-DA reported lower overall rates of classification, which suggest that more research is needed before using them for assessing potato processing aptitude.

5. Maintenance of consumption quality in dehydrated potato over a long storage period

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The preparation and storage of dehydrated potato can be aided by pre-treatments such as bleaching and sulfitation, which act as a practical and efficient way to control oxidation and enzymatic or non-enzymatic browning of the product. Dehydration is a process that influences perishability, as it promotes microbiological stability and reduces chemical reactions. This study aimed to demonstrate the effect of bleaching and of doses of sodium metabisulfite on the maintenance of quality in dehydrated cubes of potato over a long period of storage. Tubers of the cultivars 'Asterix', 'Macaca' and 'Agata' were sanitized in a sodium hypochlorite solution (200 mg/L free chlorox), peeled and sanitized again with 100 mg/L of sodium dichloro-s-triazinetrione. Then, the tubers were cut into cubes (1 cm^3) and treated in one of the following groups: control; bleaching; bleaching + 0.05 % sodium metabisulfite ($Na_2S_2O_5$); bleaching + 0.1% sodium metabisulfite; and bleaching + 0.2% sodium metabisulfite. At the onset of the experiment (time 0), a sulphur dioxide (SO_2) residue evaluation and microorganism detection were performed. Water activity, color, rehydration ratio, cooking time and rehydration ratio after cooking were determined at time 0 and at the following two years (year 1 and year 2). Potato cubes treated with bleaching or bleaching and sodium metabisulfite, dehydrated at 60°C and conditioned in hermetically closed glass containers, can be stored for two years with no effect on quality. The dry mass content of tubers affected cooking time and rehydration ratio after cooking.

6. Effect of growing technology on acrylamide precursor content in potato tubers

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In three-year field trials reducing sugar (RS) and asparagine (Asn) content was measured in raw potatoes and fried chips. Three varieties for chip production were involved in the trial. These varieties were bred for low accumulation of RS during storage: Pirol (medium early German variety), Lady Claire (medium early Dutch variety), and Crispy (medium early Dutch variety). Fertilization variants involved nitrogen and sulphur levels. The following rates were used: 40 kg N/ha (N1), 160 kg N/ha (N2), 40 kg N/ha + 40 kg S/ha (NS1), 160 kg N/ha + 40 kg S/ha (NS2). RS content was statistically affected by year and variety. In dry and warm years, the lowest RS content was determined. All studied factors, i.e. year, variety and fertilization variants had a statistically important effect on Asn content. The relation of Asn and year is opposite to that for RS. Significantly the highest content was found in years with highest rainfall deficit. The results indicate tendency to higher Asn and also acrylamide contents with increased rates of nitrogen fertilizers. Sulphur fertilizer did not positively influence decrease of Asn content, as referred by data from literature. Based on trial results the relation was calculated between acrylamide precursors and acrylamide final content in fried chips. Whereas in the case of RS content, linear dependence was confirmed, in the case of Asn content, no dependence was detected.

7. Assessing food losses in the potato value chain in Ecuador and Peru

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Potato production, because of its dual purpose, is still an important source of income and food security for most small-scale farmers in the Andes. Value chain transformation is important to farmers' incomes, rural employment, and access to and affordability of staples for urban consumers. Reducing food losses along the market chain can improve food availability in accordance with investments on the production side (Schuster & Torero, 2016). However, estimating the magnitude of post harvest losses (PHLs) has proven to be a daunting task with estimates that vary considerably.

This paper reports on a study conducted by the International Potato Center, aimed at developing a general framework to evaluate the extent and sources of food losses in developing countries.

The study provides a comprehensive identification and characterization of losses in terms of: 1) Type of losses (price reduction, quality and product losses); 2) What are the factors determining the losses? 3) Where in the value chain the losses are occurring? 4) Who in the value chain is experiencing the consequences? This analysis provides the economic value of the different types of losses across the value chain. The most important losses occur in the production node, from 90% to 95% of the total losses in the chain. Farmers on average lose between 20% and 26% of their production before moving on to the next link.

The results will inform policy makers, researchers and development agents, on the identification and design of initiatives to reduce losses and their impacts on the efficiency of the market chains.

8. Agricultural mechanization: the need for speed of future development

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The demand for food in the different regions of the world, calls for various and appropriate technological solutions. This demand for technology in each region is a response to the need for more food and efficiency in global production. Potato provides a clear example for the needs of technology, because potato is in the frontline in the fight against hunger and for a better quality of life.

