A publication of the International Society for Horticultural Science

Chronica Horticulturae

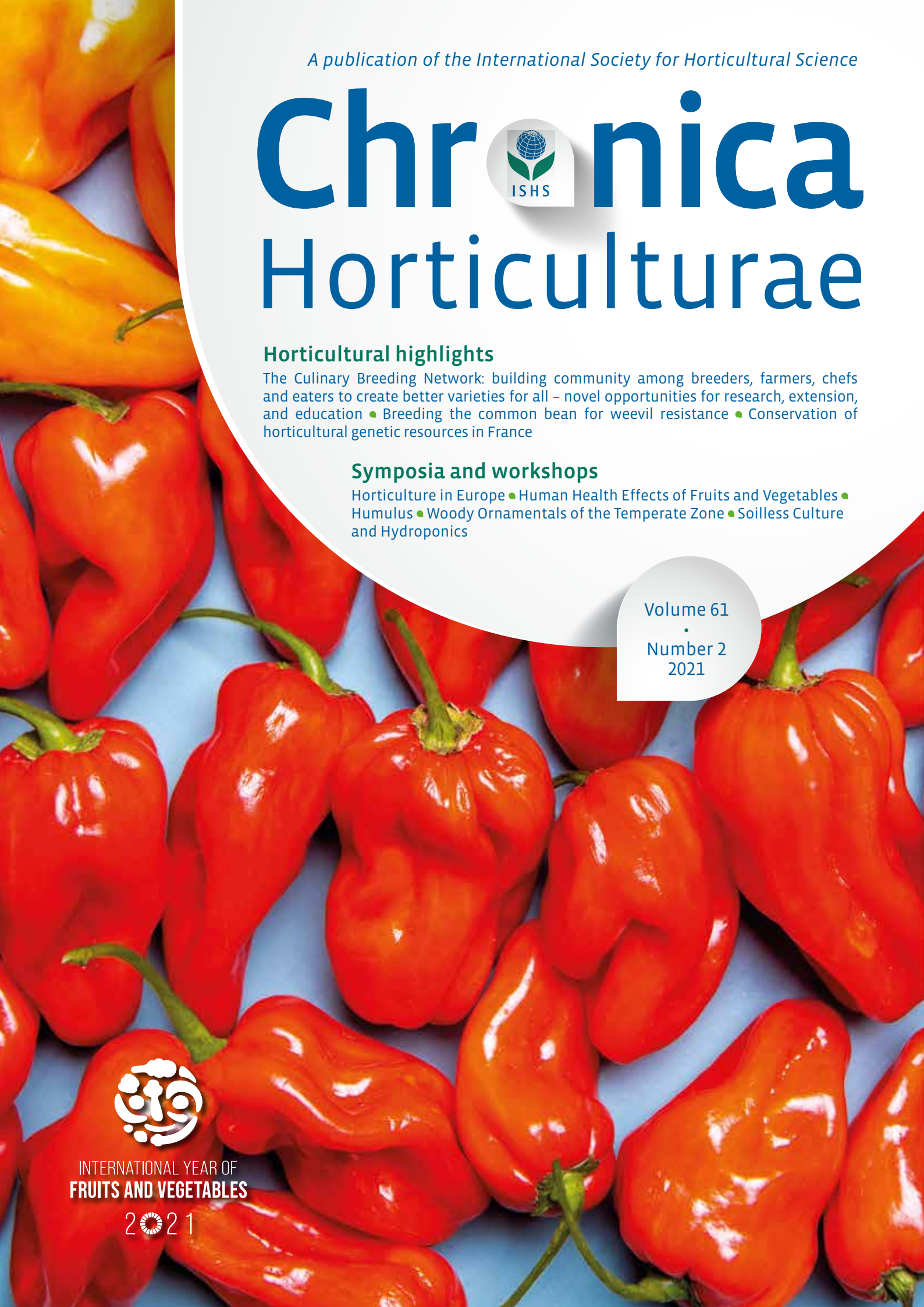
Horticultural highlights

The Culinary Breeding Network: building community among breeders, farmers, chefs and eaters to create better varieties for all – novel opportunities for research, extension, and education • Breeding the common bean for weevil resistance • Conservation of horticultural genetic resources in France

Symposia and workshops

Horticulture in Europe • Human Health Effects of Fruits and Vegetables • Humulus • Woody Ornamentals of the Temperate Zone • Soilless Culture and Hydroponics

Volume 61
•
Number 2
2021



INTERNATIONAL YEAR OF
FRUITS AND VEGETABLES
2021

Chronica Horticulturae

Chronica Horticulturae© Volume 61 – Number 2; June 2021;
ISSN: 0578-039X (print), 2506-9772 (electronic).

Published quarterly by the International Society for Horticultural Science, Leuven, Belgium. Lay-out and printing by Drukkerij Graphius, Gent, Belgium. All previous issues are also available online at www.ishs.org. Contact the ISHS Secretariat for details on full colour advertisements (1/1, 1/2, 1/4 page) and/or mailing list options

Editorial office and contact address:
ISHS Secretariat, PO Box 500, B-3001 Leuven 1, Belgium. Phone: (+32)16229427, Fax: (+32)16229450, E-mail: **info@ishs.org**, Web: **www.ishs.org** or **www.actahort.org**.

Membership and orders of *Chronica Horticulturae*
Chronica Horticulturae is provided to members free of charge: Individual Membership is 95 EUR (including VAT) per year (or two years for members in developing countries). Student Membership: 50 EUR per year (including VAT). For details on ISHS membership categories and membership advantages, or to apply for ISHS membership go to **www.ishs.org/members**.

Payments
All major Credit Cards accepted. Always quote your name and invoice or membership number. Make checks payable to ISHS Secretariat. Money transfers: ISHS main bank account number is 230-0019444-64. Bank details: BNP Paribas Fortis Bank, Branch "Heverlee Arenberg", Naamsesteenweg 173/175, B-3001 Leuven 1, Belgium. BIC (SWIFT code): GEBABEBB08A, IBAN: BE29230001944464. Please arrange for all bank costs to be taken from your account assuring that ISHS receives the net amount. Prices listed are in euro (EUR) but ISHS accepts payments in USD as well.

Acta Horticulturae
Acta Horticulturae is the series of proceedings of ISHS Scientific Meetings, Symposia or Congresses (ISSN: 0567-7572). ISHS Members are entitled to a substantial discount on the price of *Acta Horticulturae*. A complete and accurate record of the entire *Acta Horticulturae* collection, including all abstracts and full text articles, is available online at **www.actahort.org**. ISHS Individual Membership includes credits to download 15 full text *Acta Horticulturae* articles. All *Acta Horticulturae* titles - including those no longer available in print format - are available on USB-drive or in the e-*Acta* format.

eJHS
The *European Journal of Horticultural Science* (eJHS) accepts original research articles and reviews on significant plant science discoveries and new or modified methodologies and technologies with a broad international and cross-disciplinary interest in the scope of global horticulture. The Journal focuses on applied and fundamental aspects of the entire food value chain, ranging from breeding, production, processing, trading to retailing of horticultural crops and commodities in temperate and Mediterranean regions. ISHS members benefit from a discounted publishing charge. eJHS is available in print + online Open Access. Additional information can be viewed on **www.ishs.org/ejhs**.

Fruits – International Journal of Tropical and Subtropical Horticulture
Fruits – International Journal of Tropical and Subtropical Horticulture accepts original research articles and reviews on tropical and subtropical horticultural crops. The Journal is available in print + online. Additional information can be viewed on **www.ishs.org/fruits**.

Scripta Horticulturae
Scripta Horticulturae is a series from ISHS devoted to specific horticultural issues such as position papers, crop or technology monographs and special workshops or conferences.

PubHort – crossroads of horticultural publications
Pubhort is a service of ISHS as part of its mission to promote and to encourage research in all branches of horticulture, and to efficiently transfer knowledge on a global scale. The PubHort platform aims to provide opportunities not only to ISHS publications but also to other important series of related societies and organizations. The ISHS and its partners welcome their members to use this valuable tool and invite others to share their commitment to our profession. The PubHort eLibrary portal contains over 78,000 downloadable full text scientific articles in pdf format, and includes The Horticulture Journal, Journal of the American Pomological Society, Journal of the International Society for Mushroom Science, Proceedings of the International Plant Propagators' Society, Journal of the Interamerican Society for Tropical Horticulture, etc.
Additional information can be viewed on the PubHort website **www.pubhort.org**.

A publication of the International Society for Horticultural Science, a society of individuals, organizations, and government agencies devoted to horticultural research, education, industry, and human well-being.

› Contents

Cover photograph: Mild Habanero peppers bred by Dr. Jim Myers of Oregon State University with input from the Culinary Breeding Network. Photo by Shawn Linehan. See article p.7.

Cover story: Each of our issues of *Chronica Horticulturae* this year celebrates 2021, the International Year of Fruits and Vegetables! as proclaimed by our colleagues at the United Nations Food and Agriculture Organization. Our featured articles in this issue focus on vegetables. The excellent images of the habaneros on the cover and the radicchios accompanying Lane Selman's article were created by Shawn Linehan. Her photographs display a diverse mix of socially responsible farmers and mission driven clients. With a journalist's sense of narrative and an artist's eye, she strives to create intimate, authentic images that celebrate the lives of our environmental stewards who are helping to better our access to local, healthy, and delicious food. Her website is https://www.shawnlinehan.com/. She lives in Portland, Oregon, USA.

› Return to normal?

Kim E. Hummer, ISHS Board Member, Treasurer

› Kim E. Hummer

Greetings everyone!

We are all crouching at the starting line waiting to begin the race to NORMAL!

It seems as if we have been forcibly separated individually in this grand competition of life and death. We have been waiting here in tuck position for more than a year, with our head looking forward and our knees bent and ready to spring into the future. But just like in a running race, we do not want to "jump the starting gun." We will keep vigilant, patient, and avoid a false start. For now, for the safety of ourselves, our family, and our friends throughout the world, we must continue to follow safe guidance: wear masks, social distance, and get fully vaccinated as soon as our country, region, or group allows. We won't congregate inside buildings in large groups just yet.

But you know what? I predict that by August 2022, if we are diligent now and get our vaccines when they become available, we will once again be able to travel. We will still need to be cautious and safe about our mobility; our meetings will need to be designed for dispersed groups rather than dense attendance. But we will be able to physically take part in what will be the greatest Congress sponsored by the International Society for Horticultural Society. Get ready for us, convener Dr. Francois Laurens and the Angers team! We are all planning to attend the 31st International Horticultural Congress (www.ihc2022.org) from 14-20 August 2022 in Angers, France, no doubt about that.

It's been so long since we have been together enjoying the bounty of our Society's symposia, Regional and International Horticultural Congresses, pre- and post-symposium scientific, cultural, and touristic tours. Not to mention that we miss sharing the latest cutting-edge scientific findings through verbal presentations and written *Acta Horticulturae* articles with our friends and colleagues. This is the core function of our Society. We have practiced this for decades and we do it well. We badly want to get back to our scientific routine.

In a nutshell, let me say, as the Treasurer for the Society, I am concerned about the present ISHS budget due to the pandemic shutdown. The revenues for our Society dropped by 25% in 2020, due to cancellation of meetings and lack of travel returns. But, by these same tokens, our expenses dropped by 31%, also due to cancellation of meetings and lack of travel costs. Thus, we have a net positive profit (63K Euros) for the year. That is little consolation for missing our great symposia!

People have been asking how will we know when we are back to normal? That can be answered by our Society's metrics, 6,000 and 35. Let me explain. Our Society's greatest financial assets, literally and figuratively, are 1) our membership and 2) our *Acta Horticulturae* publications. Over the years, we have fared reasonably well financially when, on an annual basis, we have more than 6,000 individual members, and we have produced a minimum of 35 thick, multi-volume *Acta Horticulturae*, or up to 50, a little less thick, as a result of the corresponding number of symposia or congresses. While things are loosening up in some areas, we are not yet back to normal. Yes, we have several other revenue streams (for example, eJHS has increased its impact factor and operates in the black), but membership and the combination of the revenue from our *Acta* are the two major elements of our budget.

The sad reality of the pandemic lockdown is that many previous ISHS members did not re-join. In 2020, our individual membership dropped to 4930. This is a travesty. Some of you who did not pay membership are reading this now. You know who you are. Please go to the ISHS website and renew your membership!

Besides those individuals who have not reinstated their membership, due to the pandemic, travel restrictions, and lockdowns, we are missing the opportunity to have new incoming members who are brought into the fold by the excitement of attending an international horticultural symposium series in person and signing up for their first time. If you know of new colleagues, contacts, or graduate students who may be interested in interacting in our Society, our Working Groups, and Divisions, now is the time to encourage them to become members of our horticultural family.

In 2020, despite the shutdown, we produced 35 *Acta*, the minimum desired amount. That will keep us in business. These *Acta* publications are a result of a backlog from the IHC2018 and 2019 symposia. As you are aware, symposia that were to be held as physical meetings were cancelled in 2020. Only few were held as hybrid events.

We on the Board send kudos out to each of the conveners who were to have meetings in 2020 and 2021. We commend you for your resilience, flexibility, and versatility in replanning and rescheduling for virtual or hybrid symposia. We realize the difficult position that was placed upon you with your previous commitments for reservation of physical meetings that had to change. The Society greatly appreciates your effort and cooperation in working with the Secretariat to reschedule throughout this pandemic. We cannot thank you enough.

Another part of the *Acta* involves financial contributions from conveners. Several conveners from completed symposia have not provided their contractual obligations to the Secretariat. These amounts are for the cost of the *Acta* for distribution to their registered attendees. The Secretariat is generous and accommodating, but these delinquent fees must be paid.

Up to now, library subscriptions for *Acta Horticulturae* have provided substantial revenue for the Society. Unfortunately, this year, these library contributions are low and remain of great concern. During the past decade we have seen a drop in the number of subscriptions. Universities and institutions are reducing their journal subscriptions from many publishers to save money. At the same time, more articles are being published as open access. Even at this time, *Acta Horticulturae* authors can choose to have their article published open access, but the fee must be paid in advance of the publication. Will more authors wish to publish in *Acta* as open access? It is available, if so.

This next year, 2021, will also be financially difficult for the Society. Conveners now realize that their meetings must either be run as virtual or a hybrid of virtual with local attendance. This meeting choice leaves a bad taste in everyone's mouth. The convener had been planning terribly hard to arrange for scientific tours of the excellent horticulture and popular culture to sample in their region. In addition, the attendees look wistfully into the sky around their house and think, "I could

have been in … (Italy, Nova Scotia, Thailand, Senegal, or you name the place) right now, and here I am in my back yard!" No one is happy about this reality. It is important for the Society to have these virtual meetings and prepare the *Acta* for this year. This ensures the continuity of the series of our scientific publications, and the continued existence of our Society.

In conclusion, I have a few suggestions of how we all can support ISHS this coming year.

In 2021, while we are still minding COVID restrictions, we will not have the in-person symposia that we usually depend on. I suggest that we have a **Membership Drive for 2021**! Encourage your colleagues to attend (and present at) virtual ISHS symposia and publish with ISHS. This networking could help increase our membership.

Each of us should take the opportunity to **attend virtual ISHS symposia** and congresses – **especially in 2021**. If we attend these ISHS symposia and submit our manuscripts, this will produce highly valued *Acta Horticulturae*. It will ensure success of the conveners for their symposia, and the future of our Society. This coming year will be a great one for virtual meetings. Finally, plan now to attend the IHC2022 in person, in France. I look forward to seeing you there. It will be the place to be!

Spotlight on Honoured ISHS Members

› Omer Verdonck

Position or previous position

Head of the section Horticultural soil science (1966-1986); Consultant on the quality of substrates (1986-2012); retired from 2012

ISHS honour

ISHS Honorary Member

› Omer Verdonck (left) with two people of the firm Finnpeat Finland visiting peat bog in 1987.

1. Tell us a bit about yourself (hometown, present location, family, hobbies, community involvement).

I was born as a son of a grower of ornamental plants in the region of Ghent (Belgium). This region is very famous for the culture of ornamental plants.

2. What got you started in a career in horticultural science?

During the school holidays, my brother and I always helped my parents at home. This was the beginning of my interest in horticultural plants. Every five years in Ghent, there was a famous flower exposition and show – the Ghent Floralies – which is known throughout the world. Many countries participate in this flower show. I helped to make these shows possible. I have published papers on plant substrates in the book of the Ghent Floralies. These flower shows encouraged me to work in studying flowers and plants.

3. Give a brief overview of your career/achievements.

After my basic studies of the humanities, I chose to study to be an agricultural engineer at the University of Ghent. After five years, I graduated with an M.Sc. in agricultural engineering. Shortly after obtaining my diploma, I started working at the Laboratory of Soil Physics, Soil Conditioning and Horticultural Soil Science under the leadership of Professor Dr. Ir. M. De Boodt. In this laboratory, I became the head of the section horticultural soil science. In this research group we studied the substrates of different ornamental plants, such as begonias and azaleas. We used mainly peat based growing media. We were also interested in developing substitutes for peat as a planting medium. Products such as bark, green waste, and coconut fibres were introduced in this research. We collaborated with the Ministry of Agriculture, and specifically with Professor Ir. J. Van Onsem. From this research I made my doctoral thesis on "The chemical and physical properties of horticultural substrates."

I became a member of the International Society for Horticultural Science directly when I began my research at the university in 1968. When I was looking for literature, I came across the publications of *Acta Horticulturae*, which gave me an overview of all kinds of interesting research in substrates.

The first symposium I participated in was from the International Society of Soilless Culture. There, I made many contacts with different researchers who were studying growing media. Shortly after this symposium we organized a symposium "Peat in Horticulture," which was hosted at the University of Ghent, Belgium, in 1971.

Later, we organized several symposia on composting of agricultural wastes, the use of bark compost as a growing medium for ornamental plants, and the use of green compost in substrates.

With our experience in physical properties of substrates and in composting of organic wastes, I was asked to become a docent at the International Agricultural Center in Wageningen (The Netherlands) on the course of vegetable growing. I presented the following courses:

- Chemical and physical properties of substrates;
- Composting of organic wastes (bark, green waste and others);
- The use of inert materials in substrates;
- Utilization of composted bark waste and coconut fibres in growing media.

The study of the utilization of bark was very successful. This study was a demand of the papermills because they have a large quantity of bark waste. In order to study these wastes, we built a composting simulator in which we could change the different properties. The important properties we were looking for were moisture content, nitrogen availability, phosphorus, calcium, temperature and oxygen content.

After testing the bark compost with plant trials, we demonstrated equivalent results of our alternative growing media as with the traditional soil media. In practice, we see now that a lot of growing medium factories use bark composts in their professional substrates not only in Belgium, but in many other countries.

In our research, we also studied the use of coconut fibre in Sri Lanka. This study was begun by a question from a nursery that liked to cultivate ornamental plants. I traveled to Sri Lanka in 1980 and 1982. We tried to collect any and all kinds of materials that could be used in a growing medium. In some parts of this country, we saw many waste deposits of coconut fibres. At that time, nursery people did not like to use coconut fibre because of toxic products that were present. We transformed these materials through composting with lime and nitrogen. The transformed wastes were studied and we saw that this material had good physical and chemical properties. We performed growth trials in local greenhouses in Sri Lanka. Now, coconut fibres are used as a growing medium in many countries.

4. What do you consider to be your greatest achievements?

Between 1982-1994 and 1999-2006, I was Chair of ISHS Commission Plant Substrates and oversaw its working groups. In this function, we started collaborating with the International Society on Hydroculture. Later on, ISHS Commission Plant Substrates was transformed into ISHS Commission Plant Substrates and Soilless Culture.

Subsequently, we started collaborating with Commission IV of the International Peatland Society (IPS). Several symposia were jointly organized. The symposia that we managed were greatly successful because all of the interested researchers and private firms worked together. All the information of these symposia are published in *Acta Horticulturae*.

In 1994, there was a re-organisation of the ISHS during the International Horticultural Congress in Kyoto, Japan. The Board of the ISHS nominated me to take the responsibility of the Secretariat as Executive Director for a short period, until Ir. J. Van Assche assumed that position in 1995.

After my period of research at the university, I collaborated with the industry as consultant for more than 10 years. In this function, I controlled the quality of substrates that were produced in Belgium. In this period, I participated in almost all of the symposia dealing with growing media. I also visited a lot of nurseries where the substrates were tested and optimized for the culture of ornamental plants.

5. Did you encounter difficulties along your career path and how did you deal with them or how did you turn them into opportunities?

One challenge in my career was that I worked on a limited contract basis (6-month or 1-year assignments). Through our successful research, private industry developed a great interest in our projects and results. They asked me if I would be willing to perform contract work for them in this area. In this job, I was able to concentrate further on the research problem for optimal growing media for different ornamental plants.

6. Tell us about one funny/exciting/interesting experience that happened to you during your career.

During my stay in Sri Lanka, I was looking for products that could be used in substrates. They were particularly looking for substrates that they could use for growing *Pelargonium* and *Petunia*. They were planning to start the production of these plants from seeds. In this country, we found a large quantity of coconut fibers that were not being used. We asked the local producers why they were not using these waste products on their fields of pineapple production. The producers told us that these wastes were toxic. The pineapples became yellow and died after a short time. During our research on these coconut fibers, we learned that together with fertilizers, the pH decreased enormously: to 1! From our study we learned that the complex coconut fibers were saturated with hydrogen ions that became released after the addition of the fertilizer. A saturation with lime before using the coconut fibers as a growing medium solved this problem. Now coconut fibers are used as an ideal growing medium for ornamental plants.

7. What made you become a member of ISHS and why did you keep the membership? What contribution or role has ISHS played in your career?

Membership in the ISHS was very important to me. The opportunity for participation in the symposia of ISHS Commission Plant Substrates provided information for my research on substrates. After several contacts with the participants, we became friends and remained in contact for many years. Therefore, I keep my membership in the ISHS so that we can follow their research.

› ISHS Executive Committee meeting, Montpellier, France, 1995. From left to right: Dr. C. Brickell, Dr. W. Simpson and Dr. O. Verdonck.

8. What advice would you give to young people interested in a career in horticulture/horticultural science?

The *Acta Horticulturae* publication series are a good reference for any scientists researching growing medium. These references provide information from recent studies and can help for future studies on substrates.

9. What are the most interesting new roles or opportunities you see emerging in the future within horticultural science?

For the future we have to find substitutes for peat based growing media. Growing media should be changed to peat-free substrates. Some new ideas suggest using a large amount of organic green waste or other waste. If we can incorporate these substances, we will reduce a problem and find a positive use. Further research should study this possibility.

› ISHS Board 1994-1998. From left to right: Dr. J.V. Possingham, Prof. Dr. A.A. Monteiro, Dr. C.D. Brickell, Prof. Dr. S. Sansavini, Dr. R.H. Zimmerman, Prof. Dr. K. Verhoeff and Dr. O. Verdonck.

The Culinary Breeding Network: building community among breeders, farmers, chefs and eaters to create better varieties for all – novel opportunities for research, extension, and education

Lane Selman

In the mid-2000s, I was hired to work on a participatory organic potato project at Oregon State University (OSU), Corvallis, Oregon, USA. I worked as part of the research team during the week, but I moonlighted doing marketing and sales for a local organic farm on weekends. The farm sold mostly at farmers markets, and I was their manager for the largest market in Portland (the most populated city in Oregon), which attracted many professional chefs buying produce for their restaurants.

For the first time, I had a foot in two different worlds. One was working in research, which rightfully prioritized issues faced by growers. The other involved the real life of the farmer, who in addition to production challenges also had to worry about marketing and sales. When working at the farmers market, I was asked repeatedly "what do these tomatoes taste like?" or "which one of these potatoes is the best for roasting?" The questions came from seemingly everyone: moms making family dinners, millennial college students testing recipes from the latest issue of Bon Appétit, and especially restaurant chefs.

It became clear that there was a priority in these local and organic markets for flavor. Better flavor and eating quality were expected by buyers and eaters, especially if they were paying a higher price. Over the last two decades, the local and organic movement in the United States has grown tremendously, particularly in the Pacific Northwestern US and California regions. Likewise, public sector programs, independent seed companies, and farmer-breeders have rapidly expanded across the country. With so many brilliant and vibrant actors, a market priority for superior flavor, and the continued need for regionally and organically adapted varieties, the stage was set for the formation of the Culinary Breeding Network (CBN).

The CBN is an initiative that I created to improve communication between plant breeders, seed growers, farmers, chefs, produce buyers and other stakeholders engaged in developing and identifying varieties and traits of culinary excellence for vegetables and grains. Celebrating ten years since its inception this year, the CBN strives to bridge the gap between plant breeders and eaters by creating unique opportunities for stakeholders to see and taste in-development vegetable and grain cultivars. Everyone in the local food system can share their opinions and be a participant in variety development. Through these events and gatherings, plant breeders gain valuable input that would normally be inaccessible. Inviting chefs, farmers, everyday eaters, and other end-users into the breeding process gives breeders insight into preferred traits and the chance to identify standout material while simultaneously increasing public awareness and understanding of organic plant breeding.

A simple sweet roasting pepper flavor evaluation led to the creation of the CBN. I organized a tasting to evaluate flavor, texture and appearance of several peppers that had been trialed on various organic farms in Oregon. Frank Morton, owner of Wild Garden Seeds (Philomath, Oregon, USA) was breeding open-pollinated replacement options for a popular hybrid corno di toro pepper being phased out by its owner. When chefs were presented with nine cultivars, including four from Morton, they quickly identified a preferred architecture for the pepper shoulders that were rounded with straight walls rather than "sunken" tops. This seemingly small morphological difference creates less kitchen waste and less processing time in the kitchen. It was the chefs who work intimately with the fruits that identified this possibly overlooked trait. It occurred to me then that these outreach events could be used as selection opportunities in breeding projects. The following year, I convened 30 chefs and farmers to take part in a selection event for OSU breeder Jim Myers' mild habanero breeding project. Participants tasted and evaluated different breeding lines and selected preferred phenotypes including color, shape, size and flavor. The results have guided Myers' pepper breeding trajectory. This low-pungency *Capsicum chinense* pepper (on the cover of this *Chronica Horticulturae*), where I first implemented this community-sourced approach for input, is symbolic of the CBN initiation a decade ago.

Admittedly, the focus is often on the research and education opportunities afforded by CBN events, but importantly farmers and seed companies also see benefits. Frank Morton says, "publicity from CBN's Variety Showcase event has increased our pepper seed sales more than 500%." Local farmers have also

contracted with chefs and food businesses to grow specific varieties, which creates new market relationships and opportunities.

I am frequently asked to write or talk about how CBN works, and it always brings pause. It feels like people want a formula or an outline to follow, but truthfully each event is different, and there certainly is no formula. In many ways, CBN's success comes down to meaningful relationships that have been cultivated over time, and it takes a certain personality to bring everyone to the table. Nonetheless, what I have tried to do here is describe some of CBN's most popular events and the philosophy behind them in the hopes that somebody somewhere gets inspired.

Culinary Breeding Network

In many instances the CBN acts as the outreach arm of grant-funded university-led research projects. In this role I find myself performing the following tasks:

- building a sense of community within research projects;
- identifying and creating relationships with stakeholders and potential collaborations;
- developing marketing campaigns for vegetables and grains;
- creating engagement with stakeholders and the greater public through interactive events and activities.

These public facing events are what CBN is most known for. In addition to knowledge exchange, they are meant to build community and inspire collaboration.

Event: Variety Showcase

Variety Showcase events are designed to build community among plant breeders, seed growers, farmers, chefs, produce buyers, consumers and more. Participating chefs are partnered with a plant breeder, and the pair work together to create a unique dish that features a specific variety. Breeders who participate in the Variety Showcase work for large seed companies (e.g., Vitalis, Bejo, Johnny's, High Mowing), small seed companies (e.g., Wild Garden, Adaptive, Uprising), the public sector (e.g., University Wisconsin-Madison, Cornell University, OSU, Washington State University), and independently. Featured varieties are usually new or upcoming releases, something that stands out in trialing, or an otherwise novel population. For example, at the 2017 Variety Showcase, different varieties of downy mildew resistant basil were turned into syrup for shaved ice. Other crowd favorites have included aji pepper and vanilla foam, and 'Blue-Eyed Blonde' sweet corn ice cream with chipotle caramel sauce.

The last in-person Variety Showcase (February 2020) included 40 breeder/researcher/chef tables, three special interactive educational exhibits (including an art show of Renaissance paintings portraying vegetables of the past), and a total of 130 participating breeders, researchers, farmers, and chefs. The event also featured numerous OSU research projects including Northern Organic Vegetable Improvement Collaborative (NOVIC), the Dry Farming Collaborative, Multi-Use Barley, Blueberries and more, thereby creating novel opportunities for extension, outreach and education across disciplines and university departments.

Typically, attendees are charged a moderate admission price, which helps pay for space rental, supplies, and participants' time. Attendees get to wander around the event, going from table to table and sampling the culinary treats prepared by chefs and immerse themselves in art or educational exhibits. For many, this is the first time they are hearing about plant breeding, let alone meeting a plant breeder, so the Variety Showcase exposes an ordinarily invisible part of the food and farming system. Dr. Bill Tracy, Professor at University of Wisconsin-Madison and Clif Bar/Organic Valley Chair in Plant Breeding for Organic Agriculture, says, "the Variety Showcase event is creating new opportunities for farmers, restaurateurs and consumers. The excitement about plant breeders' work because of this event is at a level I have never experienced. It is really expanding and enlightening the greater public – a group most plant breeders have little success reaching."

Professor Tracy isn't the only public breeder who has touted CBN's Variety Showcase either. OSU's Professor Jim Myers says that the Variety Showcase has become an "integral" part of his vegetable breeding program. "A vibrant [event], evolving cuisine and an exceptional creativity often result when melding breeders and chefs, and this is a unique catalyst for this process."

While the 2020 Variety Showcase (held in February) occurred before the onslaught of COVID-19, the 2021 event went virtual. For a week, 31 presenters from all over the world took the "stage" on YouTube giving 30- to 60-minute talks on a topic of their choice. Subjects ranged from beginning seed saving and plant breeding taught by the Organic Seed Alliance, to traditional techniques for blanching stalk celery in Lancaster County, Pennsylvania, to features of specific varieties like the beloved Palestinian gourd 'Yakteen' and the PanAmerican Seed new mini-Marzano tomato, 'Marzito.' Most presenters pre-recorded a 15- to 20-minute video, which was screened for the audience watching from home. The final 15 to 20 minutes saw the audience submit questions that were answered live. The virtual format allowed the event to reach the biggest audience yet (Table 1), and presenters joined from Austria, Belgium, the Middle East, and nearly every corner of the United States.

■ Table 1. Growth of CBN's annual Variety Showcase.

Year	Location	Attendees
2014	Portland, Oregon, USA	100
2015	Portland, Oregon, USA	210
2016	Portland, Oregon, USA	325
2017	Portland, Oregon, USA	540
2018	Oahu, Honolulu, Hawaii, USA	225
2018	New York City, New York, USA	250
2019	Oahu, Honolulu, Hawaii, USA	275
2020	Portland, Oregon, USA	700
2021	Virtual (CBN YouTube page)	181[a]

[a]Highest number of unique views for single presentation as of 12 April 2021.

Event: Sagre

Sagre are Italian celebrations of food, vegetables, and locality. I was inspired by these festivals while visiting Italy in 2014. There are nearly 30 thousand sagre in Italy annually – each one a proud salute to local traditions, community, and the food that brings people together. It seemed only fitting to bring the idea back to the US.

The first sagra CBN organized was in 2017 as part of a research project called "Eat Winter Squash." The research looked at long-storing varieties in Oregon state, where growers deal with a voracious storage rot pathogen. The sagra served as an opportunity for the community to meet the varieties that store well (often different than the ones people were familiar with) and learn how to cook, process, and enjoy them successfully. While the Variety Showcase events try to feature specific varieties, sagre are more about building community excitement around a vegetable crop in general and empowering people to cook them at home. Ideally, this translates into more sales for local farmers and more vegetable consumption for local eaters.

Table 2. History of CBN sagra events.

Year	Event	Location	Attendees
2017	Winter Squash Sagra	Portland, Oregon, USA	500
2018	Sagra del Radicchio	Seattle, Washington, USA	325
2018	Squash and Bean Sagra	Portland, Oregon, USA	500
2019	Sagra del Radicchio	Seattle, Washington, USA	350
2019	Winter Vegetable Sagra	Portland, Oregon, USA	1000
November 2020	RadTV	Virtual	1335
November 2020- March 2021	Virtual Winter Vegetable Sagra	Virtual	1.7K[a]

[a]Highest number of unique views for single presentation.

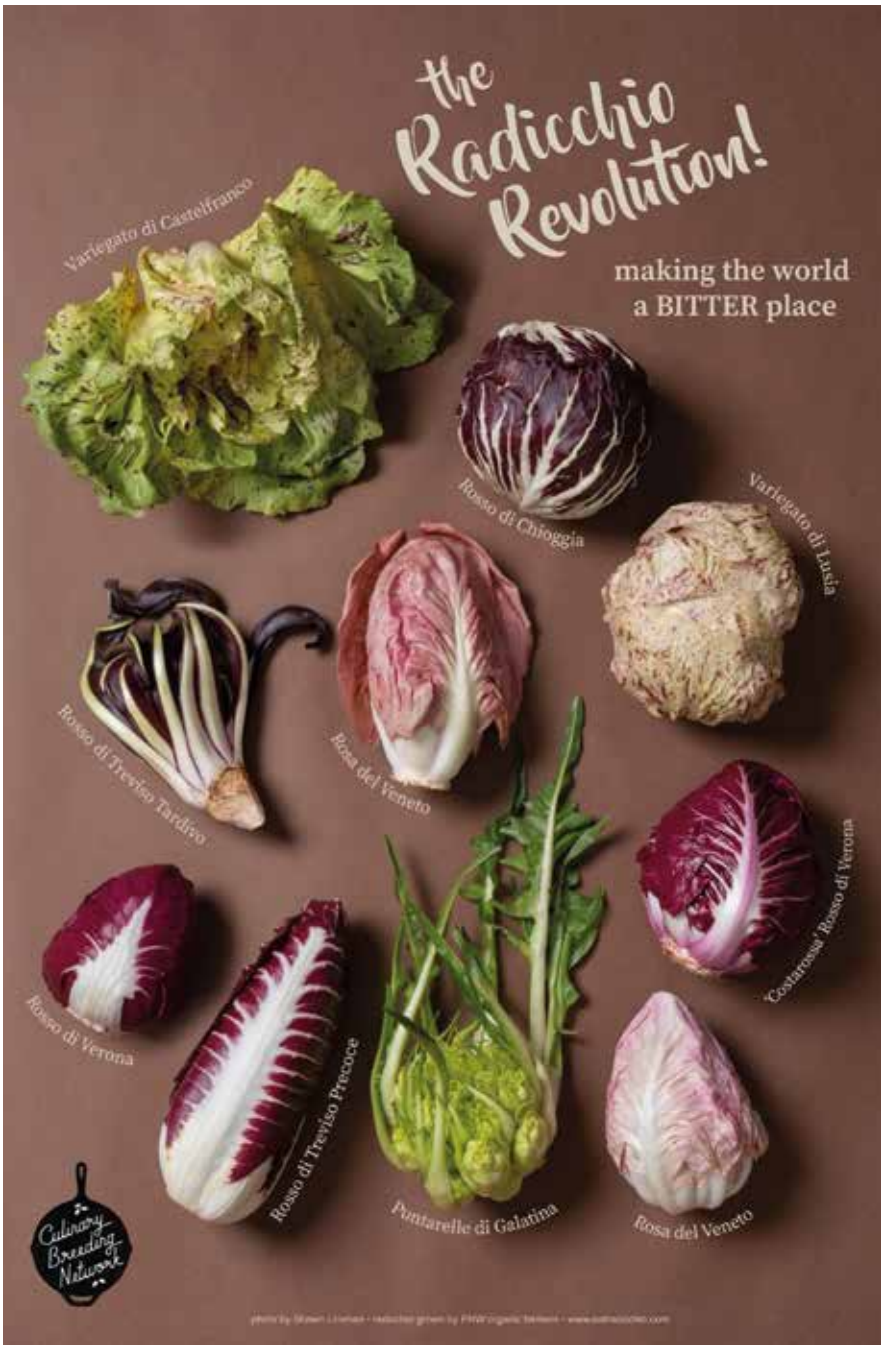


Figure 1. Radicchio poster designed by Lane Selman and photographer Shawn Linehan to educate consumers and farmers on the different types and proper nomenclature of radicchio.

Tables and activities for sagra events are slightly different than those at the Variety Showcase. For example, Tim Wastell, a chef in Portland, gave a live demonstration on "Squash Butchery" to help consumers become more comfortable and safer when breaking down large squashes at home. We have also seen success partnering sagra events with local non-profits like Friends of Family Farmers who host an annual Fill Your Pantry sale. By combining and collaborating on the two events, local farmers sold over $87,000 USD in locally grown produce, a 45% increase over previous years.

The success of early sagra events for winter squash and radicchio was obvious to the farmers and chefs who participated. This motivated further expansion and incorporating more crops that grew well in the region but were not necessarily exciting for consumers. In 2019, the Eat Winter Squash project became Eat Winter Vegetables to ultimately include squash, radicchio, garlic, collard greens, purple sprouting broccoli, cabbage, cauliflower, and celeriac (eatwintervegetables.com).

Another difference between Variety Showcase and sagra events is that the latter seek to make new connections for attendees. Variety Showcase really focuses on plant breeding and its effect on flavor, but sagre are meant to be more encompassing. We know that people (especially Americans) eat for affective reasons, so opportunities to taste things are important. But people also seek out particular foods for other reasons too, like health or cultural significance. During Garlic Week at the 2020 Virtual Winter Vegetable Sagra, a folk herbalist regaled the audience with myths, legends, and folktales focused on the wondrously pungent allium. It gave people new connections and new reasons to go out and seek more garlic.

Marketing campaigns

CBN also performs many marketing functions to promote research projects and specific vegetables or grains. Activities include:

- collaboration with artists and photographers to create project identity and posters. Example of radicchio photo by Shawn Linehan (Figure 1);
- creation of educational content to increase consumer interest including crop histories, origins and domestication; medicinal and nutritional information; specific varieties of interest and their attributes; cooking recommendations and recipes; art and folklore;
- promotion through the CBN Instagram account (›23k followers) with national and international reach;
- development of vegetable and grain zines (small books) to educate consumers;
- public relations duties by making media contacts aware of research projects and outreach events and pitching journalists with stories;
- execution of virtual events broadcast live through the CBN YouTube channel with ›1,300 subscribers and ›25,000 unique views.

Examples of these marketing campaigns include Eat Winter Vegetables (www.eatwintervegetables.com) and Chicory Week (www.chicoryweek.com).

Inspiration to others

I am pleased and motivated by the amount of attention this work has received. Flatteringly, CBN has inspired others to develop similar initiatives and events. For example, the Seed to Kitchen Collaborative's (Madison, Wisconsin, USA) annual Farm to Flavor event is inspired by the Variety Showcase. "We have really tried to learn from what CBN is doing for outreach and education. Lane really has a gift for communicating what is important to food professionals and the public. I think that is why CBN has had such an impact, and the importance of this outreach step is often one that scientists underestimate," says Dr. Julie Dawson, Professor at University of Wisconsin-Madison. Johnny's Selected Seeds (Maine, USA) credits CBN as the inspiration for their Northeast Seed-to-Table Initiative (NESTI), and CBN has even stimulated international initiatives at the University of British Columbia and Agricola Azienda Foradori (Mezzolomardo, Italy).

To learn more, please visit www.culinarybreedingnetwork.com and follow us on Instagram. In summary, I encourage university faculty and extension personnel to step outside the box when designing outreach events and programming and partner with people who have complementary skillsets. It is high priority that an event be interesting and fun if it is to be successful, memorable, and engaging. Personally, I think event attendance, stakeholder feedback, and CBN's current projects support that claim too.

In short, joy is at the root of all CBN activities. Embrace it!

› Lane Selman

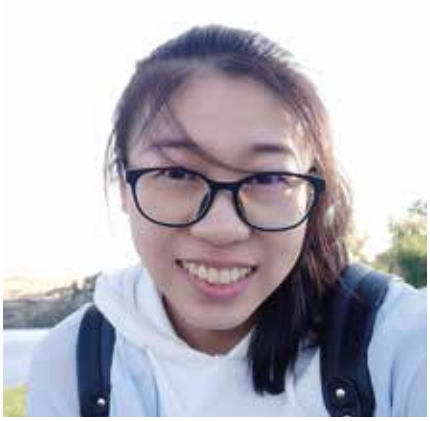
› About the author

Lane Selman grew up on a citrus farm that her Sicilian great-grandparents planted in 1919 on Florida's space coast in the USA. She studied Agronomy (BS) and Entomology (MS) at the University of Florida before moving to Oregon in 2000. Lane is an Assistant Professor of Practice at Oregon State University where she has worked with organic vegetable and grain farmers, managed collaborative research projects, and planned outreach events for over 15 years. In 2011, Lane created the Culinary Breeding Network to build communities of plant breeders, seed growers, farmers, produce buyers, chefs and other stakeholders to improve quality in vegetables and grains. She currently serves on the Portland-Bologna Sister City Association board. Lane loves a sagra; read more about that in her Medium article: https://tinyurl.com/ItalianSagraInspiredCBN. E-mail: lane.selman@oregonstate.edu

› ISHS Young Minds Award winner summaries

Below is a selection of research summaries from winners of ISHS Young Minds Awards for best oral and poster presentations at ISHS symposia. To view other exciting research summaries by other winners, please visit www.ishs.org/young-minds-award.

Molecular mechanisms of cold acclimation in overwintering azaleas



› Bing Liu

Bing Liu is a postdoc in Ornamental Horticulture at the Department of Horticulture in Zhejiang University, China. She graduated with a Ph.D. in philosophy from the same university. During her studies as a graduate student, she worked for two years with Dr. Rajeev Arora at Iowa State University, on the photoprotective strategies employed by evergreen rhododendrons. Currently, her research explores the molecular mechanisms of cold acclimation in overwintering azaleas via RNA-seq. Obtaining maximum mid-winter freezing tolerance through full cold acclimation (CA) is key for winter survival of wintergreen shrubs, especially in winter when air temperatures are increasing and unseasonably warm temperatures are frequent. Though mechanisms of CA in woody perennials have been mostly studied in environmental chambers, Bing determined that artificial CAs had limitations to understand the field full CA. Bing compared field and artificial CAs in *Rhododendron* 'Elsie Lee'. The light signals, such as changes in photoperiod, light intensity, and light quality in autumn could induce the accumulations of abscisic acid (ABA) and jasmonic acid (JA). This would activate the ABA and JA signal transductions before the occurrence of low temperatures, while light conditions in the chamber were constant. The photoprotection-related pathways were only enriched in the field CA, and the significant upregulated differentially expressed genes (DEGs), like *HY5*, in the circadian rhythm of the plants in the field CA showed no change in artificial CAs. Although carbon metabolism was commonly enriched in both field and artificial CAs, DEGs in the carbon metabolism pathway were mostly upregulated in the field CA, but downregulated in artificial CAs. Furthermore, ABA and JA contents in overwintering leaves gradually decreased from autumn to winter. The cause of this unusual finding may be due to zeaxanthin and unsaturated fatty acids. Zeaxanthin biosynthesis and unsaturated fatty acids metabolism are upstream of ABA and JA biosynthesis.

Bing Liu won the ISHS Young Minds Award for the best oral presentation at the IV International Symposium on Woody Ornamentals of the Temperate Zone, which was held virtually in Italy in March 2021.

› Contact

Bing Liu, Department of Horticulture, Zhejiang University, 866 Yuhangtang Road, Zhejiang 310058, P.R. China, e-mail: binger@zju.edu.cn

Plant virus causing variegation in *Camellia*

› Kento Terada

Variegation in *Camellia japonica* flowers, so called "Fuiri" in Japanese, is identified as a white pattern in a red background. The margin of the pigmented area is unclear. This condition could be caused by a plant virus because the symptom can be transmitted to other individuals through grafting. But, until now, a causal virus had not been associated with the "Fuiri" symptoms. Our objective was to determine if this variegation was caused by a plant virus. We performed a bioassay and an isolation of double-stranded RNA (dsRNA). Sap inoculation on *Nicotiana benthamiana* is a rapid and efficient way to diagnose virus presence. Seven variegated *Camellia* cultivars were examined. Samples of two cultivars, 'Hagoromo' and 'Kumagai', induced chlorosis and necrotic spots in the indicator; another cultivar, 'Shokko-nishiki', induced necrotic spots and stunt. These different symptoms likely indicated that two or more viruses were present in these *Camellia* cultivars. Many plant viruses are known to produce dsRNA during the process of replication. We extracted dsRNA from the *N. benthamiana* inoculated by variegated 'Shokko-nishiki' using dsRNA binding protein. A dsRNA bigger than 1.5 kbp was obtained. These results indicated the existence of plant viruses in these variegated *Camellia* cultivars. Our RNA-Seq analysis is ongoing to identify the candidate virus from this sample.

Kento Terada won the ISHS Young Minds Award for the best poster at the IV International Symposium on Woody Ornamentals of the Temperate Zone, which was held virtually in Italy in March 2021.

› Contact

Kento Terada, Botanical Gardens, Graduate School of Science, Osaka City University, Osaka 576-0004, Japan, e-mail: d21sc004@jf.osaka-cu.ac.jp

Phytoextraction of mercury-contaminated soils using legumes

› Nadine Sommer

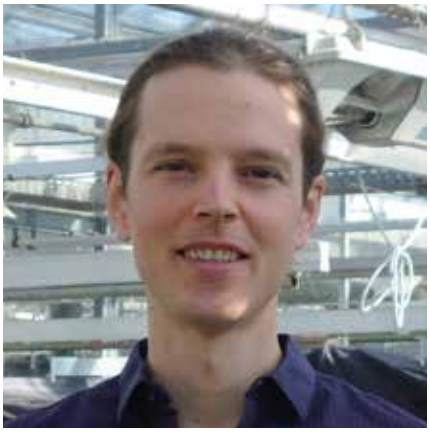
Nadine Sommer is a PhD Student at the University of Hohenheim in Stuttgart, Germany. Her research focuses on the identification of mercury (Hg) tolerant plant species that are able to remediate soil by accumulating this heavy metal in their plant biomass. In Ghana, many soils are heavily contaminated with mercury, which is widely used in the amalgamation process of mining gold. Phytoremediation depends on the ion-accumulation capacity of plants. Hyperaccumulator plants can absorb high metal concentrations without visible or physiological symptoms. Until now, no Hg-hyperaccumulator has been reported. For this research, the indigenous legumes *Acacia mangium, Leucaena leucocephala, Mimosa Pudica* and *Senna siamea* and the crucifers *Moringa oleifera* and *Brassica juncea* were chosen. *Brassica juncea* was selected as reference plant because it is well-studied and is a known Hg-accumulator. To evaluate the physiological reactions of the experimental plants to mercury exposure, carbon assimilation and biomass production of the plants were measured. The experiment was conducted in containers in a greenhouse. Mercury (10 mg kg^{-1}) was applied as mercury chloride ($HgCl_2$) when plants were about 10 weeks old. Sixteen days after mercury exposure, plants were harvested, and mercury concentration was measured in the above ground biomass. The results showed no significant influence of the mercury concentration on the examined species under the tested conditions. Neither biomass production nor assimilation rate was significantly affected by the mercury treatment. Each of the examined plant species accumulated mercury in their above ground biomass with particularly high values found in shoots (46.45 mg kg^{-1}) and leaves (46.45 mg kg^{-1}) of *S. siamea* followed by leaves (42.2 mg kg^{-1}) and shoots (28.85 mg kg^{-1}) of *A. mangium*. Because these two plant species accumulated these high concentrations of mercury without observed symptoms, they may be candidates for phytoremediation of Hg contaminated soils in Ghana.

Nadine Sommer won the ISHS Prof. Jens Wünsche Young Minds Award for the best oral presentation at the IV International Symposium on Horticulture in Europe (SHE2021), which was held virtually in Germany in March 2021.

› Contact

Nadine Sommer, University of Hohenheim, Dept. of Crop Physiology of Specialty Crops, Emil-Wolff-Str. 23, 70599 Stuttgart, Germany, e-mail: nadine.sommer@uni-hohenheim.de

Determination of ammonia exposure of potted herbs in organic cultivation



› Christian Frerichs

Christian Frerichs is a PhD student at the Osnabrück University of Applied Science, Germany, supervised by Prof. Diemo Daum as well as Prof. Gabrielle Broll from the Osnabrück University. His research focuses on strategies to reduce the risk of nitrogen losses by ammonia volatilization and nitrate leaching in vegetable production. To assess this, he has conducted a series of fertilizer and field management trials with basil (*Ocimum basilicum* L.) in the greenhouse, as well as field-grown spinach (*Spinacia oleracea* L.). In the poster presentation entitled "Determination of ammonia exposure of potted herbs in organic cultivation", he described an easy-to-use measuring system for the detection of gaseous ammonia in greenhouse pot plant production. In organic cultivation of pot-grown herbs particularly, ammonium concentrations and substrate pH may temporarily increase, which facilitates ammonia volatilization. Basil growth can be inhibited and plant damage can occur under such substrate conditions. The objective of this project was to distinguish the effect of both ammonical nitrogen species (ammonium and ammonia) on plant performance. An open top chamber approach was developed and evaluated. The results show that when ammonia concentrations were above 0.2 ppm, the open top chamber measurements corresponded with data from passive samplers as well as calculated concentrations based on known substrate equilibrium and air temperature. In this way, Christian used the new approach to compare different substrate storage and fertilization treatments that can reduce ammonical nitrogen exposure in pot-grown basil production. However, plants were affected at concentrations below 0.2 ppm ammonia. Therefore, the sensitivity of the new approach has to be improved in the lower concentration range.