The level of agricultural mechanization in each region of the world, as reflected in potato production, serves as one of the indicators of what is needed in each region, and what we have to offer and develop for more efficiency.

Companies such as Grimme, who make agricultural mechanization equipment, are offering solutions and tools to improve the work of the farmer.

These tools and solutions include: equipment, consulting, practice, precision farming and after sales concepts.

All this is focused on an efficient use of natural and technological resources, starting from mechanical tools, through to IT and data management.

The technology allows the farmer a comprehensive vision of potato production, starting from soil preparation and variety of potatoes to be cultivated, through to growing conditions and destination markets.Technology for potato production includes: equipment and tools for soil preparation, planting, harvesting, storage and processing, and equipment for data management.

9. A Review of North American and international potato storage recommendations

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Extended potato storage (more than 12 weeks) for fresh consumption, processing and seed requires proper storage design to ensure the potato quality from storage is acceptable for the intended use of the potato. The design of these storage facilities require attention to the local environment and production practices along with the intended end use of the potato from storage. This presentation will provide insight into the design of ventilation, humidification, heating, cooling and air mixing systems to produce the proper environment to maintain optimum potato quality. The recently reviewed and released ASABE Standard EP475.2 for bulk potato storage design will be used to demonstrate current storage design parameters for North America. This work will be extended through local environmental analysis to other areas around the world. The goal of this presentation is to bring to light some of the fundamental forces driving the design engineering resulting in the variation in global potato storage recommendations for ventilation rates. The author will also introduce some questions and potential direction on the potato storage facilities of the future.

Technical session G and H:
Potato Biodiversity and its use in Breeding, Nutrition and Health

1. Improvement and participatory selection of biofortified clones in the high Andes of Huancavelica, Peru

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Breeding for micronutrient density (biofortification) is a new objective of the International Potato Center (CIP), where resilient clones for climate change are bred and tailored to multiple environments through participatory variety selection (PVS). Biofortification is a food-based approach aimed at reducing malnutrition, oriented to highland communities where high rates of potato consumption

coincide with iron and zinc deficiencies. Yanapai is an NGO working with families in the Central Andes of central Peru, to reduce malnutrition through the introduction and selection of diverse nutritious and climate change resilient varieties. As the first products of this collaborative effort resemble Andean landrace potatoes, they are readily accepted by families without changes in farming or food systems. CIP researchers identified parental material in Andean landrace potato germplasm in 2004 and conducted recurrent selection to cycle III, doubling iron (Fe) and zinc (Zn) levels from the original baseline. Seventeen clones from cycle II were grown in 4 communities in Huancavelica during 3 growing seasons and subject to PVS, using the Mother&Baby trial design. Criteria at flowering included resistance to late blight, frost and hail, traits of importance to men and women, and at harvest, yield, tuber shape and color. The post-harvest criteria - cooking time, taste, texture and storability - were of highest importance to women. Iron content of tubers was higher in communities above 4000 mas. After 3 years of evaluation, 6 clones were selected, of which two will be planted in validation trials to start the process of varietal registration with INIA, Peru.

2. Collection of Polish potato varieties in the in-vitro genebank

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The potato in-vitro genebank was established in 1981 in the Plant Breeding and Acclimatization Institute - National Research Institute in Bonin, Poland. The main task of the genebank is collecting and long-term storage of tetraploidal potato genotypes in the form of in-vitro plantlets. Currently, the collection of potato varieties includes 1598 accessions from 23 countries. Polish varieties registered after 1945, account for 277 accessions - 20% of the collection. Significant numbers of accessions come from Germany (478), Netherlands (270), Russia (96), Czech Republic and Slovakia (65), Great Britain (55), France (30), USA (42) and many other countries. The collection mainly consists of edible potato varietes (957), general-purpose (173), industrial (85) and starch varieties (144). Most of them are moderately early varietes (546), moderately late (278), early (240), late (204) and very early (122).