Christian Frerichs won the ISHS Prof. Jens Wünsche Young Minds Award for the best poster at the IV International Symposium on Horticulture in Europe (SHE2021), which was held virtually in Germany in March 2021.

› Contact

Christian Frerichs, Osnabrück University of Applied Science, Am Krümpel 31, 49090 Osnabrück, Germany, e-mail: c.frerichs@hs-osnabrueck.de

Consumer behavior analysis for apples biofortified with selenium and the implications for conducting a market test in German food retailing

› Ruth Kleine-Kalmer

Ruth Kleine-Kalmer is a PhD candidate in the field of agricultural marketing under the supervision of Prof. Dr. Ulrich Enneking. In her cooperative PhD at the Osnabrück University of Applied Sciences and the University of Göttingen, she focuses on future challenges of food innovations taking into consideration global megatrends. Under the leadership of Prof. Dr. Diemo Daum, her research focused on consumer acceptance of a newly developed apple that was enriched with selenium via biofortification. The study included two quantitative online consumer surveys and a subsequent market sales test in three German supermarkets. The results were applied to design a marketable apple product, which was named Selstar®. First, the most popular apple varieties, health benefits of selenium, and the respondent preferences for the name of the new apple were measured. Second, the results of a nationwide consumer survey indicated that a large share of the German respondents were unsure of what selenium was, and what its impact was on human health. Consumers stated their high preference for locally produced apples and plastic-free packaging. Consequently, the product package for this project was made solely of cardboard. The package was imprinted with information about the health benefits of selenium for the immune system and the product's local origin of "Altes Land". In the market sales test, all units of Selstar® were sold and accounted for 5-6% of all apple sales during the test period.

Ruth Kleine-Kalmer won the ISHS Prof. Jens Wünsche Young Minds Award for the best oral presentation at the VIII International Symposium on Human Health Effects of Fruits and Vegetables (FAVHEALTH2021), which was held virtually in Germany in March 2021.

› Contact

Ruth Kleine-Kalmer, Osnabrück University of Applied Sciences, Oldenburger Landstraße 62, 49090 Osnabrück, Germany, e-mail: r.kleine-kalmer@hs-osnabrueck.de

Innovative, sustainable practices to enhance quality and yield of tomato and pepper, main solanaceous fruit crops

› Bonga Ngcobo

Bonga Ngcobo is a senior PhD student at the University of KwaZulu-Natal (UKZN), Pietermaritzburg, South Africa, in the Discipline of Horticultural Science. He holds a BSc Agric and Masters (*cum laude*) from the same University. Currently he is in the final stages of his doctoral studies under the supervision of Professor Isa Bertling and Dr. Alistair Clulow. Bonga's research focuses on using innovative and environmentally friendly treatments, such as LEDs, moringa, and heat treatment, to enhance growth, yield and nutritional quality of solanaceous (nightshade) crops. Bonga has published several articles in peer reviewed journals as well as in conference proceedings. The objective of his current research on the quality of two solanaceous crops, tomato (*Solanum lycopersicum*) and pepper (*Capsicum annuum*), is to enhance health-related compounds, such as lycopene, β-carotene, capsanthin, capsorubin, and vitamin C in the fruit. Bonga evaluated the effect of combining moringa leaf powder (MLP) and synthetic fertilisers to improve growth and yield parameters, as well as nutritional quality, of tomatoes and peppers. His study revealed that the use of chemical fertilisers can be partly reduced by incorporating MLP and chemical fertilisers. He further evaluated the effect of various solvents used to produce moringa leaf extracts. These solvents included hot water, cold water, and chemical solvents. The effect of foliar moringa application on growth, yield and quality of tomato and pepper fruit was studied. The study revealed that moringa leaf extraction with hot water has the potential to replace chemical-based solvents. Apart from the use of the biostimulant moringa, Bonga also evaluated the postharvest effects of combining heat treatments, particularly hot water treatment, and LEDs on the quality and colour of cherry tomatoes. His study demonstrates that combined effects of white LED light and HWT for 1 min is a promising postharvest treatment to enhance shelf-life and quality of solanaceous fruit crops.

Bonga Ngcobo won the ISHS Prof. Jens Wünsche Young Minds Award for the best poster at the VIII International Symposium on Human Health Effects of Fruits and Vegetables (FAVHEALTH2021), which was held virtually in Germany in March 2021. We are pleased to note that this is Bonga's second ISHS Young Minds Award. He was also recognized for the best poster at the II International Symposium on Moringa in 2019.

› Contact

Mr. Bonga Ngcobo, Horticultural Science, University of KwaZulu-Natal, 22 Scottsville Rd, Pietermaritzburg, South Africa, e-mail: bongalewisfuze@gmail.com, 213516834@stu.ukzn.ac.za

Genetic variations within the hop promoter genes for bitter acid and flavonoid biosynthesis partly explain phenotypic cultivar diversity

› Pauline Seeburger

Pauline Seeburger is a BSc student at the University of Hohenheim in Stuttgart, Germany. Her research examines the role of regulatory elements of biosynthesis genes for the production of secondary metabolites in hop plants.

The hop plant is rich in secondary metabolites of which the bitter acids are essential for the characteristic taste of beer. Bitter acids are produced in the glands of the female hop flower (cone) through the bitter acid biosynthesis pathway. The biosynthesis relies on three key enzymes: valerophenone synthase, prenyltransferase 1, and prenyltransferase 2. Prenyltransferase 1 has a double function and is a key element of the biosynthesis of the pharmacologically interesting hop flavonoids, xanthohumol and 8-prenylnaringenin. The study aims to examine the genes and gene regulation of these important enzymes. Transcription factors have a known regulatory function for genes when binding to promoter elements. Thus, variations in the promoter elements alter the gene expression, and might be associated with the bitter acid concentration in the hop cone.

Promoter elements of the bitter acid biosynthesis genes and related pathways have been sequenced. Variations within these elements evoke different concentrations of bitter acids, especially the alpha acid, among hop varieties. The results showed that knowledge-based targeted sequencing is suitable for the identification of associations between variants in the genotype and phenotypic traits. Significant gene-trait associations were found in promoters of both prenyltransferase genes, and surprisingly, in a gene promotor from anthocyanin biosynthesis. In the long-term, the study of these promotors could be the basis for developing molecular markers to improve hop breeding strategies to reduce the time and cost to create new varieties with high alpha acid content.

Pauline Seeburger won the ISHS Prof. Jens Wünsche Young Minds Award for the best oral presentation at the V International Humulus Symposium, which was held virtually in Germany in March 2021.

› Contact

Pauline Seeburger, Department of Crop Physiology of Specialty Crops, University of Hohenheim, Emil-Wolff-Straße 23, 70599 Stuttgart, Germany, e-mail: pauline.seeburger@uni-hohenheim.de

Mapping the powdery mildew resistance locus R1

› Joshua Havill

Joshua Havill is a Ph.D. candidate in the Department of Agronomy and Plant Genetics at the University of Minnesota, USA. He previously completed his BSc in Horticultural Science in 2014, and his MSc in Plant Pathology in 2017, which were both also obtained from the University of Minnesota. Hop (*Humulus lupulus* L.) cultivation has rapidly expanded across North America, returning to historical production areas that were focal points of production. This expansion has also led to the subsequent return and dispersal of various hop pathogens such as hop powdery mildew, caused by *Podosphaera macularis* (Wallr.) U. Braun & S. Takam. Hop powdery mildew is the likely reason for the collapse of the northeastern US hop industry during the early 20th century. To combat these issues, disease resistant cultivars are commonly grown in combination with chemical and cultural practices. Hop breeding, like other perennial cropping systems, is laborious and time-consuming. The advent of marker-assisted selection has the capacity to increase throughput and decrease the evaluation period required to release cultivars. Given the laborious nature of hop breeding, combining and selecting on multiple phenotypes is an important breeding effort that can be improved via marker-assisted selection. Joshua's dissertation research aims to 1) dissect the genetic and evolutionary relationships of natural populations of *H. lupulus* and 2) to identify the genomic regions that confer resistance to the hop powdery mildew pathogen. A bi-parental population was developed between the resistant female 'Zenith' with the susceptible male breeding line USDA 21058M to address the second aim of his dissertation research. Progeny from this population were evaluated for their disease response following inoculation with a well-characterized *P. macularis* isolate to describe inheritance of the resistant phenotype. Subsequently, genotyping-by-sequencing was performed on both parents and progeny to identify single nucleotide polymorphisms (SNPs) useful for building a linkage map and downstream quantitative trait loci (QTL) analysis to isolate genomic regions controlling variation for this agronomically-important trait. Following QTL analysis, validation work was carried out by developing a competitive allele-specific polymerase chain reaction (PCR) (KASP™) assay useful for high-throughput marker-assisted selection, specifically for powdery mildew resistance conferred by 'Zenith'.

Joshua Havill won the ISHS Prof. Jens Wünsche Young Minds Award for the best poster at the V International Humulus Symposium, which was held virtually in Germany in March 2021.

› Contact

Mr. Joshua Havill, Department of Agronomy and Plant Genetics, University of Minnesota, 411 Borlaug Hall, 1991 Upper Buford Circle, St. Paul, MN 55108, USA, e-mail: havil008@umn.edu

Microorganisms in aquaponics: insights on their functions and the potential modifications of their communities over the course of a full lettuce growth cycle

› Mathilde Eck

Mathilde Eck is a PhD student at Gembloux Agro-Bio Tech, University of Liège, Belgium, under the supervision of Prof. Haïssam Jijakli. Her thesis focuses on the study of microorganisms in aquaponics and their roles in nutrient cycles and plant growth promotion. Indeed, a better knowledge of the microbial processes in aquaponics could help foster the development of more sustainable and viable systems. Hence, she has decided to hinge her PhD around two main themes, each composed of two specific questions.

The first theme tackles the description of the bacterial communities in aquaponics with a first question focused on what the aquaponics bacteria are and a second dealing with how they evolve throughout time in a given system. To answer that first question, she sampled ten different systems in northern Europe to compare their bacterial communities with the help of 16S rRNA sequencing. The main conclusions were that i) each system has its own community, and ii) despite this apparent diversity, a few common taxa could be observed in every system. These taxa belonged to families commonly found in freshwater but also in plant roots and surprisingly in soil. The second experiment was carried out on the closed-loop aquaponic system in Gembloux Agro-Bio Tech in which she followed the composition of the bacterial communities of the sump, the biofilter and the lettuce roots over the course of a lettuce growth cycle. It came out that each compartment harboured a specific community. Analysis of the evolution of each community is still going on.

The second theme deals with the plant beneficial functions present in the aquaponic bacterial communities and how they can impact lettuce growth. Thirty-one bacterial strains were therefore collected from the sump of our aquaponic system and grown in vitro and were then submitted to biochemical tests to assess their ability to solubilize phosphorus and potassium and to produce ammonia, siderophores and IAA. In vivo tests were next conducted in a controlled growth chamber to evaluate the impact of three strains of interest (presenting a combination of potentially beneficial functions) on lettuce yields. The data thus obtained are still under analysis.

Mathilde Eck won the ISHS Young Minds Award for the best oral presentation at the III International Symposium on Soilless Culture and Hydroponics: Innovation and Advanced Technology for Circular Horticulture, which was held virtually in Cyprus in March 2021.

› Contact

Mathilde Eck, Gembloux Agro-Bio Tech, University of Liège, Passage des Déportés 2, 5000 Gembloux, Belgium, e-mail: mathilde.eck@gmail.com

The world of Horticulture

Breeding the common bean for weevil resistance

James R. Myers, Paul M. Kusolwa and James S. Beaver

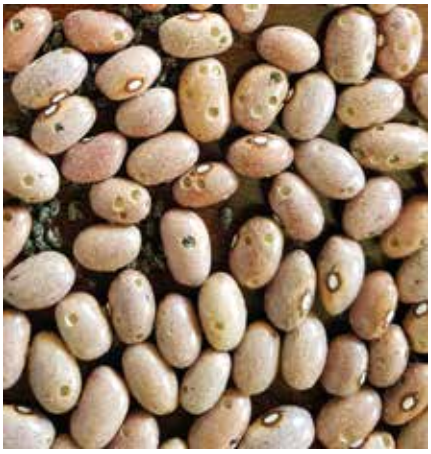


Figure 1. Bruchid or bean seed weevil damage to Kablanketi type dry beans grown in a field near Morogoro, Tanzania. Source: J.R. Myers.

Bruchids are specialized weevils that feed on legume seeds. These insects are a difficult problem for subsistence farmers who grow beans throughout the world but particularly in Africa. This article summarizes our three decade long, but successful, program to breed weevil resistance into the common bean.

What do bruchids do to beans?

Legumes are critical for the human food supply. Unfortunately, legumes also provide food for weevils, shelter for their eggs, and space for their larval development. The bruchids puncture the beans and lay their eggs. As the weevils grow, legume seed quality and viability become severely compromised (Figure 1). The seed perforations damage the embryo and create points of entry for pathogens. The culinary quality of the harvest is diminished. Globally, production losses in beans can be as high as 48% due to bruchids (Slumpa and Ampofo, 1991).

Problem of bean bruchids

Common bean (*Phaseolus vulgaris* L.) seeds are subject to predation by two main species of bruchids. These may be found worldwide in the tropics and subtropics, and sometimes in temperate climates, wherever dry and snap beans are grown. In pantropical areas, the pest may be a year-round problem. It often invades temperate zone bean production areas but usually does not persist beyond the growing season. Two main bruchid species are thought to have co-evolved with *Phaseolus* species: the common bean weevil (*Acanthoscelides obtectus* Say.), and the Mexican bean weevil (*Zabrotes subfasciatus* Boh.). In their natural state, the two bruchid species feed on wild common, tepary (*P. acutifolius* A. Gray), runner (*P. coccineus* L.) and lima (*P. lunatus* L.) beans. The two species are now distributed globally in nearly every bean producing region. Although both species can be found in the same region, they favor different climatic conditions (Abate and Ampofo, 1996). The Mexican bean weevil thrives under warmer temperatures found at lower elevations in the tropics, while the common bean weevil is better adapted to high altitudes with a cooler tropical climate coinciding with harvest time. While the former species only infests in storage, the common bean weevil initiates infestation in the field, which continues in storage. Because of their different life histories, beans stored in bruchid-proof containers are protected against Mexican bean weevil, but not the common bean weevil if it has already infested in the field. Based on its life cycle and climatic adaptation to bean producing areas, the common bean weevil is more widespread and presents a significantly greater threat to bean production than the Mexican bean weevil.

Smallholder farmers in developing countries limit the time that they keep their harvest to avoid losses due to these weevils. Many farmers sell the crop shortly after harvest when the prices are lowest, to avoid bruchid damage. Farmers who may already be food-insecure, also cope by not producing large quantities of seed during any one season for the fear of such postharvest losses. The presence of bruchids can cause significant market-price fluctuations during the year, leading to short periods of low-priced, high quantity beans shortly after harvest, interspersed by long periods of bruchid-infested low quantity, but expensive seeds. The period of low-quality supply can vary from three to six months in regions with bimodal rainfall, and six to eight months in unimodal rainfall areas.

Control methods

Subsistence farmers employ several strategies to control bean bruchids, including mixing and storing seeds with threshing residues, dust, and wood ashes. These materials pack into the interstitial spaces between seeds and restrict bruchid movement inside the storage containers. These compounds also irritate the adult bruchids and reduce egg laying potential. Frequent sun drying of bean seeds may be used because exposure of seeds to extreme warm and dry conditions inhibits bruchid development. Tumbling of storage containers causes damage to eggs laid on the surface of the bean seeds and disorients the larvae from penetrating the seed (Quentin et al., 1991) but is only practical and effective for the common bean weevil on small seed-lots of stored beans. Cold storage rooms can retard the developmental and reproductive activities of weevils where seeds are kept at 4-5°C, and freezing the seeds for 24 h at -10°C will kill the larvae. However, these methods are not feasible for low-income small-scale bean producers in tropical regions due to high cost of investment and operation, and unreliable power supplies.

The use of vegetable oils and botanical herbs provide a possible control measure (Schoonhoven, 1978; Mazzonetto and Vendramim, 2003). The mixtures can be combined with bean seeds prior to stocking the beans in storage warehouses. These plant products include leaf extracts of *Eucalyptus citriodora*, neem leaves or seeds (*Azadirachta indica* L.), tobacco leaves, leaves of coriander, *Chenopodium ambrosioides*, citrus rinds, and tephrosia (*Tephrosia* spp., a source of rotenone), which act as insecticides. Maize oil, soy oil and concentrated juice from banana plants appear to suffocate various insect stages and penetrate eggs thereby reducing bruchid fertility (Schoonhoven and Cardona, 1986; Baier and Webster, 1990; Slumpa and Ampofo, 1991).

Other local management strategies employ timely harvesting and use of airtight containers to minimize bruchid infestation before and during storage. Bean seeds may be fumigated and/or dusted with insecticides immediately after harvesting. Because chemical control of bruchids is costly and requires significant infrastructure, it is mainly practiced by large-scale farmers. These cultural and chemical control strategies also do not provide effective control of bean bruchids from one cropping season to another unless used

repeatedly. Treatments involving seed applications can be potentially hazardous to the health of workers, farmers and consumers.
A strategy that we have pursued is to breed dry bean cultivars with bruchid resistance, and we believe that this strategy combined with an integrated pest management approach is the best approach to mitigating postharvest losses.

Insect resistance via seed storage proteins

In legumes generally, and in common bean specifically, various seed storage proteins have evolved to act as feeding deterrents or antinutritional factors (Duarte et al., 2018). Some target invertebrates while others affect mammalian consumers. These include α-amylase inhibitors, trypsin inhibitors, phytohemagglutinins and arcelins. Several of these antinutritional factors are related to one another and form the α-amylase inhibitor - phytohemagglutinin - arcelin or complex APA locus. Some α-amylase inhibitors have a weak negative effect on bruchid development, but it is the arcelins that have evolved as the most effective toxins. Arcelins were first found in wild common bean accessions from Mexico, and do not exist in the cultivated gene pool. In the early use and cultivation of common bean, this trait was apparently lost during the genetic bottleneck phase of domestication. Arcelins and arcelin-like proteins are also found in wild relatives of common bean, including tepary bean. The eight alleles of arcelin in common bean likely represent a mutual arms race between the plant and insect. Some arcelins are more effective against one or the other bruchid species and vary in level of resistance that they provide. For example, *arcelin-1* is effective against Mexican bean weevil but not the common bean weevil. None of the alleles in common bean identified to date are particularly effective against the common bean weevil, but an arcelin-like protein found in tepary bean does confer high levels of resistance to both species.

Breeding for resistance

International Center for Tropical Agriculture (CIAT) researchers initially identified the highly bruchid resistant tepary bean accession G40199 (Figure 2), which increased adult mortality, reduced adult emergence, and prolonged larval developmental time (Shade et al., 1987). In 2003, we obtained this tepary bean and implemented a program to transfer bruchid resistance into the common bean (Mbogo et al., 2009). Tepary bean is in the secondary gene pool of common bean, and while they can be crossed, it is most successful with common bean as the female, and using embryo rescue to obtain viable F_1 hybrids. Another key to successfully making the cross is choosing a compatible common bean parent. We used 'ICA Pijao' (Figure 2) as the common bean parent, which had previously been demonstrated to have compatibility for crosses to tepary bean. After crossing and pod set, embryos were excised after about 20 days of seed development and cultured on a nutrient medium that supported further embryo development and eventual transition into plantlets that could be moved to the greenhouse, where they grew and flowered. The resulting hybrids were male sterile, but we obtained seed by backcrossing them as females to the common bean parent. The resistance factor in G40199 had not been characterized, but we were able to show that this accession possessed a novel arcelin-like protein of similar molecular weight to arcelins of common bean (Kusolwa and Myers, 2011). This marker was used to select for the tepary seed protein storage profile during further introgression of the trait into the common bean background. There may be additional alleles of interest in tepary bean, and Jim Beaver (University of Puerto Rico-Mayagüez [UPR]) and Tim Porch, USDA-ARS Research Geneticist, are currently screening the USDA-NPGS tepary bean collection for response to the common bean weevil. A genome wide association study is planned to better understand the genetics of bruchid resistance in tepary beans.

Figure 3. Map of Tanzania showing location of Sokoine University of Agriculture. Source: Wikimedia Commons, modified by J.R. Myers.

Germplasm development

After two backcrosses of the interspecific hybrids to the 'ICA Pijao' parent, these lines were crossed to 'Rojo' (Figure 2), a large, red-seeded cultivar developed by the Sokoine University of Agriculture (SUA) bean breeding

Figure 2. Seed of the parents used in crosses to introgress bruchid resistance from wild tepary bean into common bean. G40199 tepary bean (left), common bean 'ICA Pijao' (lower right) and 'Rojo' (upper right). G40199 and 'ICA Pijao' were provided by the CIAT genebank. 'Rojo' was provided by Susan Nchimbi-Msolla, bean breeder at SUA. Source: J.R. Myers.

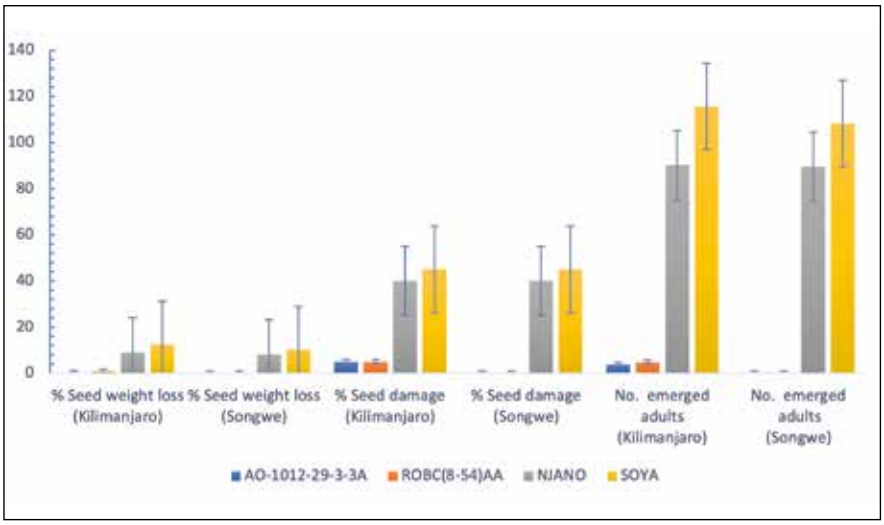


Figure 4. Performance of bruchid resistant bean lines compared to local check cultivars kept in storage by farmers in northern (Kilimanjaro) and southern (Songwe) agroecological zones in Tanzania. Error bars represent standard error.

Table 1. Development rate of immature stages of the major bruchid species on bruchid resistant and susceptible bean lines and cultivars.

Genotype	No. of days (larvae – adults)[a]		
	A. obtectus	*Z. subfasciatus*	Mean
AO-1012-29-3-3A	48a	39b	44a
ROBC(8-54)AA	42b	47a	45a
Njano[b]	28c	26c	27b
Soya[b]	28c	26c	27b

[a]Means followed by the same letter are not significantly different ($P \leq 0.05$).

[b]Susceptible farmer preferred landrace.

program (Figure 3) in Tanzania (Hillocks et al., 2006) to move the trait into large-seeded Andean types more preferred in Africa. Advanced lines from the 'ICA Pijao' and 'Rojo' crosses were tested for bruchid resistance, and we were able to show a substantial delay and significantly lower emergence for common bean weevil adults. The few adults that did emerge from arcelin-containing introgression lines were smaller and weighed half as much as normal adults. One of the most important lines from these crosses was ROBC(8-54)AA, which has been widely used in the SUA breeding program.

Advanced 'Rojo' backcross lines with resistance were provided to Jim Beaver's dry bean breeding program at UPR, where further screening for bruchid resistance was conducted as well as screening for bean common mosaic virus resistance. Selections from these efforts produced a red kidney germplasm line AO-1012-29-3-3A that was released in 2016 (Kusolwa et al., 2016).

The UPR Puerto Rican program has generated small-seeded black and larger-seeded Andean bean breeding lines that combine bruchid resistance with resistance to bean golden yellow mosaic and bean common mosaic necrosis viruses. These advanced generation lines are currently undergoing yield trials in Puerto Rico with the goal of deployment in Central America and the Caribbean. These lines have also been provided by Juan Osorno, US-principal investigator of the USAID funded Legume Systems Innovation Lab project, and his counterpart, Kelvin Kamfwa, University of Zambia. AO-1012-29-3-3A was used to map bruchid resistance loci (Kamfwa et al., 2018). This research identified novel genes for bruchid resistance and produced markers for molecular marker assisted breeding. Dr. Kamfwa leads the southern African region Legume Systems Innovation Lab project to introgress bruchid resistance using AO-1012-29-3-3A into various market classes in Zambia, Malawi and Mozambique. He has been advancing seven populations that are now in the F_5 generation.

In Tanzania, AO-1012-29-3-3A and ROBC(8-54)AA were evaluated in the laboratory and under farmers' storage conditions to validate bruchid resistance. Kusolwa's group at SUA demonstrated that the bruchid resistant lines were effective against both bruchid species and nearly doubled the number of days to adult emergence of the individual insects that did emerge (Table 1). In postharvest storage trials by farmers in northern and southern bean growing regions of Tanzania, they also saw that resistant lines had little seed damage, essentially no weight loss and few emerged adults compared to two susceptible check cultivars (Figure 4). Screening of a large set of African landraces and cultivars identified a set of Malawian lines that possessed novel sources of bruchid resistance (Maro, 2017) as well as having preferred seed types and disease resistance. ROBC(8-54)AA was crossed to the Malawian lines to develop bruchid and disease resistant grey-seeded Kablanketi and Njano (yellow-seeded) beans in addition to the 'Rojo' background (red-seeded) of the original germplasm line.

Cultivar release

Breeding efforts have produced three bruchid resistant releases from SUA to date. These are 'SUA-Red', a dark red large-seeded kidney bean, 'SUA-Karanga' (Figure 5), a light red kidney bean, and 'SUA-Rose', a red speckled kidney bean. These were identified and tested in field trials in the Tanzanian southern highlands near Mbeya, northern highlands in the Kilimanjaro region and eastern lowlands in Morogoro. The trials were conducted from 2014 to 2017 with five farmers from each village in each region hosting trial plots. These lines generally performed as well

Figure 5. Seed of 'SUA-Karanga' light red kidney type bruchid resistant cultivar released by Sokoine University, Tanzania in 2019. Source: J.R. Myers.

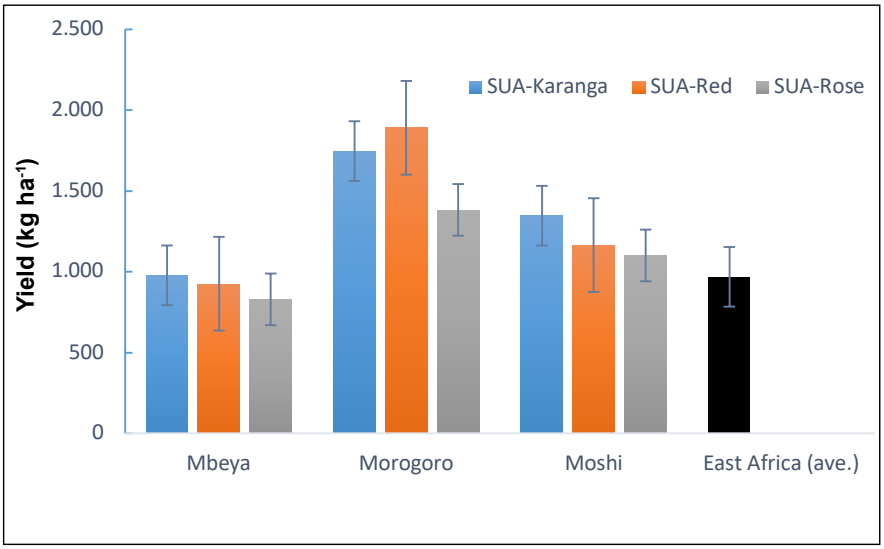


Figure 6. Mean yield of three bruchid resistant dry bean cultivars grown for three production seasons in north (Moshi), mid (Morogoro) and south (Mbeya) Tanzania in on-farm field trials. East African mean dry bean yield derived from FAOSTAT data for the same three production seasons. Error bars represent standard error.

Figure 7. Experimental bruchid resistant bean lines being distributed to farmers in Nambala village Mbozi district-Mbeya, Tanzania in April, 2020 for on-farm trials. Source: P. Kusolwa.

or better than the East African dry bean yield averages for those years (Figure 6). 'SUA-Karanga' ranked highest overall in yield, followed by 'SUA-Red' and 'SUA-Rose'. Another aspect of the program was breeding for disease resistance and all cultivars demonstrated resistance to common bacterial blight, angular leaf spot, *Bean common mosaic virus* (BCMV) and common bean rust based on field evaluation for disease symptoms. Yields were generally lower in Mbeya and in 2017 anthracnose and ascochyta blight defoliated bean plants. Additional resistance to these two diseases may be required for best adaptation to this region. In general, these varieties demonstrated very high adaptability to growing conditions across the test locations indicating that they could contribute to increased yields and bean productivity in the target bean growing communities, not only during the growing season, but in the postharvest season as well.

A farmer participatory approach was used in these trials to seek farmer input on the cultivars before proposing for release in the target locations (Figure 7). Overall, farmers ranked 'SUA-Karanga' as first, 'SUA-Rose' as second and 'SUA-Red' as third, but superior to existing unimproved cultivars. Farmers found these cultivars to be high yielding and adapted to their local growing conditions using minimal inputs. In addition to yield, farmers gave these cultivars high ranks based on resistance to bruchids and major foliar diseases, short cooking time, good taste, thick broth and good aroma. The combination of these traits into a single genetic package reduces uncertainties of crop production and unexpected crop failures. The addition of bruchid resistance may allow farmers to hold larger quantities of beans for their own use, thereby increasing food security. This trait may also allow farmers to wait to sell beans later in the offseason when prices are higher.

Bruchid resistance should not be regarded as the "magic bullet" to solve the problem of this stored product pest of common bean. While currently very effective, it is not complete resistance, and while showing evidence of reduced fitness, some bruchids do survive to adulthood and may reproduce. This can lead to the development of resistance to the seed storage proteins over time. It is more likely to happen as the production of bruchid resistant cultivars expands and replaces bruchid susceptible cultivars. Because of this, we recommend that these cultivars be deployed along with an integrated pest management package to provide multiple means of controlling these insects.

We close by acknowledging the excellent collaborations that have made this work possible. Plant breeding is a long-term process, and a sustained effort is necessary. The path leading to the deployment of these bruchid resistant cultivars has taken over 30 years and has involved the support of multiple agencies to many researchers in various breeding and genetics programs. Researchers at CIAT were instrumental in identifying the tepary source of resistance. USAID support through the Bean/Cowpea CRSP (predecessor to the Legume Systems Innovation Lab) permitted the transfer of bruchid resistance to common bean. McKnight Foundation and USAID via the Legume Systems Innovation Lab support ongoing efforts to develop and deploy cultivars with resistance in Africa and the neotropics.

› Jim Myers. Source: Shawn Linehan.

› Paul Kusolwa

› Jim Beaver

› About the authors

Professor Jim Myers holds the Baggett-Frazier Endowed Chair of Vegetable Breeding and Genetics in the Department of Horticulture at Oregon State University, USA. He breeds dry and snap bean, snap pea, broccoli, tomato, pepper, winter and summer squash. His main interests have been to improve vegetable and field crop varieties for disease resistance, human nutrition and organic production systems. He has worked on bean breeding projects in Africa for about 30 years. E-mail: james.myers@oregonstate.edu

Paul Kusolwa is an Associate Professor in Biotechnology and Horticulture working in the Department of Crop Science and Horticulture at Sokoine University of Agriculture, Tanzania. A coordinator of the African Seed Health Center, he has worked in the bean genetic improvement and rice mutation breeding programs with McKnight Foundation and International Atomic Energy Agency funding. His program extends from basic research to farmer participatory applied research and technology transfers. E-mail: kusolwap@gmail.com.

Jim Beaver is Professor (*Ad Honorem*) in the Department of Agroenvironmental Sciences, University of Puerto Rico at Mayagüez, Puerto Rico. Dr. Beaver served as the Principal Investigator for USAID-funded projects that developed numerous high yielding, early maturing, and disease resistant cultivars and germplasms of common bean in diverse market classes that are being grown by smallholder farmers in Central America and the Caribbean. E-mail: james.beaver@upr.edu

› References

Abate, T., and Ampofo, J.K.O. (1996). Insect pests of beans in Africa: their ecology and management. Annu. Rev. Entomology *41*, 45–73.

Baier, A.H., and Webster, B.D. (1990). Control of bruchids (*Acanthoscelides obtectus*; Coleoptera: Bruchidae) in beans stored on small farms in Colombia. Annu. Rep. Bean Improv. Coop. *33*, 158–159.

Duarte, M.A.G., Cabral, G.B., Ibrahim, A.B., and Aragão, F.J.L. (2018). An overview of the APA locus and arcelin proteins and their biotechnological potential in the control of bruchids. Agri Gene *8*, 57–62. https://doi.org/10.1016/j.aggene.2018.05.001

Hillocks, R.J., Madata, C.S., Chirwa, R., Minja, E.M., and Msolla, S. (2006). *Phaseolus* bean improvement in Tanzania, 1959-2005. Euphytica *150*, 215–231. https://doi.org/10.1007/s10681-006-9112-9

Kamfwa, K., Beaver, J.S., Cichy, K.A., and Kelly, J.D. (2018). QTL mapping of resistance to bean weevil in common bean. Crop Sci. *58*, 2370–2378. https://doi.org/10.2135/cropsci2018.02.0106

Kusolwa, P.M., Myers, J.R., Porch, T.G., Trukhina, Y., González-Vélez, A., and Beaver J.S. (2016). Registration of AO-1012-29-3-3A red kidney bean germplasm line with bean weevil, BCMV and BCMNV resistance. J. Plant Registrations *10*, 149–153. https://doi.org/10.3198/jpr2015.10.0064crg

Kusolwa, P.M., and J.R. Myers. (2011). Seed storage proteins ARL2 and its variants from the APA locus of wild tepary bean G40199 confers resistance to *Acanthoscelides obtectus* when expressed in common beans. Afr. Crop Sci. J. *19*, 255–265.

Maro, C. (2017). Genetics and mechanisms of bruchid resistance in selected common bean (*Phaseolus vulgaris* L.) landraces from Tanzania and Malawi. M.S. thesis (Morogoro, Tanzania: Sokoine University of Agriculture).

Mazzonetto, F., and Vendramim, J.D. (2003). Effect of powders from vegetal species on *Acanthoscelides obtectus* (Say) (Coleoptera: Bruchidae) in stored bean. Neotropical Entomol. *32*, 145–149.

Mbogo, K.P., Davis, J., and Myers, J.R. (2009). Transfer of the arcelin-phytohaemagglutinin-alpha amylase inhibitor seed protein locus from tepary bean (*Phaseolus acutifolius* A. Gray) to common bean (*P. vulgaris* L.). Biotechnology *8*, 285–295. https://doi.org/10.3923/biotech.2009.285.295

Quentin, M.E., Spencer, J.L., and Miller, J.R. (1991). Bean tumbling as a control measure for the common bean weevil, *Acanthoscelides obtectus*. Entomol. Exp. Appl. *60*, 105–109.

Schoonhoven, A.V. (1978). Use of vegetable oils to protect stored beans from bruchid attack. J. Econ. Entomol. *71*, 254–256.

Schoonhoven, A.V. and Cardona, C. (1986). Main insect pests of stored beans and their control. Study Guide (Cali, Colombia: CIAT).

Shade, R.E., Pratt, R.C., and Pomeroy, M.A. (1987). Development and mortality of the bean weevil, *Acanthoscelides obtectus* (Coleoptera: Bruchidae), on mature seeds of tepary beans, *Phaseolus acutifolius*, and common beans, *Phaseolus vulgaris*. Environ. Entomol. *16*, 1067–1070.

Slumpa, S., and Ampofo, J.K.O. (1991). Evaluation of different methods for the control of bean bruchids (*Acanthoscelides obtectus*). Annu. Rep. Bean Improv. Coop. *34*, 66–67.

Conservation of horticultural genetic resources in France

Michel Roux-Cuvelier, Michel Grisoni, Arnaud Bellec, Emmanuel Bloquel, Carine Charron, Magalie Delalande, Marine Delmas, Audrey Didier, Charles-Eric Durel, Charles-Henry Duval, Florence Esnault, Laurence Feugey, Emmanuel Geoffriau, Bouchaïb Khadari, Sandra Lepers-Andrzejewski, François Luro, Cécile Marchal, Alix Pernet, Jérémy Salinier, Marc Seguin, Rebecca Stevens, Bernice van Issum-Groyer and Rémi Kahane

The conservation of biodiversity, and particularly of cultivated biodiversity or agro-biodiversity, is an issue of growing importance, particularly due to the acceleration of global change that is affecting the planet, human health, and nutrition. This article presents the strategy and the diversity of conservation actions of horticultural genetic resources as currently practiced in France. It also emphasizes the international horticultural connections of the French Republic, which include temperate, Mediterranean, as well as tropical environments, particularly considering overseas departments and territories.

The role of Biological Resource Centers

Plant genetic resources are the basis for varietal innovation in agriculture. They are an important source of diversity for the evolution of food systems and the development of agro-ecological cropping systems designed for sustainability and resilience. The evolution of regulations on biodiversity management by States and the implementation of the access and benefit sharing (ABS) regime have reinforced the strategic importance of agricultural plant genetic resources (PGR), and particularly of *ex situ* collections. Horticultural genetic resources are a subset of the agro-biodiversity that allows the improvement and development of horticultural value chains in the world. Conservation and valorization of these resources make agriculture more resilient to biotic and abiotic pressures, climate change, and are essential today for the food and nutritional security of the human population. They are also a matter of food sovereignty, which has become exceedingly apparent during the COVID-19 pandemic crisis.

The term "Biological Resource Center" (BRC) was coined in 1999, following work carried out by the Organization for Economic Cooperation and Development (OECD). It refers to any structure holding biological samples and their associated data from the different kingdoms of life: human, animal, plant and micro-organisms.

BRCs and gene banks are dedicated to the collection, management, characterization, conservation, enrichment and distribution of biological samples. To do this, BRCs implement procedures, techniques and databases according to standardized and optimized quality assurance and certification approaches.

They are operated under the responsibility of public research organizations. Their role is essential for research and development of horticulture. They also play an important social and cultural role through the conservation of heritage resources and traditional knowledge.

Infrastructures and organizations servicing BRCs

GIS IBiSA

The Scientific Interest Group GIS IBiSA (Infrastructure in Biology, Health and Agronomy, https://www.ibisa.net/) is a public instrument for the facilities maintained by the French life science establishments, including the BRCs. It carries out national policies for labeling and funding biology, health and agronomy platforms as well as BRCs. It promotes the organization and pooling of resources and equipment necessary for life sciences. The GIS IBiSA labels BRCs according to criteria of openness to all users, implementation of a quality management system, technological evolution and training.

RARe, a French agronomic BRC infrastructure

In France, in the field of agronomic and environmental research, BRCs are organized into networks (Mougin et al., 2018). The infrastructure AgroBRC RARe (Agronomic Resources for Research) brings together five networks of BRCs that conserve genetic, genomic, and biological resources:

- Microbial biological resources (https://doi.org/10.15454/1.5613788897481968E12);
- Crop resources and plant genomics – BRC4Plants (https://www.agrobrc-rare.org/agrobrc-rare_eng/Presentation/Plant-pillar);
- Forest resources (https://doi.org/10.15454/1.5613761929199846E12);
- Genomic or reproductive animal resources (https://doi.org/10.15454/1.5613785622827378e12);
- Resources associated with an environmental matrix (https://doi.org/10.15454/TRBJTB).

The AgroBRC RARe aims to pool skills, harmonize practices, encourage comparative biology projects and offers a single-entry web portal to facilitate access to well-documented samples. These objectives take into account the regulatory context that varies with the biological nature of the resources, both for sanitary and legal aspects. AgroBRC RARe provides organizational support to its members in the implementation of the Convention on Biological Diversity (CBD) in 1993, the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGR) in 2004, and the Nagoya Protocol in 2010. France has implemented the rules of access to genetic resources and the fair and equitable sharing of benefits arising from their utilization through the European regulation N° 511/2014 and French law No. 2016-1087 for the recovery of biodiversity, nature and landscapes.

The BRCs are under the responsibility of French research organizations working in the field of agronomy and biology: Research Institute for Agriculture, Food and Environment (INRAE), Research Centre for International Development (CIRAD), Research Institute for Sustainable Development (IRD), National Centre for Scientific Research (CNRS), and their partners – the technical institutes and higher education institutions. The BRC4Plants includes 47 living collections of species or groups of species shared between 18 BRCs.

Box 1. Plant collections, a window on viral biodiversity. Contributions of the Safe PGR project - EraNet Netbiome Program (2012-2015)[1]

Vegetatively propagated crops are prone to the accumulation of viruses because they do not benefit from viral sanitation following reproduction by seed. On the other hand, Biological Resource Centers (BRCs) bring together a large number of species and varieties from diverse geographical origins.

The general objective of the Safe PGR project was to improve the knowledge of the diversity of viruses infecting the crops addressed by the partners' BRCs, to develop or optimize diagnostic techniques. Ultimately, it aimed to limit the risk of spreading viral diseases through the exchange of tropical plant germplasm.

To reach its objective, the BRC partners from Guadeloupe, Madeira, Azores, and Reunion, combined classical molecular biology and next generation sequencing (NGS) approaches, leading to unprecedented virus discovery in the targeted crops (banana and plantain, sugarcane, yam, sweet potato, garlic and vanilla).

A total of 21 new virus species were discovered (1 in banana, 3 in garlic, 3 in sweet potato, 4 in sugarcane, 3 in vanilla and 7 in yam) and their molecular diversity was explored. This gave the possibility of setting up diagnostic methods for these new agents as well as the optimization of methods for 10 already known viruses. Thus, the knowledge of the viral status of the germplasm collections was improved, which helps to prevent the spread or emergence of diseases.

[1]For more information, see Pavis (2015).

In total, more than 103,000 accessions are conserved in the French plant BRCs, of which about 57,000 are horticultural resources belonging to 62 genera.

This organization of the plant BRCs into a network makes it possible to think about and carry out research projects around common issues specific to the BRCs such as genetic diversity and plant genome analysis or viral diversity of vegetatively propagated species (Box 1) or, more generally, the application of national and international phytosanitary regulations.

The French national coordination for plant genetic resources: safeguarding "orphan species"

The national coordination works towards the official recognition of collection curators and the identification of plant resources of cultivated species and their wild relatives (other than forest trees) that are relevant for France. Set up by the Ministry of Agriculture, the coordination is composed of a national support structure (SCN) hosted within the GEVES (Group for the Study and Control of Varieties and Seeds), and a Cross Section of the CTPS (Permanent Technical Selection Committee) bringing together a diversity of stakeholders (47 members) involved in the conservation and development of these resources.

In this context, the SCN acts to safeguard species, which are relevant for French agriculture. It focuses in particular on the conservation of "orphan" species, species without an identified collection or with a collection for which the regeneration or characterization are not carried out: for example, beans (*Phaseolus* sp.), grass pea (*Lathyrus* sp.), lentils (*Lens culinaris*) and onions (*Allium cepa*). Research has been carried out on existing collections, inviting other stakeholders who are interested in getting involved in the management of these species. For beans and onions, public and private cooperation networks are in the process of being created. For grass pea and lentils, the approach was unsuccessful due to an insufficient number of stakeholders. Nevertheless, discussions are being held with international centers to identify potential solutions for safeguarding these collections. Other species will be studied, such as buckwheat (*Fagopyrum esculentum*), radish (*Raphanus sativus*) or asparagus (*Asparagus officinalis*).

Involvement of French BRCs at European level

Though genetic resources management is organized mainly in crop-oriented networks and BRCs in France, centralized multi-species gene banks prevail in Europe. The cooperation on PGR in Europe is organized though ECPGR (The European Cooperative Programme for Plant Genetic Resources, https://www.ecpgr.cgiar.org/) with 33 member-countries and 23 working groups with several addressing horticultural crops: *Allium*, berries, *Brassica*, cucurbits, leafy vegetables, *Malus*/*Pyrus*, medicinal and aromatic plants, potato, *Prunus*, *Solanaceae*, umbellifer crops and *Vitis*. French BRCs actively participate to ECPGR. Genetic resources in Europe covering 43 countries, 400 institutes and 2 million accessions can be found in the Eurisco database (https://eurisco.ipk-gatersleben.de).

Biological Resource Centers in France for horticultural plants

Within the BRC4Plants, eleven BRCs manage horticultural living collections (Figure 1; Table 1). An additional BRC, the CNRGV (French Plant Genomic Resources Center), is specifically dedicated to genomic resources (Box 2). A French specificity within the European space is to have several ultramarine territories, called RUP (ultra-peripheral region) at the European level or DROM-COM (overseas departments and regions - overseas collectivities) at the French level. These territories are mainly located in tropical environments. They are home to significant biodiversity and host many collections of tropical horticultural genetic resources organized in BRCs.

The Florilège portal (http://florilege.arcad-project.org/fr/collections) provides a focal point for web entry into the biological resources of plants for agriculture conserved in France (metropolitan and overseas). In its

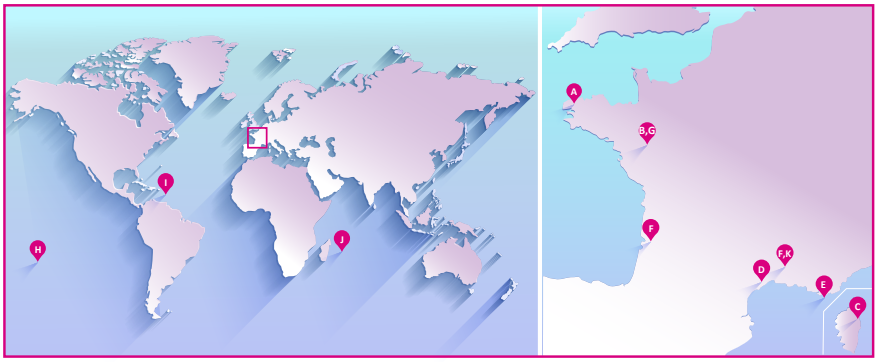


Figure 1. Localization of the 11 French Biological Resource Centers (BRCs) around the globe. Left: overseas BRCs, right: mainland France and Corsica BRCs. A = BrACySol, B = Carrot and other vegetable *Apiaceae*, C = Citrus, D = Grapevine, E = Olive trees, F = *Prunus-Juglans*, G = Rose-Pom, H = Tahitian vanilla, I = Tropical plants, J = Vatel, K = Vegetables. (Figure designed by M. Duportal, CIRAD).

Box 2. The French Plant Genomic Resources Centre (CNRGV)[2]

The CNRGV is a national infrastructure within the National Research Institute for Agriculture, Food and Environment (INRAE). Settled in Toulouse (France) in 2004, it is both a Biological Resource Centre (BRC) dedicated to plant genomic libraries and a service provider for plant genomics projects. A genomic library consists of collection of DNA fragments cloned into bacteria (so called BAC clones) that, altogether, represent the complete genome of a plant. The BAC clones are easy to conserve, to screen for genes of interest, to isolate DNA from and to sequence.

The missions of the CNRGV are to produce, conserve, characterize, and distribute genomic resources to, ultimately, understand the organization of plant genomes or to link biological functions or agronomical traits to the DNA sequences that govern their expressions. To fulfil these objectives, the CNRGV can either screen the genomic libraries to isolate the BAC clones of interest and sequence them, directly target and sequence large DNA fragments, using internally developed CATCH methods, or produce an assembled genome sequence of a genotype of interest in collaboration with sequencing facilities.

To date, the CNRGV conserves 392 genomic libraries corresponding to 45 plant species including 20 vegetable and horticultural species. Through collaborations on these particular species, the CNRGV has implemented various projects representative of the services available. They include the production of preliminary genomic data for species not or scarcely characterized (parsnip, passion fruit), the characterization of regions governing resistances to biotic (resistance to viruses in pepper) and abiotic (frost tolerance in pea) stresses, the production of reference genome sequences (tomato, vanilla). Recently, the CNRGV has developed tools to characterize intraspecific variations in chromosome structure (apricot).