The source of plants maintained in the in-vitro genebank are healthy potato tubers, free from bacteria *Clavibacter michiganensis* ssp. *sepedonicus* and *Ralstonia solanacearum*. Before depositing into the bank, potato plants are subjected to 3-week thermotherapy for virus elimination. Only plants which are free of quarantine objects are qualified for further processing. Plantlets grown from meristems are 2-3 times controlled by a DAS-ELISA assay for the presence of PVA, PVX, PVS, PVM, PVY and PLRV. Only virus-free in-vitro plants are introduced into the genebank collection. All stored gene resources are described in detail and valorized for botanical and functional characteristics in field conditions during annual identification.

3. Effect of fertilization with zinc in an agronomic fortification strategy in two potato varieties (Solanum tuberosum) in soils from the coast and highlands

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It is not well known to what extent the agronomic fortification strategy of the potato crop and the interaction with soil chemistry characteristics can affect the absorption of microelements. Nor do we know the optimal doses and forms of zinc application to maximize absorption and translocation to the tuber to achieve effective fortification benefits to man. Zinc is an essential micronutrient for crops and very important in potato cultivation. Despite its recognized functions, zinc fertilization has received little attention in the potato fertilization programs in Peru. The present study aims to determine the effect of the application of zinc, via foliar and soil, on potato zinc absorption. In this paper I conduct a set of two experiments (field and pots) to obtain the necessary evidence to answer these questions.

In this paper, scientific evidence to support the development of a larger scale project for fortified potato, as an alternative and sustainable solution in the medium and long term to combat the incidence of chronic malnutrition (hidden hunger) in the rural Andean population, is developed. Specifically, the effectiveness of agronomic fortification to increase the content of zinc in the potato tubers is measured; the optimal dose of zinc in two soil types, from the coastal region and the Andean highlands is identified; and the bioavailability of micronutrients (Zn) after agronomic fortification to meet the essential minimum requirements of these elements in human diet is identified.

4. Principal components analysis of six tuber quality traits of 72 potato (Solanum tuberosum L.) clones

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Potato (*Solanum tuberosum* L.) is the most widely grown tuber crop, and the fourth largest crop after rice, wheat and maize, in China. With the increasing demand for processing potato varieties and corresponding products, breeders paid more attention to corresponding tuber quality traits. This study comprehensively evaluated six tuber quality traits including: dry matter content (DM), starch content (SC), protein content (PC), reducing sugar content (RS), vitamin C content (VC) and chip color grading (CC) for 72 potato advanced clones screened by IVF-CAAS. The results showed that: (1) The coefficient of variations of the six traits ranged from 11.7% to 67.9%, which showed a wide genetic variation for 72 clones; (2) The variations were mainly contributed by the frying-related traits (reducing sugar content, chip color grading), which can be clearly observed by their highest cumulative presence in the principal components analysis of 40.8%. (3) Four principal components were extracted with a cumulative contribution rate of 89.11%, representing the most variation of six tuber quality traits, component 1 represented CC, DM, RS, SC, PC and VC; component 2 represented CC, DM, RS, SC and PC. (4) 72 potato clones can be classified into two groups based on cluster analysis, namely Group I, including 45 clones with high DM and SC, low RS and CC; Group Ⅱ, including 27 clones with low DM and SC, high RS and CC. (5) Compared with Shepody, 11144w-266 and 11251w-70 showed 1%-1.7% higher DM and 2-2.3 lower CC ($P<0.05$), which shows them to be suitable as potential processing potato cultivars.

5. Quantifying diversity of the potato crop (Solanum spp.) in an agrobiodiversity zone in the Peruvian Andes

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The Peruvian Central Andean region is an important center of diversification for potato, which is expressed in the presence of thousands of traditional varieties managed by local people. Previous studies on potato diversity have focused on assessing varieties' richness, without considering evenness. This component of diversity may provide an idea about the existence of predominant varieties, and those rarer ones which are under risk of being lost. Accordingly, we quantified potato diversity of seed stocks from 12 farmers in the agrobiodiversity zone of Kichki, Huánuco; specifically, from the communities of Monte Azul and Huayllacayán. We used the Shannon-Wiener (H) and Simpson (1-D) indexes, which integrate richness and evenness. Each variety name and its weight were registered, in order to use their relative amount of biomass for calculating the indexes. We found 705 potato traditional varieties, the richness being higher in Monte Azul than in Huayllacayán (520 and 427 traditional varieties, respectively). However, in Monte Azul we found greater diversity (Simpson: 0.79 and 0.89, Shannon: 2.28 and 2.99, respectively). A similar pattern was found at farmer level. For instance the second richest stock of potato varieties (182 varieties) was the eighth in diversity (Shannon: 1.65, Simpson: 0.67). Therefore, a greater varietal richness does not always mean greater diversity. The implications of these results are discussed. We hope this methodological contribution may be used to monitor not only potato diversity, but crop diversity at large, since it allows obtaining valuable information for decision making for conservation of these important genetic resources.