In the future, the CNRGV aims to help to better characterize the genetic resources at the genomic level.

[2]For more information, see https://cnrgv.toulouse.inrae.fr/

current configuration, it represents the network of plant BRCs managed by INRA, CIRAD and IRD members of the national infrastructure AgroBRC RARe. It should soon be interconnected with the European portal Eurisco (https://www.ecpgr.cgiar.org/resources/germplasm-databases/eurisco-catalogue).

The Inter-TROP portal (http://crb-tropicaux.com/Portail) is dedicated to the biological resources of tropical plants for agriculture, maintained by the plant BRCs attached to French research organizations in tropical areas.

Biological Resource Center BrACySol (Figure 1A)

The BRC BrACySol preserves and characterizes collections of genetic resources of different cultivated genera: *Brassica* (cabbage, turnip, rape and mustard), *Allium* (shallot and garlic), *Cynara* (artichoke) and *Solanum* (potato and related species). It is supported by two INRAE units: the Joint Research Unit Institute of Genetics, Environment and Plant Protection (IGEPP) and the Experimental Unit Genetic Resources in Oceanic Conditions (RGCO), and is based in Ploudaniel in Brittany. The BRC BrACySol is involved in various European (H2020 G2P-Sol; Prima Bras Explor) or national (PIA Rapsodyn; CASDAR Brassidel, PoTStaR, GeCoNem) projects, and projects funded by professional partners (Promosol, GIE Colza, Association des Créateurs de Variétés Nouvelles de Pomme de Terre, Fédération Nationale des Producteurs de Plants de Pomme de Terre). The objectives of these projects are i) to explore, describe, and structure genetic diversity, ii) to develop core collections, iii) to carry out genetic association analyses to identify the regions of the genome involved in resistance traits to different pests or abiotic constraints, iv) to introduce this diversity into pre-selection material by exploiting recombination, and v) to develop markers that can be used in marker-assisted selection.

The *Brassica* collection includes 1,200 accessions of vegetable crucifers, which are populations collected from farmers before their disappearance in favor of hybrid varieties, and 2,200 accessions of oilseed crucifers including lineage varieties representing world variability. It also includes original scientific material presenting traits of agronomic importance such as resistance to different pests, or seed quality. The accessions of this collection are stored as seeds in freezers (-18 °C) or in cryopreservation containers (-196 °C). The seed lots are regenerated every 10 to 15 years, depending on the evolution of their germination faculty.

The *Solanum* collection includes 12,000 accessions. It is composed of i) clones of potato-related species originating from South America and characterized for a certain number of traits of interest, ii) varieties representing world variability, including heritage ones that are not maintained in any other European BRC, and iii) original scientific material presenting traits of agronomic importance such as resistance to different pests, or related to the technological quality of tubers. These accessions are maintained by vegetative propagation in the form of tubers, in vitro plantlets or cryopreserved meristems. The maintenance of related species in the form of characterized clones constitutes a specificity of this collection.

The *Allium* collection includes 120 garlic accessions and 300 shallot accessions. It is composed of populations collected in France before the opening of the catalog in 1991, old and new varieties and original scientific material for the selection of agronomic characteristics such as disease resistance or dry matter content of bulbs. The accessions are maintained by vegetative multiplication in the form of bulbs and planted in the field every year.

The *Cynara* collection includes 20 artichoke accessions. It is composed of French varieties and varieties used as reference in the trials. The accessions are maintained in the form of plants in the greenhouse.

The BrACySol BRC coordinates three national networks for the conservation of plant

Figure 1A. A. Diversity of potato varieties. Credit: C. Maitre, INRAE. B. Diversity of cabbage populations. Credit: N. Quéré, INRAE.

Table 1. Detailed list of French Biological Resource Centers dealing with horticultural collections.

Code	BRC name	Town (region)	Affiliation	Contact	Family
A	BrACySol	Ploudaniel (Brittany)	INRAE	Bracysol@inrae.fr	*Brassicaceae* *Alliaceae* *Asteraceae* *Solanaceae*
B	Carrot and other vegetable *Apiaceae*	Angers (Pays de la Loire)	Agrocampus Ouest	crbcarotte@agrocampus-ouest.fr	*Apiaceae*
C	Citrus	San Giuliano (Corsica)	INRAE-CIRAD	emmanuel.bloquel@inrae.fr	*Rutaceae*
D	Grapevine	Montpellier (Occitania)	INRAE	cecile.marchal@inrae.fr	*Vitaceae*
E	Olive tree	Porquerolles (French Riviera)	CBN Med/INRAE	b.khadari@cbnmed.fr magalie.delalande@inrae.fr	*Oleaceae*
F	*Prunus-Juglans*	Avignon (Provence), Bordeaux (Aquitaine)	INRAE	marine.delmas@inrae.fr	*Rosaceae*
G	Pome fruits and roses (RosePom)	Beaucouzé (Pays de la Loire)	INRAE	Alix.Pernet@inrae.fr Laurence.Feugey@inrae.fr	*Rosaceae*
H	Tahitian vanilla	Raiatea (French Polynesia)	EVT	sandra.lepers@vanilledetahiti.pf	*Orchidaceae*
I	Tropical plants	Petit Bourg (Guadeloupe), Le Lamentin (Martinique)	CIRAD/INRAE	crb.plantes-tropicales@cirad.fr	*Musaceae* *Bromeliaceae* *Poaceae* *Anacardiaceae* *Dioscoreaceae*
J	Vatel	Saint Pierre (Reunion Island)	CIRAD	carine.charron@cirad.fr marc.seguin@cirad.fr	*Orchidaceae* *Amaryllidaceae* *Araceae,* *Euphorbiaceae,* *Dioscoreaceae,* *Convolvulaceae* *Fabaceae* *Cucurbitaceae*
K	Vegetables (Leg)	Avignon (Provence)	INRAE	rebecca.stevens@inrae.fr	*Solanaceae* *Cucurbitaceae* *Asteraceae*

genetic resources: the "vegetable crucifers" network, the "oilseed crucifers" network and the "potato" network, and it participates in the Cynara network. In addition, the BRC BrACySol is part of the European network ECP/GR and is a member of the *Brassica*, *Allium* and Potato working groups. The collections maintained within the BRC BrACySol are visible on the French portal Florilège. The BRC BrACySol is engaged in a certification process according to the ISO 9001-2015 standard.

BRC Carrot and other vegetable *Apiaceae* (Figure 1B)

Based on genetic resources research and management activity initiated in 1996, the BRC "Carrot and other vegetable *Apiaceae*" was re-established in 2011. This BRC is supported by the Institut Agro | Agrocampus-Ouest, with joint research with IRHS (Institute of Research on Horticulture and Seeds). The related activities involve carrot and wild relatives genetic diversity and evolution, the genetic determinants of compounds involved in quality and resistance to diseases in carrot, and the effect of environment,

Main genus/ species	Common names	Number of accessions preserved	Number of accessions released (2019)	Selected scientific references
Brassica *Allium* *Cynara* *Solanum tuberosum*	Cabbage, rape seed Garlic, shallot Artichoke Potato	3,400 420 20 12,000	1,310	Aissiou et al. (2018) Esnault et al. (2014, 2016)
Daucus *Chaerophyllum* Other *Apiaceae*	Carrot Tuberous rooted Chervil, parsnip, fennel, etc.	4,376 706 37	5	Chevalier et al. (2021) Geoffriau (2020) Martinez Flores et al. (2019)
Citrus	Citrus	1,100	420	Ahmed et al. (2019) Curk et al. (2016) Luro et al. (2017)
Vitis	Table grape Grape	2,262 5,738	500	Bonhomme et al. (2020) Candresse et al. (2020) Dumas et al. (2020)
Olea	Olive	63	0	El Bakkali et al. (2019) Khadari and El Bakkali (2018) Khadari et al. (2019)
Prunus sp. *Juglans*	Apricot, almond, peach, cherry, plum Walnut	2960 400	NA	Bernard et al. (2020) Cirilli et al. (2020)
Malus *Pyrus* *Cydonia* *Rosa*	Apple Pear Quince Rose	4,917 2,474 59 2,518	638	Lassois et al. (2016) Liorzou et al. (2016) Lopez Arias et al. (2020) Muranty et al. (2020)
Vanilla	Vanilla	321	2	Lepers-Andrzejewski et al. (2012) Lubinsky et al. (2008)
Musa *Ananas* *Saccharum* *Mangifera* *Dioscorea*	Banana Pineapple Sugarcane Mango Yam	403 467 335 120 430	600	Arnau et al. (2017) Martin et al. (2020) Umber et al. (2020)
Vanilla Tropical garlic Roots and tubers Neglected vegetables	Vanilla Garlic Taro, Cassava, Yam, Sweet potato, etc. Beans, peas, etc. Luffa, snake gourd, etc.	700 33 82 103	300	Andriamihaja et al. (2020) Bouétard et al. (2010) Roux-Cuvelier (2017)
Solanum melongena *Capsicum* *Solanum lycopersicum* *Cucumis melo* *Lactuca*	Eggplant Pepper Tomato Melon Lettuce	2,333 2,173 3,378 2,332 948	1,595 (distribution out of the research unit)	Daunay et al. (2011) Salinier et al. (2019a, b)

practices and genetic interactions on quality and resistance. The BRC collaborates internationally (e.g., with European and Tunisian gene banks, ECPGR, University of Wisconsin). This BRC focuses on carrot genetic resources with 1,376 patrimonial accessions (among which 350 wild relatives) and nearly 3,000 scientific accessions resulting from research activities (inbreds, segregating populations, intercrossing populations). It holds a unique collection of tuberous-rooted chervil (23 patrimonial and 683 scientific accessions) and a few accessions of other *Apiaceae* crops.

The BRC Carrot and other vegetable *Apiaceae* coordinates the national network of carrots and other *Daucus* genetic resources (including 7 companies and 3 professional organizations), hosts and manages the network collection. It provides expertise and resources in the CTPS (variety registration and maintenance controls). This BRC runs projects in partnership with seed companies, and provides scientific support to participatory breeding process of organic vegetable growers. Knowledge management of wild carrot populations is done in collaboration with national botanical conservatories (e.g.,

Figure 1B. A. Diversity of carrot root color. Credit: E. Geoffriau. B. Wild carrot umbels for seed regeneration. Credit: E. Geoffriau.

Bailleul, Porquerolles, Corsica) and a taxonomy expert (Via Apia). At European level, the BRC Carrot and other vegetable *Apiaceae* is the French representative on the ECPGR working group *Umbelliferae* (coordination 2008-2013), and is involved in ECPGR Carrot Diverse and EVA carrot projects. It coordinates collecting missions.

The national patrimonial carrot collection can be accessed through https://crb-carotte-cn.agrocampus-ouest.fr/. The BRC Carrot and other vegetable *Apiaceae* is engaged towards ISO 9001-2015 certification.

BRC Citrus (Figure 1C)

In 1959, the BRC Citrus was created by the introduction of material initially from the Mediterranean area, then from other growing areas such as Southeast Asia, the region of origin of citrus. It is located in Corsica, on the INRAE station of San Giuliano, and managed jointly by INRAE and CIRAD. Today, the Citrus BRC has more than 1,100 accessions from more than 50 countries, which constitutes one of the five most important citrus collections in the world. All groups or cultivated species are represented but the group of mandarins and their hybrids are a specialty core collection (about ¼ of the BRC). Citrus is conserved in the form of grafted trees (3 or 4 trees per accession) planted in orchards on 14 ha in total. Today, about 25% of the collection is duplicated and maintained in an insect-proof greenhouse. More secure forms of conservation are being studied such as cryopreservation of polyembryonic seeds (apomictic multiplication by somatic embryo). From 2014 to 2020, the Citrus BRC was certified according to the NFS 96-900 standard. In 2020, this was switched to the international quality system ISO 9001-2015. A management software has been developed and consists of modules dedicated to each major activity: introduction, conservation,

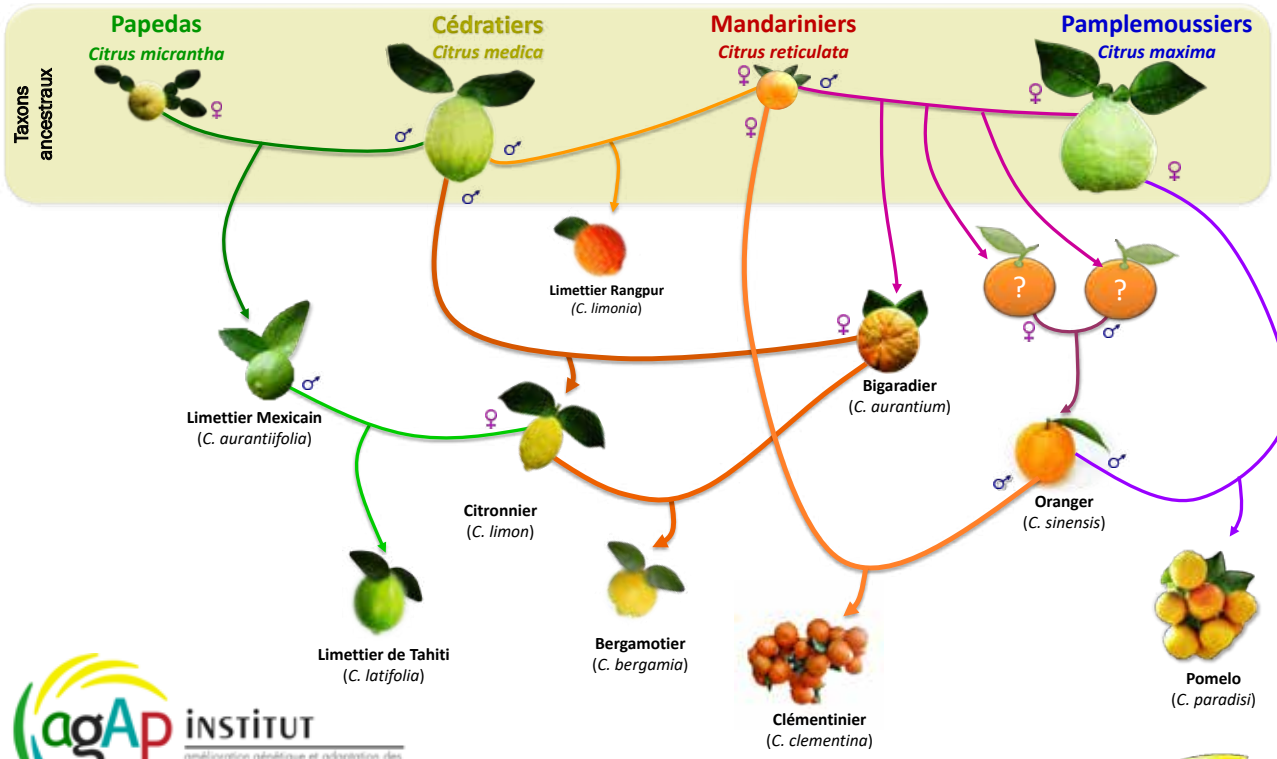
Box 3. The origin of citrus fruit – F. Curk (INRAE) and P. Ollitrault (CIRAD)

Citrus ancestors first diversified in different regions from the southern Himalayas to Oceania. This so-called allopatric evolution differentiated a number of taxa, of which four (*C. maxima* (Burm.) Merr [pummelos], *C. reticulata* Blanco [mandarins], *C. medica* L. [citrons] and *C. micrantha* Wester [papedas]) are at the origin of the main horticultural groups (Figure 2). Hybridization between these ancestral taxa has occurred as a result of overlapping geographical ranges, certainly linked to major climatic changes. These hybridizations have generated new species, some of which modern man has inherited after identification and selection by humans over millennia. Recent phylogenetic studies have uncovered and confirmed this history.

We now know that the sour orange (*Citrus aurantium* L.) is a direct hybrid between a pummelo and a wild mandarin tree. The orange (*Citrus sinensis* L. (Osb.)) merged from a more complex combination of *C. maxima* and *C. reticulata* genomes. Lemon (*C. limon* (L.) Burm.) is a hybrid between a sour orange and a citron. The citron is the male parent of all acidic citrus, including the Mexican lime (*C. aurantiifolia* (Christm.) Swing.), a direct hybrid between *C. micrantha* and *C. medica*. The most recent results have highlighted the complex origin of the Tahitian lime (*C. latifolia* Tan.), which has a complex mosaic genome derived from the four ancestral taxa. This lime is, in fact, a hybrid between the Mexican lime and the Mediterranean lemon.

In addition to identifying the ancestral species at the origin of cultivated citrus, this information opens the way to new strategies for breeding based on a wide exploitation of the genetic resources of the species complex to generate the genotypes of tomorrow.

Figure 1C. A. Citrus field collection. Credit: F. Luro, BRC Citrus. B. Greenhouse citrus collection. Credit: E. Bloquel, BRC Citrus.



Centre de Ressources Biologiques Citrus Inra-Cirad
Centre Inra de Corse - 20230 San Giuliano

■ Figure 2. Genetic origin of the main citrus sub-groups.

characterization, and dissemination of plant material.

Until 1999, the conservatory had its own quarantine strategy. Thermotherapy and regeneration by somatic embryogenesis were used, in the beginning, to guarantee the sanitary status of the introduced material. Then, from 1981, apex micrografting was applied and opened the possibilities of introduction to all varieties of all geographical origins. Since the beginning of the 21st century, the National Agency of Sanitary Safety of Food, Environment and Work (ANSES) of Clermont-Ferrand (mainland France) ensures the quarantine services. Corsica has low pest pressure for citrus. Then, the regular controls enable this BRC to be one of the rare locations where all outdoor trees remain healthy.

Nearly 32% of the accessions are available for distribution through shipment of budwood or seeds (about 170 accessions each year). These forms are available for research on plants, leaves, fruits, and flowers (about 250 accessions per year). The collection supports numerous genetic, agronomic, physiological or biochemical studies, and varietal development by selection for hybridization. The important varietal diversity of mandarins, lemons, limes, and citrons has been exploited to develop phylogenetic studies and to analyze the structure of genomes (Box 3).

BRC Grapevine (Figure 1D)

The Vassal-Montpellier Grapevine BRC is the oldest and richest ampelographic conservatory in the world, both in number and diversity of accessions. The conservatory was created in 1876 at the Montpellier School of Agriculture (now the Institut Agro | Montpellier SupAgro). During the phylloxera crisis in 1949, INRAE began managing the collection at the Domaine de Vassal site. Under the scientific aegis of the research team on vine genetics in Montpellier (now the AGAP Institute (Genetic Improvement and Adaptation of Mediterranean and Tropical Plants research unit, team “Diversity, Adaptation and Improvement of the Grapevine”), the collection has been studied and enriched continuously. The documentation of the collection and associated data are also of great importance.

Today, the collection consists of over 8,000 accessions of cultivated vines, rootstocks, and wild relatives from 54 countries. The collection conserves 2,262 accessions of table grapes, representing 1,187 different varieties, of which 243 are considered “dual purpose” for wine and table.

The accessions are cultivated in the vineyard on five rootstocks. They are characterized for morphological, phenological, agronomic, technological, sanitary, genetic, and bibliographical traits. In recent years, the emphasis has been placed on behavior in the face of the main pathogens, in particular through the Vitirama project (https://www6.montpellier.inrae.fr/vassal/Activites/Projets/Vitirama), to support the use and creation of varieties requiring less phytosanitary treatment. Each year, an average of 500 varieties are distributed as cuttings-graft or fresh material (leaves, berries), to professionals in the sector, amateurs, or French and foreign researchers. The research topics in which the BRC Grapevine is involved are very diverse, from archaeobotany to virology, including physiology and adaptation to climate change.

The documentary collection is a resource in its own right and is being digitized thanks to a sponsorship program. It is used in particular in projects with historians, such as the historical ampelographic atlas of France (CepAtlas, http://citeres.univ-tours.fr/spip.php?article3174).

In addition, the BRC Grapevine collaborates with the French Wine and Vine Institute and the French Network of Vine Conservatories,

Figure 1D. A. Domaine de Vassal, field collection. Credit: C. Cruells. B. 'Italia Rubi' cultivar. Credit: BRC Grapevine. C. 'Malaga' cultivar. Credit: BRC Grapevine.

which brings together 36 professional partners from all wine-producing regions. The common database for this network is https://bioweb.supagro.inra.fr/collections_vigne/Home.php.

BRC Olive trees (Figure 1E)

The olive tree (*Olea europaea*) is one of the emblematic species of the Mediterranean. It is cultivated for the production of edible oil and table olive on a surface area of over 10 million hectares worldwide. It is an "immortal" tree, particularly because of its ability to regenerate after extreme weather events. *Olea* includes six subspecies, but only the olive tree *Olea europaea* subsp. *europaea* was domesticated about 6,000 years ago. This subspecies is present throughout the Mediterranean, both in its wild (var. *sylvestris*) and cultivated (var. *europaea*) forms. Domestication *sensu stricto* began with the vegetative multiplication of wild trees selected for traits probably related to fruit size and oil content. The BRC Olive trees is supported by the National Mediterranean Botanical Conservatory (CNBMed), based in Hyères-les-Palmiers in PACA (Provence-Alpes-Côte d'Azur) region, and managed jointly by INRAE, within the framework of the AGAP Institute in Montpellier.

The BRC focuses on the national olive tree collection, hosted by the Port-Cros National Park on the Porquerolles Island (PACA region). The core collection is composed of French heritage varieties and those from other Mediterranean countries. In partnership with the olive-growing professional organization (France-Olive), a French national collection has been established, constituted by 63 formally identified accessions and considered as reference of French olive varieties. This has been possible following a huge identification work based on morphological (tree, leaf, fruit, kernel), molecular (microsatellite markers) and bibliographical (validation of names) information and according to the opinions of the France-Olive stakeholders. This identification work continues to remove any ambiguities about certain varieties for which the reference genotype has not yet been validated.

The BRC Olive trees is based on a collection located on an island within a national park, following an organic cropping system. Moreover, its management takes into account a national level through local collections managed in partnership with France-Olive stakeholders, and an international level through world collections managed within the genetic resources network of the International Olive Oil Council (IOC). BRC Olive trees organization ensures a safeguarding of French genetic resources *ex situ* in local (France-Olive network) and worldwide collections (IOC network), as well as *in situ* through trees geo-located by France-Olive in orchards.

The BRC Olive trees is considered an innovative research tool on adaptation to climate change conducted by the AGAP Institute in collaboration with national and international partners mainly in Morocco and Spain (OliveMed project funded by Agropolis Foundation, 2021-2025). Two research topics are currently implemented within this framework: i) understanding the flowering processes in relation to the cold requirements of varieties, and ii) investigating the variability of functional traits related to drought resistance in olive trees (https://umr-agap.cirad.fr/en/research/main-projects/olivemed). These research lines are linked to NGS (next generation sequencing) analyses in order to identify adaptive genomic variants.

BRC *Prunus-Juglans* (Figure 1F)

The BRC *Prunus-Juglans* is managed by INRAE, in orchards or in sheltered containers of fruit and related species belonging to the genera *Prunus* (stone fruit) and *Juglans* (walnut). A large part of this material is composed of traditional and modern varieties of agronomic interest. Another part is made of accessions of scientific interest, mainly resulting from INRAE research work. Related species are also included in the collections: some are of interest as rootstocks, others may carry genes of interest such as disease resistance ones. Japanese cherry (*Prunus serrulata*), highly prized for its abundant flowering, and myrobolan (*Prunus cerasifera*), widely used as rootstock for plum, apricot or almond trees, are among the best-known species of the *Prunus* collections. These trees are grown and observed in two production regions in France:

- In Provence-Alpes-Côte d'Azur (south-east of France) the INRAE-GAFL (Genetics and Breeding of Fruit and Vegetables) research unit manages exclusively stone fruit trees: apricot (600 accessions), almond (250 accessions) and related species;
- In Nouvelle-Aquitaine (south-west of France), the Fruit tree Experiment unit of INRAE manages both *Prunus* and *Juglans* trees: cherry (3 species, 500 accessions), peach (1 species, 500 accessions), plum (1 species, 350 accessions), and related *Prunus* species (30 species, 70 accessions); and walnut (15 species, 40 accessions).