6. Genetic diversity and origin of cultivated potatoes based on plastid microsatellite polymorphism study of herbarium specimens from WIR and LE herbaria

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In the present study we screened 207 herbarium specimens of cultivated potatoes and their wild relatives from WIR and LE Herbaria with plastid DNA markers (SSR, SCAR, CAPS) to investigate cultivated potato diversity and phylogeny. The most specimens are represented by authentic herbarium materials and nomenclatural types of potato species and intraspecific taxa. They represent material collected by the first scientific collecting missions of Sergey Bukasov (1925 to 1926), Sergey Juzepczuk (1926 to 1928) and Nikolay Vavilov (1932 to 1933) in different countries of South America. These specimens are of great historical and scientific importance, since they reflect the diversity of cultivated potatoes from their centers of origin, and document the views of Russian solanologists on their taxonomy and phylogeny.

These herbarium specimens have never been used in molecular studies. The data from cpSSR analysis of herbarium specimens were compared with the results of investigation of the field germplasm collection performed with the same 15 plastid microsatellites (Gavrilenko et al.2013). Subset from the field collection included 392 accessions; most of which were collected in the second part of the 20th century. In addition both subsets - from Herbaria and from the field collections were characterized by DNA markers detecting different cytoplasm types. This study revealed the changes in cytoplasmic diversity of tetraploid cultivated potatoes. At the same time, the results of the analysis of both subsets allow us to make similar conclusions about maternal origin (plastid genome donors) of cultivated potatoes.

7. Potato cryocollection at VIR

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Cryoconservation experiments at VIR were started in 2010 based on the application of droplet-vitrification method (Panis et al. 2005) for shoot tips of microplants. This method was further modified by us (Dunaeva et al.2011; Shvachko, 2012; Ukhatova et al.,2017). Modifications included: elimination of the initial microplants' pretreatment stage, and the use of modified media at the stages of: initial micropropagation, explants isolation and post-cryogenic regeneration. Three repetitions per accession were done with 60 explants per each (30 explants for cryopreservation in the VIR Cryobank, and 30 explants to control their regeneration ability after rewarming). Currently the VIR potato cryo-collection consists of 216 accessions including: 162 accessions of cultivated potato species, 44 breeding varieties and 10 breeding clones. Regeneration rates of explants after rewarming varied depending on genotype from 15.0 to 94.9%. About 77% of the cryopreserved accessions have a regeneration rate higher than 40%.

We try to cryopreserve well-characterized material. Thus, cultivated potato species accessions are the part of the experimental subset genotyped by SSR-markers, characterized by chromosome number counts (Gavrilenko et al.2010, 2013) and with known cytoplasm types. Some of these accessions were characterized for resistance to pathogens. The most important part of the cryocollection are accessions of cultivated potato species collected by VIR expeditions (including the expeditions of 1920s-1930s) in different countries of South America. Breeding varieties before cryopreservation were also genotyped with nuclear SSRs, as well as with cytoplasmic DNA markers and with DNA markers associated with R-genes conferring resistance to the most harmful pathogenes.

8. Use of cryopreservation for long-term storage of potato germplasm in the Czech Republic

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Long-term storage of potato germplasm is usually carried out by means of *in vitro* cultivation of potato explants at slow-growth condition or by cryopreservation methods. In the Czech Republic the complete

germplasm collection is kept at the Potato Research Institute in Havlíčkův Brod under slow-growth conditions in *in vitro* conditions. To improve standards of germplasm storage a safety backup for the most valuable accessions was established at the Czech Cryobank of Plants and Microorganisms in the Crop Research Institute in Prague. The advantage of the slow-growth conditions is availability of explants for their multiplication and subsequent testing or distribution. Potato seeds are produced in shorter time when compared with cryopreservation. The disadvantage of this method is a risk of callus formation connected with somaclonal variation, and potential microorganism contamination. In contrast, cryopreservation at ultra-low temperatures is more secure against contamination by microorganisms. At the same time, plant growth and development are completely stopped; biochemical and genetic changes are excluded due to vitrification status of plant material at ultra-low temperature. Thus, the cryopreservation method is preferable for long-term storage of potato germplasm.

9. Phytochemical screening for content of total phenols and antioxidant activity of five Peruvian varieties of Solanum tuberosum in the process of liofilization and pre-cooking

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Several studies indicate that potatoes with color are a natural source of phytochemicals related to antioxidant activity and the prevention and control of chronic diseases, such as cardiovascular disease, cancer, diabetes, and neurodegenerative diseases. For this purpose, five Peruvian varieties of *Solanum tuberosum* from the regions of Ayacucho and Huancavelica were analyzed through phytochemical screening (Lock), in the fresh material, and the content of total phenols (Folin Ciocalteu method) and antioxidant capacity by DPPH (1,1 diphenyl-2-picrilhidrazil) in fresh, lyophilized and heat-treated samples (90 °C 5 min -1). The most abundant chemical groups in the five varieties corresponded to tannins, phenolic compounds, amino acids, flavonoids and triterpene steroids. The presence of anthraquinones and naphthoquinones was moderate in the “sangre de toro” variety, with some traces in “cacho de toro”and “pumapa makin”. The reaction for cardenolides was low, with traces of “pumapa makin”and “sangre de toro”, while leucocyanidins and catechins showed a moderate reaction in those same varieties. The presence of alkaloids was not evident. The content of total phenols was higher in “sumac sonqo” with 130 mg EAG (100 g sample) -1, while the percentage of inhibition for DPPH was higher for “leona” with 92%. The thermal treatment favored the retention of the content of total phenols and the antioxidant capacity, while the lyophilization affected the content of both, in the five varieties.

10. Dry matter and specific gravity content evaluation in the Central Colombian Potato Collection Solanum tuberosum group Andigena

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Since 1995, the Colombian Corporation for Agricultural Research - Corpoica, has been responsible for the conservation of the Central Colombian Potato Collection (CCCP) belonging to the Colombian National Germplasm Bank, whichseeks to preserve potato genetic resources of constituting the starting material for plant breeding, agrobiodiversity conservation and food and nutritional security. The field collection comprises 1110 accessions that are renewed each year in the municipality of Zipaquirá (2950 masl) and is considered to be an active collection propagated vegetatively through seed tuber in the field. It contains genotypes of the groups: Andígena (671 accessions); Tuberosum (68 accessions); Phureja: (204 accessions) and improved varieties (guata) (89 accessions). In recent years a large amount of information has been generated at genetic variability level through phenotypic and genotypic characterization, agronomic evaluation, industrial variables and quality. During the year 2017, dry matter content and specific tuber weight of the Andigena group were evaluated and analyzed by cluster analysis. As a result, accessions were grouped according to the origin of each material and the quality traits. This information is important for a deeper knowledge of the collection, and for identifying genotypes that could be used as parental material with desirable characteristics regarding these two variables for use in potato breeding programs. The study of patterns of accumulation of dry matter in the tuber, the variability of these patterns between materials and the effect of environmental conditions in the process, can help to maximize productivity and select crops with a high quality both for consumer and industry purposes.

11. Estimation of seed storage longevity of potato using accelerated aging

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Genebanks are entrusted to conserve valuable genetic resources so that they are available in a useable form for breeding or research by current and future generations. While we are very fortunate that potato seed has evolved into a desiccation-tolerant, relatively hearty package, there is limited understanding on the longevity of potato seed under genebank storage conditions. Further, understanding differences in seed longevity between species is also crucial for effective long-term management of seed collections, because the storage life of the seed underpins the determination of when viability tests are needed and most importantly, in defining regeneration intervals and strategies. Prediction models for seed longevity of *Solanum acaule*, *S. bukasov*ii, *S. dolichocremastrum*, *S. chiquidenum* were developed using accelerated aging techniques. Four accessions per species were exposed to accelerated aging (45°C and 60%HR) and samples were removed at regular intervals and the % germination was assessed. The amount of time at which germination declines to 50% (P_{50}) was determined using a Probit analysis and this was then correlated with the seed longevity. Based on these analyses, the seed from these four species were characterized as short-lived (*S. chiquidenum)* or long-lived (*Solanum acaule*, *S. bukasov*ii, *S. dolichocremastrum)*. In addition, the interspecific and intraspecific variability was calculated as well as correlating seed storage longevity to geographical origin of the accession. These results suggest that wild potato species are diverse and the shelf life in potato is not a family characteristic as in some other crops, e.g. *Apiaceae* short-lived seed or *Malvaceae*, long-lived seed.