The *Prunus* collections are used by research units of the "Biology and Plant Breeding" department of INRAE, involved in varietal innovation or stress resistance. This is illustrated by the CASDAR-funded project "Caress *Prunus*" (Characterization of *Prunus* genetic resources for biotic and abiotic stresses). This project characterized the available genetic resources through a multi-criteria approach targeting phenology (dormancy, flowering, maturity and senescence) and sensitivity to pests and diseases. The *Juglans* collections are used both for breeding purposes in a partnership with the Interprofessional Fruit and Vegetable Technical Centre (CTIFL), and for research purposes, particularly in animal

Figure 1E. A. Turning color olives of 'Petit Ribier' cultivar. Credit: J.-P. Roger, CBNMed. B. Organic clay treatment against the fly *Bactrocera olea* in the French national collection located in the Parc National de Port-Cros Porquerolles. Credit: M. Delalande, INRAE.

Figure 1F. A. Flowering *Prunus* from the Rose-pom collection. Credit: BRC Rose-pom. B. Flowering of walnut in new plantation. Credit BRC *Prunus-Juglans.*

physiology in a research project developing plant hormonal compounds in goat breeding.

BRC Pome fruits and roses (RosePom) (Figure 1G)

The BRC "Pome fruits and roses" (BRC RosePom) is hosted by INRAE near Angers, in the region Pays de la Loire, on two main sites: Beaucouzé and La Rétuzière. It is managed by the joint research unit Research Institute in Horticulture and Seeds (IRHS), and by the experimental unit Horti. It includes collections of i) apple, pear, and quince accessions, mostly in the field and as DNA samples, and ii) rose accessions. Scientific accessions of the *Rosa* genus are preserved in the field and as DNA samples, whereas patrimonial accessions are mostly as DNA samples, the heirloom field roses being preserved by different private and public rose gardens in France.

The missions of the BRC RosePom include:

- The preservation of biological resources of pome fruit and roses, including improvement and rationalization of the collections;
- The phenotypic and genotypic characterizations of these resources, to be able to supply samples and data for research and breeding purposes, mainly in the framework of collaborative projects;
- The provision of expertise and available materials from the pome fruit collections for distinctness, uniformity and stability (DUS) testing;
- Data analyses associated with these resources in collaboration with research teams and external germplasm managers.

BRC RosePom also leads or contributes to pome fruit and rose genetic resources networks at national, European and international levels.

The BRC RosePom currently preserves nearly 10,000 accessions in the field (4,917 *Malus*, 2,474 *Pyrus*, 59 *Cydonia*, and 2,518 *Rosa*) and several thousand additional accessions as DNA samples only. To efficiently store all associated data, a database is under construction and should soon be available. This resource, whether patrimonial or scientific, is the basis of many research projects. For example, the CorePom project funded by the Foundation for Research on Biodiversity produced an unprecedented increase in knowledge about the accession identity and uniqueness/duplicate status of the French apple germplasm genotyped with SSR. The genetic diversity and structure were analyzed and helped in constructing core collections. A first parentage analysis was also performed. In the EU-funded FruitBreedomics project (https://cordis.europa.eu/project/id/265582), more than 2,400 accessions from 14 European collections, including that of the BRC RosePom, were further analyzed and revealed a prominent gene flow in apple at the European level. The same accession set was also used in a genome-wide association study on flowering and ripening periods and for the reconstruction of an extra-large, multi-generation, highly-connected pedigree. For rose, the DNA stored in the BRC of French cultivars of the 19th century allowed the FlorHiGe project (2013-2016) to show introgression of the European genetic background by the Asian one. Rose mapping prog-

Figure 1G. A. An overview of the different colors and fruit shapes of the apple varieties conserved in the BRC RosePom. Credit: L. Feugey, INRAE. B. Scientific genetic resource collection of *Rosa* at INRAE, Beaucouzé, France. Credit: Thouroude, INRAE.

enies present in the BRC RosePom fields are the support of several quantitative trait loci studies on different traits, including scent of roses, prickle and disease resistance. Other projects on rose diversity such as those on *Rosa gallica*, or the RosesMonde project (2015-2019) highly contributed to enrich the DNA collection of the BRC RosePom.

BRC Tahitian vanilla (Figure 1H)

The Tahitian vanilla BRC is located on the island of Raiatea, in French Polynesia. It is managed by the Etablissement Vanille de Tahiti (EVT) and was labelled by the GIS IBiSA in 2015. Its quality management system is based on the ISO 9001 standard.

This BRC includes 71 vanilla accessions (*Vanilla × tahitensis, V. planifolia, V. pompona* and hybrids) conserved in two shaded greenhouses, plus 250 varietal creations conserved in vitro. Out of these 321 accessions, 316 are only present at the BRC Tahitian vanilla (Polynesian vanillas and hybrids created by the EVT). Five accessions are also present in the BRC Vatel: *V. planifolia, V. pompona* and *V. × tahitensis* 'Haapape'.

The analysis of the genetic diversity of the vanilla plants in the collection has provided insight into the secondary diversification of vanilla plants in French Polynesia and unraveled their hybrid origin. Moreover, genetic analyses have shown that the majority of varieties found in Polynesian plantations result from spontaneous germination of seeds of the 'Tahiti' cultivar, or by natural polyploidisation (doubling of the number of chromosomes) for the 'Haapape' and 'Tiarei' cultivars, for example. These elements highlight the specificity of Polynesian vanilla plants. They have made it possible to define protection and development strategies such as local regulations and the PDO certification process currently underway.

The most widely grown cultivar in French Polynesia is *V. × tahitensis* 'Haapape', which is vigorous but not very floriferous and of average aromatic quality. In the Tahitian vanilla BRC, various vanilla varieties have been evaluated as part of a program to select better performing varieties, i.e., which are better adapted to climatic hazards and emerging diseases. The selection is made by monitoring agronomic traits in the EVT greenhouse, at Polynesian producers' farms, and in laboratory by in vitro tests of susceptibility to fusariosis. Some accessions selected in this way are now offered to producers. These are varieties with excellent aromatic quality and high flowering capacity, or more tolerant to fusariosis.

Figure 1H. A. Cured beans of Tahitian vanilla. Credit: T. McKenna. B. Tahitian vanilla flower. Credit: EVT.

BRC Tropical plants (Figure 1I)

In Guadeloupe and Martinique, the French Caribbean Islands, CIRAD and INRAE have been building up large collections of tropical crop genetic resources for several decades. In 2010, the two organizations joined forces to create the Biological Resource Center "Tropical Plants-Antilles" (BRC-TP). Four collections of vegetatively propagated horticultural species, conserved in the field, make up the BRC: banana, mango, pineapple and yam. These collections are managed under quality assurance, BRC being certified according to the NF-S 96 900 standard and in the process of being certified for the ISO 9001-2015 standard. The BRC also hosts the Guadeloupe Herbarium, which contains more than 12,000 botanical plates. It actively participates in the BRC4Plants networking activities at national level.

The banana collection comprises 403 accessions representing a significant proportion of the world's banana diversity. It is maintained in the field and secured in vitro for the most fragile accessions. The following types of banana are represented: plantain, cooking, dessert, ornamental and wild bananas, including *Musa acuminata* and *Musa balbisiana*, the ancestral relatives of cultivated banana. This collection is part of the Musa-LAC (Latin America and Carribean) network supported by Bioversity International. It is involved in numerous research projects in genetics and banana breeding. It is one of the most important banana field collections in the world in terms of the genetic diversity and number of accessions conserved.

The yam collection, managed by INRAE, is composed of 430 accessions conserved in vitro, part of which is renewed in the field each year. The main species represented are *Dioscorea alata*, *D. trifida*, *D. cayenensis-rotundata*, *D. bulbifera* and *D. esculenta*. Virology research is conducted on this collection, which is also used in international projects (e.g., RTBfoods, https://rtbfoods.cirad.fr/; Africayam, http://africayam.org/).

The mango collection is a historical CIRAD collection. It comprises 120 accessions kept in the field, mainly of the *Mangifera indicae*

Figure 1I. A. Pineapple field collection in Martinique. Credit: M. Roux-Cuvelier. B. Diversity of banana fruit. Credit: BRC Tropical Plants. C. In vitro plantlet (yam collection). Credit: M. Roux-Cuvelier. D. Diversity of mango fruit. Credit: BRC Tropical Plants.

species. Seventy percent of the genotypes come from Africa. Recently enriched with heritage varieties from the French Caribbean Islands, this collection is used to diversify mango production.

The pineapple collection, located in Martinique, includes 467 wild and cultivated accessions representative of the diversity of the genus and of the Amazon Basin, the pineapple area of origin. The pineapple collection is currently conserved in the field, but should be secured by cryopreservation in a near future. It is one of the most important pineapple collections in the world.

The BRC is responsible for the development of OLGA software (local accession management tool), a computer tool used by many BRCs in France to manage stocks of genetic resources and associated data. The collections maintained within the BRC are listed on the Florilège web portal.

BRC Vatel (Figure 1J)

The BRC Vatel (vanilla, garlic, tubers and vegetables) is located on Reunion Island, in the Indian Ocean. It is managed by CIRAD as part of the Peuplements Végétaux et Bioagresseurs en Milieu Tropical research unit (CIRAD/University of Reunion Island). Four collections of agricultural plant genetic resources are conserved in the BRC Vatel:

- Vanilla: 700 accessions, 25 species of the genus *Vanilla* (*Orchidaceae*);
- Tropical garlic: 33 varieties of *Allium sativum* (*Amaryllidaceae*);
- Root and tuber vegetables: 82 accessions, 11 species (cassava, taro, yam, sweet potato, etc.), 7 families (e.g., *Euphorbiaceae*, *Araceae*, *Dioscoreaceae*, and *Convolvulaceae*);
- Seed vegetables: 103 accessions, 30 species (including squashes, pigeon peas, cowpeas), 9 families (mainly *Cucurbitaceae* and *Fabaceae*).

The vanilla collection includes accessions of the three cultivated species (*Vanilla planifolia, V. pompona* and *V. × tahitensis*) as well as 25 wild relatives and interspecific hybrids. It is one of the most important collections worldwide for the genus *Vanilla*. In recent years, the BRC has contributed to major work on the genetic diversity and evolution of cultivated and wild vanillas, on the elucidation of the mechanisms of biosynthesis and storage of aromatic compounds in the fruits, and on resistance to fusariosis. It is also involved in the creation and selection of improved vanilla genotypes. Since 2018, the BRC Vatel has been coordinating the VaniSeq project carried out by a French public-private consortium to decipher the genome of the main cultivated vanilla species *V. planifolia*.

The three collections of garlic and vegetables are made up of traditional varieties from the southwestern Indian Ocean region, most of which were collected in Reunion Island. These collections meet the challenge of conserving an agricultural and cultural heritage ("legume lontan"), but are also of interest in terms of food diversification in the region.

The BRC Vatel is using four CIRAD facilities in Reunion Island: the laboratories of the Plant Protection Platform and three field stations. The accessions are kept in the form of living collections cultivated in the field or in greenhouses (vanilla, garlic, root and tuber vegetables) or seed collections in cold storage (seed vegetables). Part of the accessions are duplicated by in vitro tissue culture for vanilla, cassava, yam and sweet potato.

Of the 918 living accessions conserved at the BRC Vatel, about 200 are available for distribution. Seed samples (seeds, lianas, bulbs or tubers depending on the species) can be ordered online on the portal of the French tropical BRC network http://intertrop.antilles.inra.fr/Portail/pages/crb-vatel. On average each year, 300 accessions are distributed to around 30 clients, for agricultural, educational, research or recreational use.

The Vatel BRC has been awarded BRC by the GIS IBiSA label since 2009. The collections are managed according to a quality assurance approach and certified under the French standard NFS 96-900 since 2016, then ISO 9001-2015 standard since 2019.

BRC Vegetables (Figure 1K)

The Centre for Vegetable Germplasm (BRC-Leg) is part of the INRAE-GAFL research unit situated in Avignon, Provence (PACA region) (https://www6.paca.inrae.fr/gafl_eng/Vegetable-Germplasm-Centre). It maintains over 10,000 accessions spread across five collections, as follows:

- Eggplant (*Solanum melongena* and relatives, 2,333 accessions): the national collection is part of the multilateral system since the species is contained in Annex 1 of the International Treaty on Plant Genetic Resources for Food and Agriculture (ITPGRFA);
- Pepper (*Capsicum annuum* and related species, 2,173 accessions);
- Tomato (*Solanum lycopersicum* and related species, 3,778 accessions);
- Melon (*Cucumis melo*, 2,332 accessions);
- Lettuce (*Lactuca* spp., 948 accessions).

The genetic resources held by the BRC-Leg are mostly used by French public institutions (research and development), and by breeders of seed companies, who actively collaborate with each other. The accessions are regenerated and described by network associations of public and private partnerships. For each crop, collections are split into two parts: i) the freely available national collection, and ii) the networking collection, access to which is subject to specific conditions. The BRC-Leg coordinates three networks: *Solanaceae* (three crops), melon, and *Lactuca*. It also provides free samples to researchers from foreign public institutions, growers, NGOs and other bona fide users who request the acces-

Figure 1J. A. Field maintenance of the garlic collection at a farm in Petite Ile (Reunion Island). Credit: M. Seguin, CRB Vatel. B. Display of the diversity of vegetable seeds for educational purposes. Credit: C. Charron, CRB Vatel. C. Maintenance of the vanilla collection under insect-proof shade-house. Credit: M. Grisoni, CRB Vatel.

Figure 1K. A. An example of the fruit diversity of *Solanum melongena* (eggplant) and related species maintained at the "CRB-Leg". Credit: CRB-Leg. B. A pepper (*Capsicum*) flower from one of the accessions of the *Capsicum* collection maintained by the BRC "CRB-Leg". Credit: CRB-Leg. C. An example of melon (*Cucurbitaceae*) fruit diversity in the collections of the "CRB-Leg". Credit: CRB-Leg.

sions through the INRAE database (https://urgi.versailles.inra.fr/siregal/siregal/grc.do). This database contains passport data and descriptions of each accession. It is linked to other databases such as Florilège (national database) and Eurisco (European database).

The duty of the BRC-Leg is to carry out morphological descriptions in the open field or in greenhouse. Historically, this activity has mostly included traits related to the harvested product (fruit or leaves). Evaluation has so far typically focused on resistance to pathogens and fruit quality. GAFL scientists are developing research programs to include root traits in the plant descriptions. Both the patrimonial collections and the scientific genetic resources (segregating populations, mutants, etc.) of the BRC-Leg are used for research topics currently including: salt resistance in tomato (ERA-NET root project, https://www.suscrop.eu/projects-first-call/root), or *Bremia* resistance in lettuce (https://www.ecpgr.cgiar.org/european-evaluation-network-eva/eva-networks/lettuce). The BRC-Leg genetic resources are part of the European G2PSol project on biodiversity in the *Solanaceae* (www.g2p-sol.eu).

All seeds are conserved at 5 °C under controlled humidity, and the daily work includes the transfer of the collections to -20 °C for long-term storage. The BRC-Leg is also currently moving towards ISO 9001 quality certification.

Conclusion

In recent years, and more particularly since the implementation of the CBD, the ITPGR, and the Nagoya Protocol, the holders of genetic resources in France have organized themselves around the constitution of networks allowing for the global consideration of common problems and the easy sharing of information.

The management of French horticultural genetic resources has benefited from recent technological advances that have enabled the acquisition of mass data, particularly in the fields of genotyping and phenotyping, thus enriching the intrinsic value of conserved genetic resources. The horticultural BRCs and collections now play an essential role in French agronomic research, particularly for the preservation and enhancement of agrobiodiversity and the agro-ecological transition of agriculture.

Like most agricultural genetic resources, public funding for the conservation of horticultural diversity is often precarious. However, it has tended to gain in sustainability in recent years thanks to a growing institutional awareness of its crucial importance for the food of tomorrow.

The horticultural genetic resources conserved by the French BRCs are under the responsibility of national public organizations that use them for agricultural research and development. They are also widely used in breeding and varietal improvement programs conducted by the private seed and plant sector. The French horticultural BRCs have made particularly significant contributions to the development of banana, clementine, apple and vegetable *Solanaceae* and *Apiaceae* by several seed companies.

Finally, the French BRCs located in tropical environments in the French overseas departments and territories, play a critical role in the preservation of tropical agricultural genetic resources. They contribute to the food security and sovereignty of territories that are particularly threatened by climate change and the standardization of eating habits. This point will be debated during the United Nations Food Systems Summit in October 2021, and also discussed during the 31st International Horticultural Congress (www.ihc2022.org) to be held in Angers (France) from 14 to 20 August 2022.

› Michel Roux-Cuvelier

› Michel Grisoni

› Arnaud Bellec

› Emmanuel Bloquel

› Carine Charron

› Magalie Delalande

› Marine Delmas

› Audrey Didier

› Charles-Eric Durel

› Charles-Henry Duval

› Florence Esnault

› Laurence Feugey

› Emmanuel Geoffriau

› Bouchaïb Khadari

› Sandra Lepers-Andrzejewski

› François Luro

› Cécile Marchal

› Alix Pernet

› Jérémy Salinier

› Marc Seguin

› Rebecca Stevens

› Bernice van Issum-Groyer

› Rémi Kahane

› About the authors

Michel Roux-Cuvelier is a scientist at CIRAD, Joint Research Unit "Genetic Improvement and Adaptation of Mediterranean and Tropical Plants" (AGAP Institute), Petit Bourg, Guadeloupe, French West Indies. He is in charge of the BRC "Tropical Plants". He is involved in international cooperation projects for the conservation and valorization of agricultural plant genetic resources. E-mail: michel.roux-cuvelier@cirad.fr

Michel Grisoni is an agronomist at CIRAD, Joint Research Unit "Plant Populations and Bio-aggressors in Tropical Ecosystems" (UMR PVBMT), Toamasina, Madagascar. He is a trained plant pathologist and has focused his research over the last twenty years on diseases and genetic diversity of vanilla. E-mail: michel.grisoni@cirad.fr

Arnaud Bellec is the Deputy Director of the French Plant Genomic Resources Center (CNRGV), Toulouse, France. He manages the plant genomic resources and is involved in developing tools and methods to characterize the structures of genomes. E-mail: arnaud.bellec@inrae.fr

Emmanuel Bloquel is in charge of the Citrus Biological Resource Center (BRC Citrus) at INRAE - Citrus Experimental Unit, San Giuliano, Corsica. He is also in charge of variety descriptions for European catalog registrations, and works to develop high throughput phenotyping activities by remote sensing within his unit. E-mail: emmanuel.bloquel@inrae.fr

Carine Charron is a scientist at CIRAD, Joint Research Unit "Plant Populations and Bio-aggressors in Tropical Ecosystems" (UMR PVBMT), Saint Pierre, Reunion Island. Her research deals with genomics and molecular biology of tropical plants, with a focus on plant-pathogen interactions and plant genetic diversity. She is in charge of the vanilla collection at the BRC Vatel. E-mail: carine.charron@cirad.fr

Magalie Delalande is an agronomist at INRAE, Research Unit "Genetic Improvement and Adaptation of Mediterranean and Tropical Plants" (AGAP Institute), Montpellier, France. She is specialized in plant phenotyping, working on high throughput aerial imagery by drone, mainly on apple trees. She also has a long experience in the management of genetic resources and collaborates with the BRC Olive Trees. E-mail: magalie.delalande@inrae.fr

Marine Delmas is an engineer at INRAE in the Arboriculture Experimental Unit (fruit and forestry research). She manages the *Prunus* and *Juglans* collections for INRAE in Nouvelle Aquitaine, France. She is a member of the *Prunus* group of the ECPGR, as data manager, and a member of the CTPS Fruit species section since 2020. E-mail: marine.delmas@inrae.fr

Audrey Didier is the national coordinator for plant genetic resources conservation and the technical secretary of the cross section of CTPS dedicated to plant genetic resources conservation and valorisation. E-mail: audrey.didier@geves.fr

Charles-Eric Durel is a scientist at INRAE, Research Institute on Horticulture and Seeds, Angers, France. He is specialized in quantitative genetics and germplasm characterization of pome fruit with particular interest in disease and pest resistance. E-mail: charles-eric.durel@inrae.fr

Charles-Henry Duval is in charge of the "orphan" species safeguarding for the national coordination structure at GEVES. He is also involved in the creation of the two new public-private cooperative networks on beans and onions. E-mail: charles-henry.duval@geves.fr

Florence Esnault is an engineer at INRAE. She works at the Institute of Genetics, Environment and Plant Protection, Ploudaniel,

France. She is specialized in potato genetics and management of genetic resources. E-mail: florence.esnault@inrae.fr

Laurence Feugey is a specialist of pome fruit genetic resources at INRAE, Research Institute on Horticulture and Seeds, Angers, France. She is also in charge of the Distinctness, Uniformity and Stability testing for *Malus* and *Pyrus* varieties. E-mail: laurence.feugey@inrae.fr

Emmanuel Geoffriau is a professor in genetic diversity and agronomy of vegetable crops at L'Institut Agro and researcher at the Research Institute of Horticulture and Seeds, Angers, France. His research deals with genetic diversity, management of genetic resources and genetic determinism combined with environment adaptation of quality traits. He is curator of the French collection of carrot genetic resources. He is a French representative to the ISHS Council and Chair of ISHS Working Group Carrot and other *Apiaceae*. He is vice-president of IHC2022 and Chair of the Scientific Committee. E-mail: Emmanuel.Geoffriau@agrocampus-ouest.fr

Bouchaïb Khadari is a geneticist at the AGAP Institute, CBNMed, Montpellier, France. He is a leader of the research program on olive tree adaptation to climate change. He has a long experience in genetic characterization of olive genetic resources and multiple collaborations with Mediterranean partners. E-mail: bouchaib.khadari@supagro.fr

Sandra Lepers-Andrzejewski has worked at the Etablissement Vanille de Tahiti, in French Polynesia, since 2003. She leads the Research and Development Department, which includes the BRC Vanille de Tahiti. Her research in genomics contributed to the genetic characterization of the Tahitian vanilla diversity, the establishment of a genetic map of Tahitian vanilla, and the breeding of new vanilla varieties. E-mail: sandra.lepers@vanilledetahiti.pf

François Luro is a researcher at INRAE in San Giuliano, Corsica. He is in charge of genetic studies on the diversity and evolution of citrus species and on the expression of agronomic traits or traits of food or cosmetic interest. He is also developing the cryopreservation of citrus seeds from the INRAE-CIRAD collection. E-mail: francois.luro@inrae.fr

Cécile Marchal is an engineer at INRAE, managing the Grapevine BRC in Marseillan (close to Montpellier), France. She is member of the CTPS Grapevine section and expert for DUS exams. E-mail: cecile.marchal@inrae.fr

Alix Pernet is a plant geneticist at INRAE, Research Institute on Horticulture and Seeds, Angers, France. She is particularly interested in the evolution of the diversity of the rose, whether through natural selection or anthropic pressure. E-mail: alix.pernet@inrae.fr

Jérémy Salinier was the scientist in charge of the INRAE Centre for Vegetable Germplasm in Montfavet from 2015 to 2020. He is now working on GR management and valorisation in the Indian Ocean together with the BRC Vatel, at CIRAD, Joint Research Unit "Plant Populations and Bio-aggressors in Tropical Ecosystems" (UMR-PVBMT), Saint-Pierre, Reunion Island. E-mail: jeremy.salinier@cirad.fr

Marc Seguin is a scientist at CIRAD, Joint Research Unit "Plant Populations and Bio-aggressors in Tropical Ecosystems" (UMR PVBMT), Saint-Pierre, Reunion Island. He is the geneticist who developed the genetic diversity and genome mapping research on tropical perennial crops. He has specialized in rubber tree genetics and breeding. He is in charge of the management of the PVBMT plant genetic resources including citrus and maize collections, in addition to the BRC Vatel. E-mail: marc.seguin@cirad.fr

Rebecca Stevens is the researcher managing the INRAE Centre for Vegetable Germplasm in Montfavet, France, part of the Genetics and Breeding of Fruit and Vegetables research unit. She has a particular interest in characterizing the genetic diversity of root system architectural traits of the collections. E-mail: rebecca.stevens@inrae.fr

Bernice van Issum-Groyer is responsible for the administrative follow-up of activities carried out at GEVES by the national coordination for plant genetic resources. E-mail: bernice.vanissum-groyer@geves.fr

Rémi Kahane has been in charge of horticultural research for development at CIRAD in Montpellier, France, since 2002. He was an onion breeder for a farmers' cooperative in France for 15 years, and the Executive Secretary of the Global Horticulture Initiative from 2006 to 2013. He is vice-president of IHC2022 and Chair of the International Committee. E-mail: remi.kahane@cirad.fr

› References

Ahmed, D., Comte, A., Curk, F., Costantino, G., Luro, F., Dereeper, A., Mournet, P., Froelicher, Y., and Ollitrault, P. (2019). Genotyping by sequencing can reveal the complex mosaic genomes in gene pools resulting from reticulate evolution; a case study in diploid and polyploid citrus. Annals of Botany *123* (*7*), 1231–1251. https://doi.org/10.1093/aob/mcz029

Aissiou, F., Laperche, A., Falentin, C., Lodé, M., Deniot, G., Boutet, G., Régnier, F., Trotoux, G., Huteau, V., Coriton, O., et al. (2018). A novel *Brassica rapa* L. genetic diversity found in Algeria. Euphytica *214* (*12*), 241. https://doi.org/10.1007/s10681-018-2318-9

Andriamihaja, C.F., Ramarosandratana, A.V., Grisoni, M., Jeannoda, V., and Besse, P. (2020). The Leafless *Vanilla* species-complex from the South-West Indian Ocean region: a taxonomic puzzle and a model for orchid evolution and conservation research. Diversity *12*, 443. https://doi.org/10.3390/d12120443

Arnau, G., Bhattacharjee, R., Sheela, M.N., Chair, H., Malapa, R., Lebot, V., Abraham, K., Perrier, X., Pétro, D., Penet, L., and Pavis, C. (2017). Understanding the genetic diversity and population structure of yam (*Dioscorea alata* L.) using microsatellite markers. PLoS One *12* (*3*), e0174150. https://doi.org/10.1371/journal.pone.0174150

Bernard, A., Barreneche, T., Donkpegan, A., Lheureux, F., and Dirlewanger, E. (2020). Comparison of structure analyses and core collections for the management of walnut genetic resources. Tree Genetics & Genomes *16*, 76. https://doi.org/10.1007/s11295-020-01469-5

Bonhomme, V., Picq, S., Ivorra, S., Evin, A., Pastor, T., Bacilieri, R., Lacombe, T., Figueiral, I., Terral, J.F., and Bouby, L. (2020). Eco-evo-devo implications and archaeobiological perspectives of trait covariance in fruits of wild and domesticated grapevines. Plos One *15* (*11*), e0239863. https://doi.org/10.1371/journal.pone.0239863

Bouétard, A., Lefeuvre, P., Gigant, R.L., Bory, S., Pignal, M., Besse, P., and Grisoni, M. (2010). Evidence of transoceanic dispersion of the genus *Vanilla* based on plastid DNA phylogenetic analysis. Molecular Phylogenetics and Evolution *55*, 621–630. https://doi.org/10.1016/j.ympev.2010.01.021

Candresse, T., Marais, A., Faure, C., Lefebvre, M., Lacombe, T., and Boursiquot, J.M. (2020). Complete genome sequence of a novel grapevine-infecting member of the genus *Polerovirus*, grapevine polerovirus 1. Archives of Virology *165* (*7*), 1683–1685. https://doi.org/10.1007/s00705-020-04640-4

Chevalier, W., Sitti-Anlati, M., Medeiros Netto Ottoni, M., Dubois-Laurent, C., Huet, S., Aubert, C., Desnoues, E., Navez, B., Cottet, V., et al. (2021). Multisite evaluation of phenotypic plasticity for specialized metabolites, some involved in carrot quality and disease resistance. PLoS ONE *16* (*4*), e0249613. https://doi.org/10.1371/journal.pone.0249613

Cirilli, M., Micali, S., Aranzana, M.J., Arus, P., Babini, A., Barreneche, T., Bink, M.C., Cantin, C.M., Ciacciulli, A., Cos-Terrer, J., et al. (2020). The multi-site PeachRefPop collection: a true cultural heritage and international scientific tool for fruit trees. Plant Physiology *184*, 632–646. https://doi.org/10.1104/pp.19.01412

Curk, F., Ollitrault, F., Garcia-Lor, A., Luro, F., Navarro, L., and Ollitrault, P. (2016). Phylogenetic origin of limes and lemons revealed by cytoplasmic and nuclear markers. Annals of Botany *117*, 565–583. https://doi.org/10.1093/aob/mcw005

Daunay, M.C., Allender, C., Astley, D., Bas, N., van Dooijeweert, W., van Treuren, R., Branca, F., Díez, M.J., Geoffriau, E., Keller, E.R.J., et al. (2011). More efficient conservation and use of vegetable genetic resources in Europe: ECPGR achievements and perspectives. Acta Horticulturae *918*, 405–417. https://doi.org/10.17660/ActaHortic.2011.918.52

Dumas, V., Saurin, N., Destrac-Irvine, A., Dedet, S., Veyret, M., Marchal, C., Ojeda, H., Van Leeuwen, C., and Duchêne, E. (2020). Influence of grape juice extraction methods on basic analytical parameters. Vitis *59*, 77–83. https://doi.org/10.5073/vitis.2020.59.77-83

El Bakkali, A., Essalouh, L., Tollon, C., Rivallan, R., Mournet, P., Moukhli, A., Zaher, H., Mekkaoui, A., Hadidou, A., Sikaoui, L., and Khadari, B. (2019). Characterization of worldwide olive germplasm banks of Marrakech (Morocco) and Cordoba (Spain): towards management and use of olive germplasm in breeding programs. PLoS One *14* (*10*), e0223716. https://doi.org/10.1371/journal.pone.0223716

Esnault, F., Solano, J., Perretant, M., Hervé, M., Label, A., Pellé, R., Dantec, J.P., Boutet, G., Brabant, P., and Chauvin, J.E. (2014). Genetic diversity analysis of a potato (*Solanum tuberosum* L.) collection including Chiloé Island landraces and a large panel of worldwide cultivars. Plant Genetic Resources: Characterization and Utilization *12* (*1*), 74–82. https://doi.org/10.1017/S1479262113000300

Esnault, F., Pellé, R., Dantec, J.P., Bérard, A., Le Paslier, M.C., and Chauvin, J.E. (2016). Development of a potato cultivar (*Solanum tuberosum* L.) core collection, a valuable tool to prospect genetic variation for novel traits. Potato Research *59* (*4*), 329–343. https://doi.org/10.1007/s11540-016-9332-x

Geoffriau, E. (2020). Genetic diversity and main carrot types. In Carrots and Related Apiaceae Crops, 2nd edn, E. Geoffriau, and P.W. Simon, eds. (CABI), p.47–60.

Khadari, B., and El Bakkali, A. (2018). Primary selection and secondary diversification: two key processes in the history of olive domestication. International Journal of Agronomy ID 5607903. https://doi.org/10.1155/2018/5607903

Khadari, B., El Bakkali, A., Essalouh, L., Tollon, C., Pinatel, C., and Besnard, G. (2019). Cultivated olive diversification at local and regional scales: evidence from the genetic characterization of French genetic resources. Front. Plant Sci. *10*, 1593. https://doi.org/10.3389/fpls.2019.01593

Lassois, L., Denancé, C., Ravon, E., Guyader, A., Guisnel, R., Hibrand-Saint-Oyant, L., Poncet, C., Lasserre-Zuber, P., Feugey, L., and Durel, C.-E. (2016). Genetic diversity, population structure, parentage analysis, and construction of core collections in the French apple germplasm based on SSR markers. Plant Molecular Biology Reporter *34*, 827–844. https://doi.org/10.1007/s11105-015-0966-7

Lepers-Andrzejewski, S., Causse, S., Caromel, B., Wong, M., and Dron, M. (2012). Genetic linkage map and diversity analysis of Tahitian vanilla (*Vanilla ×tahitensis*, Orchidaceae). Crop Science *52*, 795–806.

Liorzou, M., Pernet, A., Li, S., Chastellier, A., Thouroude, T., Michel, G., Malécot, V., Gaillard, S., Briée, C., Foucher, F., et al. (2016). Nineteenth century French rose (*Rosa* sp.) germplasm shows a shift over time from a European to an Asian genetic background. J. Exp. Bot. *67*, 4711–4725. https://doi.org/10.1093/jxb/erw269

Lopez Arias, D.C., Chastellier, A., Thouroude T., Bradeen, J., Van Eck, L., De Oliveira, Y., Paillar, S., Foucher, F., Hibrand-Saint Oyant, L., and Soufflet-Freslon, V. (2020). Characterization of black spot resistance in diploid roses with QTL detection, meta-analysis and candidate-gene identification. Theor. Appl. Genet. *133* (*12*), 3299–3321. https://doi.org/10.1007/s00122-020-03670-5

Lubinsky, P., Cameron, K.M., Molina, M.C., Wong, M., Lepers-Andrzejewski, S., Gomez-Pompa, A., and Kim, S.C. (2008). Neotropical roots of a polynesian spice: the hybrid origin of Tahitian vanilla, *Vanilla tahitensis* (Orchidaceae). American Journal of Botany *95* (*8*), 1040–1047.

Luro, F., Bloquel, E., Tomu, B., Costantino, G., Tur, I., Riolacci, S., Varamo, F., Ollitrault, P., Froelicher, Y., Curk, F., and Pailly, O. (2017). The INRA-CIRAD citrus germplasm collection of San Giuliano, Corsica. In AGRUMED: Archaeology and History of Citrus Fruit in the Mediterranean: Acclimatization, Diversifications, Uses, V. Zech-Matterne, and G. Fiorentino, eds. (Naples: Publications du Centre Jean Bérard), p.243–261. ISBN: 9782918887775. https://doi.org/10.4000/books.pcjb.2107

Martin, G., Cardi, C., Sarah, G., Ricci, S., Jenny, C., Fondi, E., Perrier, X., Glaszmann J.-C., D'Hont, A., and Yahiaoui, N. (2020). Genome ancestry mosaics reveal multiple and cryptic contributors to cultivated banana. The Plant Journal *102*, 1008–1025. https://doi.org/10.1111/tpj.14683

Martinez Flores, F., Crespo, M.B., Geoffriau, E., Allender, C., Ruess, H., Arbizu, C., Simon, P., and Spooner, D.M. (2019). Extended studies of interspecific relationships in *Daucus* (Apiaceae) using DNA sequences from ten nuclear orthologues. Botanical Journal of the Linnean Society *191*, 164–187.

Mougin, C., Artige, E., Marchand, F., and Mondy, S. (2018). BRC4Env, a network of Biological Resource Centres for research in environmental and agricultural sciences. Environ. Sci. Pollut. Res. *25*, 33849–33857. https://doi.org/10.1007/s11356-018-1973-7

Muranty, H., Denance, C., Feugey, L., Crepin, J.L., Barbier, Y., Tartarini, S., Ordidge, M., Troggio, M., Lateur, M., Nybom, H., et al. (2020). Using whole-genome SNP data to reconstruct a large multi-generation pedigree in apple germplasm. BMC Plant Biol. *20*. https://doi.org/10.1186/s12870-019-2171-6

Pavis, C. (2015). Towards Safer Plant Genetic Resources through improved viral diagnostics (SafePGR). Final outreach report. https://hal.inrae.fr/hal-02800498

Roux-Cuvelier, M. (2017). Contribution à la conservation et la valorisation de l'agrobiodiversité à l'île de la Réunion. Thèse de doctorat (Montpellier SupAgro), pp.138.

Salinier, J., Daunay, M.-C., Goussopoulos, J., Gros, C., and Lefebvre, V. (2019a). The fascinating diversity of pepper and eggplant collections held at the INRA centre for vegetable germplasm. Paper presented at: Innovations of Genetics and Breeding of Capsicum and Eggplant. 17th Eucarpia Meeting on Capsicum and Eggplant (Avignon, France: INRA).

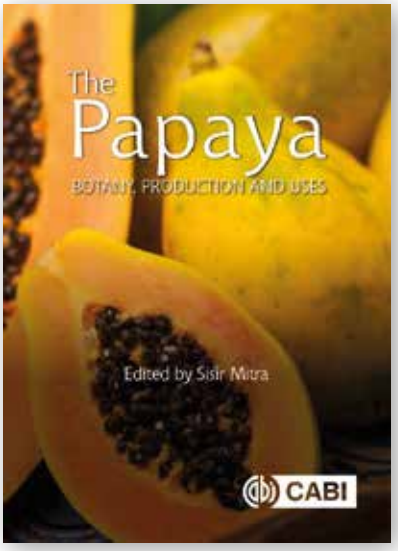
Salinier, J., Daunay, M.-C., Talmot, V., Lecarpentier, C., Pagès, L., Bardel, A., Fournier, C., Torres, M., and Stevens, R. (2019b). Root architectural trait diversity in aubergine (*Solanum melongena* L.) and related species and correlations with plant biomass. Crop Breed. Genet. Genom. *1*, e190011. https://doi.org/10.20900/cbgg20190011

Umber, M., Filloux, D., Gélabale, S., Gomez, R.-M., Marais, A., Gallet, S., Gamiette, F., Pavis, C., and Teycheney, P.-Y. (2020). Molecular viral diagnosis and sanitation of yam genetic resources: implications for safe yam germplasm exchange. Viruses *12*, 1101. https://doi.org/10.3390/v12101101

› New books, websites

Book reviews

The books listed below are non-ISHS-publications. For ISHS publications covering these or other subjects, visit the ISHS website www.ishs.org or the *Acta Horticulturae* website www.actahort.org



Mitra, S., ed. (2020). The Papaya: Botany, Production and Uses (Wallingford, Oxfordshire, UK; Boston, MA, USA: CABI), pp.286. ISBN 9781789241907 (hardback). £95.00 / €110.00 / $130.00.

SPECIAL OFFER: A 25% discount will be received by entering the code "CCISHS25" when ordering through https://www.cabi.org/bookshop/book/9781789241907/

Papaya is the third most widely produced tropical fruit worldwide, grown commercially in more than 60 countries. Production in the last decade has increased at a significant annual rate, reaching 13.7 MT in 2019 due to a noticeable rise in global demand. Although most of the global papaya production is consumed in producing countries, international trade is increasing rapidly, and its cultivation has spread from its areas of origin.

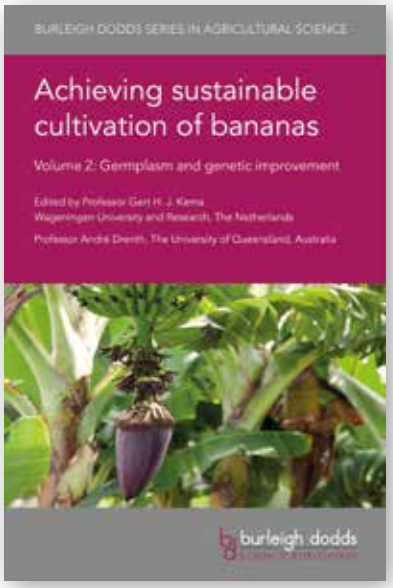
Though there have been numerous published research articles over the past fifty years about the biology, production, and utilization of papaya, an exhaustive compendium that communicates the extensive knowledge about the papaya plant has been lacking. This book provides a truly international and comprehensive look at the papaya. Forty-three authors with remarkable experience working in many different countries have participated in the book's development. They give the reader a comprehensive knowledge of papaya biology, cultivation, and production. In particular, the division of this book into chapters is very specific and delivers new information about all aspects. Emphasis is given to the effects of physiology and growing environment on productivity, plant development and cultivation: propagation, irrigation, plant water relations, and nutrition are treated in separate chapters. The importance of greenhouse cultivation as a technique used in mild-subtropical countries is also underlined.

A large portion of the book is dedicated to propagation, varieties, and crop improvement with a modern vision of recent breeding technologies. The production was examined from flowering followed by fruit set, development, maturity, ripening, through to postharvest operations.

Finally, three chapters are dedicated to abiotic and biotic stresses: physiological disorders, insects, and nematode pests with an eye to the problems that affect this plant such as viruses, plant resistance, and possible solutions to these problems.

Overall, the coverage of every aspect of papaya history, physiology, culture, and marketing is comprehensive in this book. 'The Papaya' is a great reference for the intended audience of the series, which includes researchers, academics, teachers, students, as well as progressive growers, advisors and end-product users.

Reviewed by Vittorio Farina, University of Palermo, Italy



This title is accompanied by a companion volume: Achieving Sustainable Cultivation of Bananas, Volume 1: Cultivation Techniques.

Kema, G.H.J., and Drenth, A., eds. (2020). Achieving Sustainable Cultivation of Bananas, Volume 2: Germplasm and Genetic Improvement (Cambridge, UK: Burleigh Dodds Science Publishing), pp.402. ISBN 9781786763440 (hardback). £170.

SPECIAL OFFER: Benefit from 25% off your purchase of either Volume 1 or Volume 2 if purchased via www.bdspublishing.com. Enter code "CHRON25" at checkout to receive this discount. Discount expires August 31, 2021.

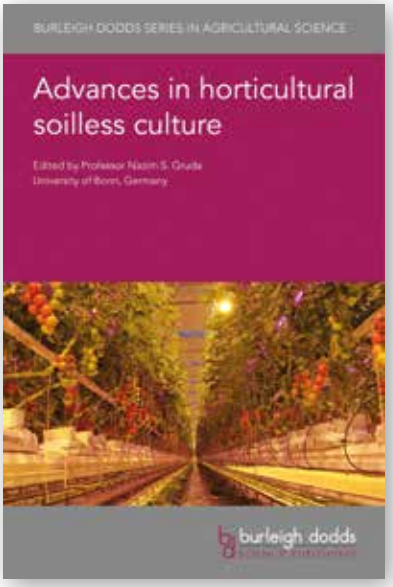
Burleigh Dodds Science publishes a series that is focused on sustainable cultivation of various crops, amongst other topics also focusing on sustainable development and production. The first volume, *Achieving Sustainable Cultivation of Bananas, Volume 1: Cultivation Techniques*, described current challenges in banana production, a survey of improving cultivation practices right across the value chain, and, finally, an assessment of how to measure and improve the environmental impact of banana cultivation. In this, the second volume of three in the series, the importance of widening the genetic base to mitigate emerging challenges in banana production globally, is presented.

Bananas are widely produced in tropical and subtropical regions around the world and they are reportedly the world's most traded fruit. However, as a result of the narrow genetic base, banana crops are becoming increasingly susceptible to biotic and abiotic stresses that are compounded by the increasing negative effects of climate change. Banana improvement therefore not only requires an increased tolerance to pests and diseases, but at the same time, existing yield and quality needs to be retained, or even improved. Breeding improved cultivars is therefore underpinned by understanding the genetics. Chapter 1, which has been inserted prior to Parts 1-3, therefore provides an extensive overview of genetic improvement of banana over the last ten decades. It includes the initial improvement strategies undertaken and highlights the fact that

banana cultivation still hinges on a relatively small pool of cultivars. Nevertheless, a number of approaches, including conventional breeding, non-conventional methods such as mutation breeding, genetic transformation, marker-assisted selection, genomics and molecular breeding, have been investigated in efforts to improve banana varieties that perform under sub-optimal circumstances. A summary of future trends in banana genetic improvement lays the foundation for the subsequent Parts. Part 1 provides a good overview of the classification of bananas and includes cytogenetics, banana cultivar identification, conservation, and exploitation of collections. It concludes with a reflection on steps towards a better understanding of banana taxonomy and cultivar identification. Part 2 expands on banana and plantain germplasm collections, their collection and use, including a chapter focusing on African banana and plantain landraces. The final chapter in Part 2 stresses the importance of safe dissemination of germplasm to ensure that diseased plant material is not inadvertently distributed throughout the world. Finally, Part 3 expounds upon sustainable, effective genetic improvement using various breeding strategies, while taking into account the challenges of fertility and the narrow genetic base. Chapters focusing on newer technologies describe not only their potential but also their challenges in terms of developing superior cultivars.

This second volume therefore provides a good overview of the status of genetic improvement of banana, highlighting both the challenges and potential to ensure sustainable cultivation. Each chapter of the book has an extensive reference list, which guides the reader towards further literature on each topic, making this second volume a comprehensive foundation of knowledge on which future banana improvement strategies can be built.

Reviewed by Karin Hannweg, Chair ISHS Division Tropical and Subtropical Fruit and Nuts



Gruda N.S., ed. (2021). Advances in Horticultural Soilless Culture (Cambridge, UK: Burleigh Dodds Science Publishing Ltd), pp.442. ISBN 978-1-78676-435-5 (hardback). £160.

SPECIAL OFFER: Benefit from 25% off your purchase if purchased via www.bdspublishing.com. Enter code "CHRON25" at checkout to receive this discount. Discount expires August 31, 2021.

In this book, the distinguished editor, along with many eminent co-authors, provides readers with the latest references and a comprehensive collection of updated information on various aspects of advanced soilless culture. This book will be a welcome global resource in this rapidly expanding field of horticultural science and commercial practice. It covers three main areas: a) materials, b) technologies, c) case studies, with both basic and applied research findings and practical application to deliver a deeper understanding on the practice of soilless culture systems (SCS). Most chapters end with a summary, conclusions, references, and future prospects providing readers with specific web links and the latest literature. The first chapter, "Soilless culture systems and growing media in horticulture: an overview," provides the reader with a detailed introduction, overview of why, what, who, how, and where to look to understand soilless culture systems (SCS), challenges and opportunities with future trends. Part 1 focuses on an informative materials introduction through explaining plant root behaviour and management in various soilless culture growing media. The discussion includes inorganic materials, synthetic organic materials and peat, as well as the development of these substrates. A key focus of this chapter is understanding and optimising the physical, chemical and biological properties of growing media for soilless culture. Part 2 looks at soilless culture technologies with an excellent introduction into both liquid and solid media production systems. It then discusses the irrigation and fertigation techniques, advances in nutrient management and modelling, advances in hydroponic design for plant cultivation, and concludes with optimising product quality in SCS. The final part (Part 3) is a series of case studies that includes learning in advances in SCS for tomatoes and other fruiting vegetables, strawberry production and ornamental production. These three case studies are important additions to this book because they apply both theory and practical application to common crops produced in SCS. The book has excellent insights into how commercial crops are typically designed and managed by focussing on a deeper understanding of the necessary integration of plant physiology and environmental management strategies for commercial success. This part also looks at how modern assimilation lighting systems (e.g., light emitting diodes, LED) are playing a bigger and more important role to optimise plant yield and quality as a future foil to degrading soils and climate change. This book provides an informative global perspective of soilless culture systems around the world and gives a future outlook on the challenges ahead as soilless culture is rapidly rising around the world due to its ability to deliver reliable yield, quality and produce uniformity, and is very much a technology-driven industry. However, we should also pay attention to best horticultural principles and this book promises to bring together the current best practice in technology and SCS horticulture to create an important industry reference for all participants.

Reviewed by Graeme Smith, Chair ISHS Working Group Hydroponics and Aquaponics

› IV International Symposium on Horticulture in Europe (SHE2021), VIII International Symposium on Human Health Effects of Fruits and Vegetables (FAVHEALTH2021), V International Humulus Symposium

› Welcome screen of the symposia

Professor Dr. Jens Wünsche, the initiator and convener of the IV International Symposium on Horticulture in Europe in 2021, envisioned this meeting to be face-to-face in the heart of the city of Stuttgart. The planned exciting side program and interesting excursions included South Germany's most important fruit, vegetable, wine, and hop production sites. However, due to the COVID-19 pandemic, the event was first postponed from 2020 to 2021, and then transformed into the first virtual symposium on horticultural science in Europe. Many aspects of the transformation resulted in new challenges. We had to completely re-organize the event, introducing our vision to the global horticultural science community, to keynote speakers, and sponsors. Despite, or maybe because of, the virtual format of the combined three symposia, it was a great success. It was supported by excellent presentations and active discussions by our curious and self-catering participants. Altogether, we had 326 registered attendees from 44 countries including 71 young minds. Overall, the symposia had 291 oral presentations and 112 posters. The breakdown of these numbers was, for the IV International Symposium on Horticulture in Europe: 192 presentations and 73 posters; the V International Humulus Symposium: 47 presentations and 19 posters; the VIII International Symposium on Human Health Effects of Fruits and Vegetables: 41 presentations and 14 posters; and the Annual Convention of the German Society for Horticultural Science (DGG): 11 presentations and 6 posters. As in a traditional live event, the symposia were divided into several sessions or "live streams," with an additional sponsor day prior to the meeting, with its own workshops and presentations.

The symposium's slogan "Advancing together: Enhancing quality of life through HortScience" summarized the main topics addressed during presentations and workshops. Topics dealt with global warming, fruit quality, breeding, market trends, emerging pests and diseases, water scarcity, soil fertility and plant nutrition, peat substitutions, sustainable greenhouse production, Horticulture 4.0 and digitalization. Considering that this symposium was the first international and fully virtual symposium on horticulture in Europe, it was an active step towards digitalization by itself. For many of our participants, it was the first virtual event of this dimension. At the end of the symposium, we received very positive feedback from the participants. They stated that the welcome screen, live-stream sessions, and the platform for online discussions of the symposia were well-designed, intuitive, and interactive.