12. Effect on iron levels of the inclusion of native potatoes in the diet of children aged 2 to 5 years, in six rural municipalities of a medium income country: cluster randomized trial

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Objective: To evaluate the effect on iron levels generated by the inclusion of native potatoes (*Solanum tuberosum* Phureja group) in the diet of children aged 2-5 years in institutional mode beneficiaries, in six rural municipalities in Colombia.

Methods: Cluster randomized trial, at 7 institutions with 244 participants randomly assigned to receive native potatoes in their diet, replacing white potatoes (treatment arm: 3 with 127 children) or assigned to continue their diet with white potatoes (control arm: 4 with 117 children). Changes in iron levels were evaluated at baseline and follow-up through ferritin, hemoglobin and transferrin biochemical tests. The outcome variable was delta ferritin corrected by C Reactive Protein, for which nonparametric tests were applied. A post hoc analysis with hemoglobin post-intervention to individually level adjusted by cluster, was performed.

Results: serum ferritin baseline was analyzed in 244 children, a total of 131 that were included in the final analysis. On follow-up mean values of ferritin delta were 4,3 µg/L (95%IC 1,83 - 6,76) and 4,2 µg/L (95%IC 2,46 - 5,94), respectively. However, this difference was not statistically significant. The post hoc analysis multivariate, to post-intervention hemoglobin, showed treatment arm increase of 0.25 g/dL ([95%IC 0,008 – 0,497] p= 0,043).

The ferritin delta shows clinical differences, but not statistically significant. Post-intervention hemoglobin showed significant differences both clinically and statistically,, which is relevant to the inclusion of native potato in feeding programs.

13. Phenotypic variability in the germoplasm of native potatoes from the Pasco region

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The objective of this research was to collect and evaluate the biodiversity of native potatoes from the Pasco region, for which 488 samples were collected from the provinces of Pasco and Daniel Alcides Carrion. Samples were characterized over four campaigns (2013, 2014, 2015, 2016), homologating successively synonyms clones, and identifying 241 different morphotypes. The cultivars with leaves of five and six pairs of primary leaflets were the most numerous. Seven cultivars were identified with the ability to express up to seven pairs of primary leaflets and seven other cultivars with three pairs of tertiary leaflets. Evidence of the environmental effect on the phenotypic manifestation of the number of pairs of leaflets is presented. The frequency of cultivars with pigmented stems indicated that about 40% of native potatoes from Pasco are “colored” potatoes. The flowering data show that the favorable environmental conditions allow profuse flowering capacity. It is suggested that the characteristics of

pigmentation of the calyx and the pedicels are not related to the pigmentation pattern of the stems. The collection showed cultivars of all primary skin colors with the exception of the brown color. Nearly half of the cultivars showed secondary color on the skin; no cultivars were found with long oblong, reniform or finger-shaped tubers, and it is noted that 36% of the cultivars have yellow pulp and that 26.4% of the cultivars present pulp with secondary color.

14. Variation of asparagine and reducing sugars in potato tubers and acrylamide in potato chips or French fries

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The discovery of acrylamide in potato chips and French fries prompted serious concerns about the carcinogenicity of potato products processed under high temperature. In this study, we carried out potato field trials over the last 3 years and collected 312 potato samples (germplasm, traditional cultivars, newly released varieties and advanced breeding clones). Megazyme Assay Kits (K-ASNAM and K-FRUGL) were used to analyze the contents of asparagine and reducing sugars in all potato samples. We processed those samples into 134 potato chips and 178 French fries and the gas chromatography (GC) with CarboPrep SPE tubes was used to extract and analyze acrylamide contents in potato chips or French fries. Our assay results and statistical tests indicated that there are significant variations in asparagine and reducing sugars in potato tubers and acrylamide in processed products. Potato accessions for French fries have significantly higher reducing sugars than those for potato chips, whereas potato chips have significantly higher acrylamide accumulation than French fries. There is no relationship between asparagine content in potato tubers and acrylamide formation in processed products, but we found that acrylamide levels in French fries have strong correlations with the content of reducing sugars in potato tubers. We identified several clones with low acrylamide level in potato chips or French fries, which have currently been used in AAFC potato breeding program to develop new cultivars with low acrylamide formation potential.

15. Kinship analysis and tuber coloration relationship between reddish potatoes belonging to the Solanum tuberosum subsp tuberosum, Chilotanum group

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The *Solanum tuberosum Chilotanum* group belongs to the low landraces Andean cultivated tetraploids species of potatoes coming from South America, which show great diversity in terms of shape and tuber color. These colored potatoes have attracted growing interest in relation to the development of new potato varieties, with emphasis on health and nutrition, mainly for their high phenolic compounds

content. The Potato Genebank at the Universidad Austral de Chile (UACh) possess a large number of colored potatoes from Chiloe Island and surroundings. Two hundred and seventy accessions from the genebank were screened for two seasons, based on International Potato Center (CIP) scores. In tubers, morphological traits evaluated were tuber form, flesh and skin color and distribution, as well as total phenolic contents.

Additionally, with the goal of establishing the relationship between a number of members from the reddish sub-groups of these potatoes, and then correlating them with the tuber pigmentation of the same accessions, a genetic analysis between these colored potatoes was developed through the amplification and analysis of 22 microsatellites (SSR), previously defined by Ghislain et al. (2009). The results obtained shows that there is a good correlation between the kinship relationship within the varieties of potatoes belonging to this sub-group (Chilotanum) and their tubers' coloration. Thus, these results could be used in order to establish the bases for the development of new "healthy varieties", and also for the establishment of a genetic analysis tool for the specific identification and classification for members of Chilotanum group.

16. Dry matter distribution during tuber development and carbohydrate metabolic gene expression between tuber ends at harvest and sprouting

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Dry matter distribution between the stem end and the bud end directly affects the yield and quality of potatoes (*Solanum tuberosum* L.). High quality fries or chips require relatively similar dry matter contents between the two potato ends. We studied the dry matter at the tuber ends in small, medium and large tubers and characterized the starch granules and gene expression of the tuber ends at harvest and sprouting in 'Russet Burbank' and 'Shepody' (two French fry cultivars) and compared dry matter contents between tuber ends in mature tubers of three table potato cultivars. We found that the dry matter contents were relatively lower in immature tubers and increased rapidly during tuber bulking in both 'Russet Burbank' and 'Shepody'. The tuber stem ends had higher dry matter contents than in the bud ends in both these French fry cultivars and three table potato cultivars ('Favorita', 'Yunshu107', and 'Yunshu505'). The average size of starch granules was larger in sprouting tubers than in growing tubers. The bud-end of developing tubers at harvest had strong gene expression for starch synthesis, which likely attracted photosynthetic sucrose. Gene expression in sprouting tubers suggested an export of carbohydrates from the stem-end to the bud-end. The findings may have practical impact for developing strategies to improve tuber yield and quality in potato production, controlling sprout growth during potato storage, and reducing stem-end darkening in fries and chips.

17. Ensuring the long-term conservation of wild relatives of potato in Peru

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Crop wild relatives are important sources of genes useful for the genetic improvement of domesticated species. However, crop wild relatives are threatened worldwide due to climate change and human-based factors such as changes of land-use and growth of urban settlements, among others. The National Institute for Agricultural Innovation (INIA) is leading a team to collect the wild relatives of potatoes in Peru. The project focuses in collecting seeds, tubers and plants of the species classified as high priority for collection due to lack or low number of accessions conserved in international genebanks, based on a recent gap analysis developed by the Global Crop Diversity Trust. A special feature of this project is that it is the first collecting project after a period of over twenty years, and part of a global initiative to conserve crop wild relatives. The methodology includes database analysis, prospection, collection and regeneration of germplasm. In 2017, three collecting missions targeting the south and central Andes of Peru were conducted, collecting a total of 82 accessions. Mission 1 visited Tacna, Arequipa, Puno, Moquegua and Apurimac, collecting 34 accessions. Mission 2 visited Tacna, Arequipa, Puno and Moquegua, and collected 5 accessions. Mission 3 visited sites in Cusco, Apurimac and Ayacucho, collecting 43 accessions. In 2018, the number of collecting missions will increase in order to collect most of the prioritized species of wild potatoes. The collected material will be conserved at INIA, with a copy at the CIP genebank, and distributed under the multilateral system.

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