The social aspect of person-to-person discussions or coffee breaks could not be fully replaced with such a virtual format. The participants made use of our networking tool and could hold private discussions via video calls in addition to the meeting rooms. One prominent advantage of the virtual symposia was the chance to watch all the presenta-

› Screenshot of an online live presentation from the V International Humulus Symposium (Andreja Cerenak).

› Winners of the ISHS Prof. Jens Wünsche Young Minds Awards at the IV International Symposium on Horticulture in Europe: A) Nadine Sommer for the best oral presentation, B) Christian Frerichs for the best poster.

› Winners of the ISHS Prof. Jens Wünsche Young Minds Awards at the VIII International Symposium on Human Health Effects of Fruits and Vegetables: A) Ruth Kleine-Kalmer for the best oral presentation, B) Bonga Ngcobo for the best poster.

tions and posters up to three months after the event. Altogether, this included more than 100 hours of video material including high level keynotes, oral presentations, and discussions as well as audio comments for each poster presented. All these and many other technical solutions towards digitalization of the events led to the registration cost, which was similar to that for organizing a classical symposium. Behind the scenes of each of the seven live streams were at least two technicians and one moderator, as well as people to assist the presenters. Only a few presenters took the opportunity to pre-record their talk. Most of the participants preferred to hold their presentation live, even though the video streams sometimes had issues with connectivity, video or audio quality. Despite these challenges, the technical team routinely managed all issues so that the participants could concentrate on the content and discussions.

For future digital events, the monetary aspect of the event needs to be reconsidered – problems like sharing account data among colleagues or viewing presentations together with several colleagues in front of one monitor, artificially lower the number of participants, which makes it difficult for the convener to calculate a fair and cost-covering symposium fee. In connection to all this, a large amount of financial support from our sponsors and appreciative participants made this online event possible in these hardly predictable social conditions. In the end, these solutions were temporary. Physical events of this dimension could be possible again. Based on our experience we think that some, especially international, meetings on specific topics could benefit from a virtual format, because it saves travel and accommodation costs. This might attract more participants. Meetings with many participants may be organized as hybrid events to allow more exclusive keynote speakers or participants for whom it might not be possible to travel, and for convenient recorded asynchrony to consume the presentations individually at any suitable day and time.

Winners of the ISHS Prof. Jens Wünsche Young Minds Awards were:

- IV International Symposium on Horticulture in Europe: Nadine Sommer from the University of Hohenheim, Germany, for the best oral presentation entitled “Phytoextraction of mercury-contaminated soils using legumes” and Christian Frerichs from the Osnabrück University of Applied Science, Germany, for the best poster entitled “Determination of ammonia exposure of potted herbs in organic cultivation”;
- VIII International Symposium on Human Health Effects of Fruits and Vegetables: Ruth Kleine-Kalmer from the Osnabrück University of Applied Science, Germany, for the best oral presentation entitled “Consumer behavior analysis for selenium biofortified apples and implications for conducting a market test in food retailing” and Bonga Ngcobo from the University of KwaZulu-Natal, South Africa, for the best poster entitled “Effect of light combined with heat treatment on colour development and fruit quality of cherry tomato (*Solanum lycopersicum*)”;
- V International Humulus Symposium: Pauline Seeburger from the University of Hohenheim, Germany, for the best oral presentation entitled “Genetic variation within the core promoter of the bitter acid biosynthesis genes of hop partly explain different levels of bitter acids between cultivars” and Joshua Havill from the University of Minnesota, USA, for the best poster entitled “Mapping the powdery mildew resistance locus R1”.

The organizers would like to thank all those who supported this event in any way or enriched it through their active participation. Finally, we thank the professional conference organization team from INTERPLAN and their commitment for making this event a success.

Henryk Flachowsky, Anton Milyaev and Michael Helmut Hagemann

› Winners of the ISHS Prof. Jens Wünsche Young Minds Awards at the V International Humulus Symposium: A) Pauline Seeburger for the best oral presentation, B) Joshua Havill for the best poster.

› Contact

Prof. Dr. Henryk Flachowsky, Pillnitzer Platz 3a, 01326 Dresden, Germany, e-mail: henryk.flachowsky@julius-kuehn.de

Anton Milyaev, University of Hohenheim, Department of Crop Science, Section Crop Physiology of Specialty Crops, Emil-Wolff-Str. 25, 70599 Stuttgart, Germany, e-mail: anton.milyaev@uni-hohenheim.de

Dr. Michael Helmut Hagemann, University of Hohenheim, Department of Crop Science, Section Crop Physiology of Specialty Crops, Emil-Wolff-Str. 25, 70599 Stuttgart, Germany, e-mail: michael.hagemann@uni-hohenheim.de

› IV International Symposium on Woody Ornamentals of the Temperate Zone

Division Ornamental Plants #ishs_dorn
Division Landscape and Urban Horticulture #ishs_durb
Division Plant Genetic Resources and Biotechnology #ishs_dbio
Division Protected Cultivation and Soilless Culture #ishs_dpro

The IV International Symposium on Woody Ornamentals of the Temperate Zone proved to be a successful scientific event, though it had to be held entirely online. It was characterized by the participation of scientists from 12 countries, including countries outside Europe, such as Australia, USA, Japan, and China.

Due to the international health emergency, the symposium was postponed twice, and the organization of a virtual worldwide symposium was challenging. However, feedback provided by some participants confirmed it as a positive experience during this year of lockdown, offering the opportunity to interact with colleagues from other countries, sharing the same research interests.

The symposium opened with a welcome and greetings from the conveners, Professor Valentina Scariot and Professor Gabriele Beccaro, followed by greetings from the ISHS representative, Dr. Margherita Beruto, and those of the SOI president, Professor Massimo Tagliavini. Two keynote speakers were invited to introduce the two days of the symposium: Daniela Romano, Professor of Horticulture and Floriculture at the University of Catania (Italy), and Alessio Fini, Professor of Arboriculture at the University of Milan (Italy).

The thematic areas covered were:

- Genetic resources, conservation, and breeding. Ten oral presentations and five posters illustrated, among various subjects, the use of new technologies, such as drones, in obtaining better data; the development of new phenotypes obtained by crossbreeding techniques; genetic evaluation of species not yet fully studied; and the investigation of the possibility to obtain new woody ornamentals varieties.
- Cultivation techniques and plant growth. This thematic area was covered with five oral presentations and six posters. Studies on the promotion of biomass and root growth, on the enhancement of pH tolerance of specific plant species, and physiological studies on aerosol and water stresses were presented.
- Multifunctionality and ecosystem services. Eight oral presentations and six posters presented the importance of the selection of tree and hedge species in urban areas for their ecosystem services, including microclimate regulation, CO_2 absorption, pollution mitigation, biodiversity provision, nutrition (edible flowers and other ornamental plants are a source of bioactive compounds for human health), social value, and their contribution to economy.
- Climate change, pests, and diseases. This thematic area included eight oral presentations and four posters, mainly focusing on appropriate species and cultivar choices for a better water management, heat tolerance molecular breeding, assessment of fungal and bacterial species reported as pathogens of woody ornamentals, and plant species responses to environmental stress caused by the changing climate.

Even though there were different time zones, most of the oral presentations were performed live; regarding the posters, a video was shown for each slot. The chat was widely used for greetings among the various participants, but also to ask questions, which were then taken up by the chairmen and chairwomen during the discussion time.

During coffee breaks, videos of the host city, Turin, were shown, to take the participants on a virtual journey and allow them to vir-

› Participants of the symposium.

tually visit the location of the symposium. Videos of the host university and department were also shown, as well as videos of the partner nurseries that were supporting the symposium and would be included in the technical visits of the post-symposium tour.
The symposium also recognized young scientists through the ISHS Young Minds Awards. Two participants were awarded: Dr. Bing Liu from Zhejiang University, China, for the best oral presentation entitled "The effects of humic acid on morphological traits, root growth, and nutrition absorption of azalea seedlings", and Dr. Kento Terada from Osaka City University, Japan, for the best poster entitled "Plant virus causing variegation in camellia".
Due to the different time zones, not all participants were able to follow the symposium online. For this reason, the symposium was recorded, and each participant was provided with the link to the recordings in order to listen to and follow the missed presentations. A picture of the participants online was also taken.

› Winners of the ISHS Young Minds Awards: A) Bing Liu (best oral presentation), B) Kento Terada (best poster).

The IV International Symposium on Woody Ornamentals of the Temperate Zone proved to be successful though online; the hope of the participants was that future symposia will occur in person, sharing moments of conviviality together between colleagues.

Nicole Mélanie Falla

› Contact

Nicole Mélanie Falla, Department of Agricultural, Forest and Food Sciences, University of Torino, Italy, e-mail: nicolemelanie.falla@unito.it

› III International Symposium on Soilless Culture and Hydroponics

Division Protected Cultivation and Soilless Culture #ishs_dpro
Division Precision Horticulture and Engineering #ishs_deng

The III International Symposium on Soilless Culture and Hydroponics was held virtually, from 19-22 March 2021. The symposium was initially scheduled to take place 1-4 November 2020, in Limassol, Cyprus, but due to the COVID-19 pandemic restriction measures, the conveners, the organizing committee and the ISHS decided to switch the symposium to an online event. The symposium was organized by the Cyprus University of Technology-CUT (Department of Agricultural Sciences, Biotechnology and Food Science) and the University of Turin (Italy) (Department of Agricultural, Forest and Food Sciences) under the aegis of the ISHS. The conveners of the symposium were Dr. Nikolaos Tzortzakis from CUT and Professor Silvana Nicola from the University of Turin. A total of 79 participants, representing 22 countries, attended the symposium. The 3-day schedule consisted of 6 invited lectures, 29 oral presentations, 43 posters (21 were presented as 3-minute flash poster presentations), 4 roundtable discussion forums and 1 ISHS Working Group business meeting. The symposium was focused on the innovation and advanced technology for circular horticulture and was sponsored by SQM (golden sponsor) and Urbinati (bronze sponsor).
The symposium started with the opening remarks by the conveners, after the welcom-

› Conveners Dr. Nikolaos Tzortzakis (top left) and Professor Silvana Nicola (bottom right) and winners of ISHS Young Minds Awards Mathilde Eck (top right, best oral presentation) and Raquel Camacho-Arevalo (bottom left, best poster) during virtual ceremony.

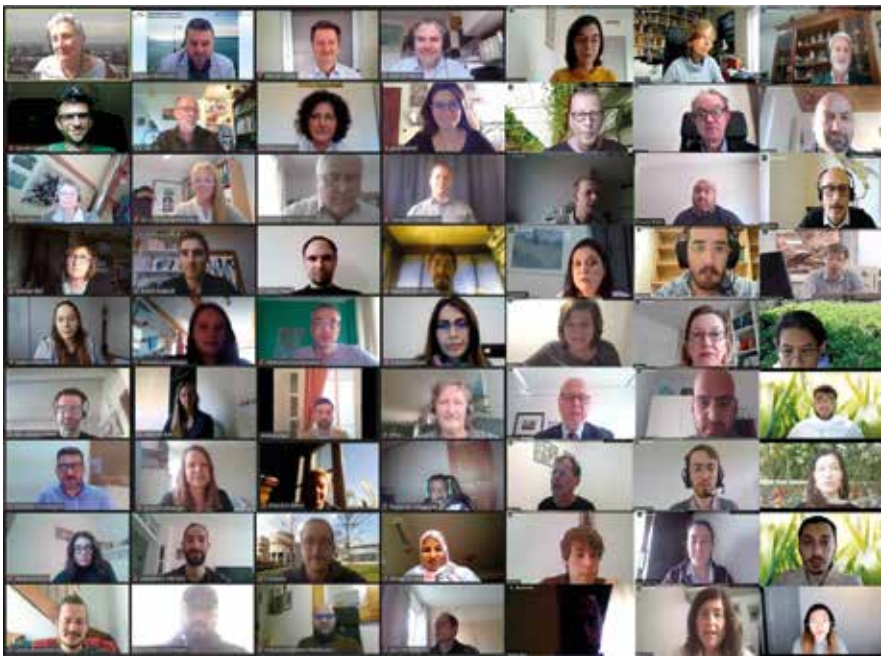
ing speech of the Rector of CUT. Professor Stefania De Pascale, Chair of ISHS Division Protected Cultivation and Soilless Culture, also welcomed the participants. Session I concerning "Indoor Farming and Microclimate" started with the invited lecture given by Professor Leo F.M. Marcelis (Wageningen University, The Netherlands). Presentations praised indoor farming as an excellent model for scientific studies since all the inputs can be manipulated (plant nutritional status, biofortification). The major factors were the full control of light spectrum, energy costs, and microclimate. "Soilless Culture and Substrate" was the topic of Session II, where it was made clear that different substrates require specific irrigation regimes to obtain optimal crop development and that throughout Europe, closed loop systems gain more and more attention nowadays. Two discussion forums ("Water and Nutrition Management" and "New Technology") followed. Sustainability was discussed thoroughly; definitions and a list of parameters that need to be defined were clearly noted, along with simulation models that can play an important role in scenario studies for decision making. In addition, cutting edge technologies were discussed regarding sensors, spectra, water treatment, and energy saving. Session III (Biocontrol and Bionutrition in Soilless Culture) started after the first part of flash poster presentations, with invited speaker Professor Monica Hofte (University of Ghent, Belgium), who gave a lecture about the biological control of root pathogens. Oral presentations followed, emphasizing that disinfection and plant pathogen treatments are under research, and extra effort has to be made because no optimal solution has yet been found.

The second day started with the invited lecture given by Professor Dimitrios Savvas (Agricultural University of Athens, Greece) for the Session IV on "Nutrient Solution Management and Salinity". The rising interest in hydroponics as a means for improving produce quality (bioactive compounds) and for reducing environmental impact were presented through very promising approaches (tailor-made nutrient solution recipes and sensors). The challenge of organic fertilizers in hydroponics was additionally featured here, preparing the floor for the Discussion Forum 3 that followed, on "Organic Hydroponics". The discussion revealed that while these systems (certified organic in the US) cannot obtain the organic label in the EU and many other countries, there is an increasing interest toward these systems and toward the use of organic fertilizer sources in soilless cultivation. Many of the challenges of organic hydroponic systems are similar to those of aquaponic systems, introducing in that way the Discussion Forum 4, and Session V, on "Aquaponics and Urban Farming". Professor Haissam Jijakli (University of Liege, Belgium) started the session as invited speaker with a talk on Urban Agriculture and innovative examples of new agricultural food systems. The session showed that the interest in new applications of soilless cultivation is growing in spite of legal and certification obstacles and that there is a need for in-depth understanding of microbiology of nutrient transformations and of beneficial effects, as well as the quality of resulting crops. Day 3 started with Session VI (Biofortification and Biostimulants), with invited speaker Professor Stefania De Pascale (University of Naples, Italy), who gave a lecture on chemical eustress and biofortification. The session was focused on a series of parameters (salinity, temperature, solar radiation) and legislation that affect quality and other attributes of cultivars and fresh produce. Session VII (New Growing Systems) hosted the invited lecture of Professor Silvana Nicola (University of Turin, Italy), providing insights on the latest applications of promising hydroponic systems (FGS, NGS).

The symposium ended with the Industrial/Working Group meeting and the closing ceremony. During the closing ceremony, the ISHS certificates and medals were given online to the conveners by Professor Stefania De Pascale and the ISHS Young Minds Awards were announced by the conveners and given to Mathilde Eck (University of Liege, Belgium) for the best oral presentation entitled "Microorganisms in aquaponics: insights on their functions and the kinetics of their communities' evolution over the course of a full lettuce growth cycle," and to Raquel Camacho-Arevalo (Autonomous University of Madrid, Spain) for the best poster presentation entitled "Uptake of tetracyclines and sulfonamides in hydroponic cultures of lettuce and carrot." The awards were accompanied with a prize of 300 euros per awardee, sponsored by the Organizing Committee. In addition, the conveners gave a Special Recognition of Appreciation to Dr. Constantinos Economakis for his outstanding contribution in hydroponic research in Greece.

The next International Symposium on Soilless Culture and Hydroponics will be scheduled at the XXXI International Horticultural Congress in August 2022, in Angers, France (www.ihc2022.org).

Nikolaos Tzortzakis and Silvana Nicola



› Participants of the symposium during the "virtual" photo.

› Contact

Dr. Nikolaos Tzortzakis, Department of Agricultural Sciences, Biotechnology and Food Science, Cyprus University of Technology, Lemesos, 3603, Cyprus, e-mail: nikolaos.tzortzakis@cut.ac.cy

Prof. Silvana Nicola, Department of Agricultural, Forest and Food Sciences, VEGMAP, University of Turin, 10090, Italy, e-mail: silvana.nicola@unito.it

From the Secretariat

› New ISHS members

ISHS is pleased to welcome the following new members:

New Individual Members

Afghanistan: Assist. Prof. Ziaurrahman Hejazi; **Australia:** Mr. David Hamilton, Mr. Levi Nupponen, Mr. Ian Rankine, Mr. Geoffrey Story, Mr. Bi Zheng Tan, Dr. Peter Taylor; **Austria:** Mr. Günther Kriechhammer; **Belgium:** Ms. Ann Gomand, Ms. Ann Schenk, Mr. Edwin Toune, Jonas Verellen; **Brazil:** Ms. Maria Teresa Gomes Lopes; **Canada:** Mr. Mathieu Allaire, Tori Ames, Laurent Boucher, Mr. Alex Cornel; **Chile:** Gerardo Arredondo, Maria Bustos, Mr. Cristian Hernández, Dr. Jorge Medina, Maria Paz Roses; **China:** Yukuo Li, Prof. Zhande Liu; **Chinese Taipei:** Dr. Su-Chiung Fang; **Colombia:** Ms. Camila Andrea Avila Ortiz; **Costa Rica:** Assoc. Prof. Pablo Bolanos-Villegas; **Ecuador:** Prof. Dr. John Franco-Rodríguez; **Finland:** Dr. Riikka Räisänen; **France:** Assoc. Prof. Benjamin Bois, Dr. Pierre Joram, Dr. Kevin Morel, Mr. Bogdan Padiu, Prof. David Rousseau, Mr. Adrien Servent, Ms. Silvia ten Have-Lopez; **Georgia:** Mr. Levan Mumladze; **Germany:** Ms. Anita Anita, Annabel Baumgartner, Eckhard Krüger, Marie Ohmes, Maren Stollberg; **Ghana:** Dr. Alfred Darkwa; **Greece:** Prof. Stavros Sotiropoulos, Dr. Georgia Tanou; **Hong Kong:** Alexis C; **India:** Mr. Ashok Jain, Mr. Ranjan Sinha; **Indonesia:** Dr. Diny Dinarti, Zainuri Hanif, Dr. Ani Kurniawati, Dr. Megayani Sri Rahayu; **Ireland:** Mr. Tom Cunningham, Assist. Prof. Mary Harty, Ms. Caroline Lewis; **Israel:** Prof. Dr. Ellen Graber, Dr. Lior Rubinovich, Dr. Vivekanand Tiwari, Ms. Maya Weinstein; **Italy:** Dr. Luigi Catalano, Mr. Giovanni Gamba, Dr. Giovanni Mian, Prof. Marco Nigro, Dr. Alberto Pacchiarelli, Dr. Gianni Panizza, Dr. Aniello Luca Pica, Dr. Giorgia Riolfo; **Japan:** Assoc. Prof. Takashi Akagi, Hiroshi Asao, Eri Hayashi, Miki Kato, Ms. Nichapat Keawmanee, Ms. Nami Kojima, Assist. Prof. Takanori Kuronuma, Ms. Eriko Kuwada, Ms. Haruna Mochizuki, Mr. Kan Murakami, Assoc. Prof. Ayako Nagase, Ms. Akari Nakata, Kenta Nomura, Mr. Kiyotaka Oho, Dr. Motofumi Suzuki, Dr. Kayoko Takaura, Dr. Takuya Wada, Dr. Akira Wakana, Mr. Masashi Yamamoto; **Korea (Republic of):** Ms. Haemi Cho, Jung Kim, Ms. Yumi Kim, Ms. EunJeong Lim, Ms. Moon-Sun Yeom; **Mexico:** Ms. Daniela Arrieta Flores, Prof. Dr. Ana Tarin Gutierrez Ibañez, Prof. Dr. Antonio Laguna Cerda, Prof. Dr. José Antonio López Sandoval, Mr. Oliver Monarres-Cuevas, Ms. Mitzi Ketzali Morales-Mora, Dr. Juan Carlos Reyes Alemán, Dr. Nallely Rosalba Roman Cortes, Prof. Dr. Jesús Ricardo Sánchez Pale, Ms. Gloria Arantxa Sotelo Alcántara, Mr. Benito Teràn Erazo, Dr. Juan Manuel Villarreal Fuentes; **Netherlands:** Dr. Rob Baas, Roxanne van Rooijen; **New Zealand:** Dr. Shahjahan Kabir, Ms. Harpreet Kaur, Ms. Chelsea Kerr, Mr. Kris Kramer-Walter, Ms. Kristie ODonnell, Michael Overall, Ms. Karangawai Paringatai-Hare, Trisha Pereira, Dr. Octavio Perez-Garcia, Ms. Erin Stroud, Mr. Mark Wang, Ruiling Wang; **Philippines:** Jessve Daypuyart, Ms. Myla Santiago, Carol Yu; **Romania:** Dr. Monica Harta, Ms. Andreea Melinescu; **South Africa:** Dr. Erna Blancquaert, Mr. Kobus Germishuys, Mr. Marno Van Der Westhuizen; **Spain:** Raquel Camacho-Arévalo, Dr. Noelia López López, Ms. Inmaculada Martos-García, Assist. Prof. Sara Pose, Ms. Nariane Q. Vilhena; **Sweden:** Assoc. Prof. Marie-Claude Dubois; **Switzerland:** Mr. Thibaut Verdenal; **Thailand:** Mr. Tripatchara Atiratana; **Turkey:** Dr. Kemal Kahraman, Assoc. Prof. Keziban Yazici; **United Kingdom:** Mr. Gerald Bonner, Mr. Alan East, Mr. Colin Herron, Mr. Damien Newman; **United States of America:** Mr. Tej Acharya, Yosvany Acosta, Maher Al Rwahnih, Mr. Walter Albeldano, Adrian Berry, Dr. Victor Blanco, Dr. Jenny Bolivar-Medina, Sue Chasen, Matthew Ciaschini, Troy Elliott, Dennis Evans, Dr. Paul Gauthier, Moisés González, David Hansen, Alexander Iniakov, Abelardo Jaime, Dr. Joseph Kawash, Ms. Sara Knowles, Pooja Kumari, Jeffrey Neyhart, Pratima Pahadi, Casey Passmore, Mr. Keith Powers, Rebecca Reeve, Dr. Lisa Rowland, Ms. Rafa Tasnim, Ozgecan Yalcin, J. Martin Zapien-Macias, Dr. Jijun Zou; **Vietnam:** Ms. Huong Pt.

› Calendar of ISHS events

For updates and more information go to www.ishs.org › calendar of events. For a comprehensive list of meetings in each Division or Working Group use the "science" option from the website navigation menu. To claim reduced registration for ISHS members, your personal membership number is required when registering - ensure your ISHS membership is current before registering. When in doubt sign in to your membership account and check/renew your membership status first: www.actahort.org or www.ishs.org

Year 2021

- June 28-30, 2021, Tel Aviv [virtual symposium] (Israel): **IX International Symposium on Mineral Nutrition of Fruit Crops.** Info: Dr. Uri Yermiyahu, Gilat Research Center, Soil and Water, Mobile Post Negev 85280, Israel. Phone: (972)89928649, Fax: (972)7992 6485, E-mail: uri4@agri.gov.il or Dr. Arnon Dag, Plant Sciences, Gilat Research Center, Agricultural Research Organization, (The Volcani Center), Mobile Post Negev, 85280, Israel. Phone: (972)506220155, Fax: (972)89926485, E-mail: arnondag@agri.gov.il Web: https://www.ortra.com/events/mnutrition2020
- July 12-14, 2021, Bangkok (Thailand): **IX International Scientific and Practical Conference on Biotechnology as an Instrument for Plant Biodiversity Conservation (physiological, biochemical, embryological, genetic and legal aspects).** Info: Dr. Kanchit Thammasiri, Department of Plant Science, Faculty of Science, Mahidol University, Rama VI Road, Phyathai, Bangkok 10400, Thailand. Phone: (66)89-132-7015, Fax: (66)2-354-7172, E-mail: kanchitthammasiri@gmail.com E-mail symposium: biotech2020thailand@gmail.com Web: http://plantscience.sc.mahidol.ac.th/biotech2020
- July 26-30, 2021, Wenatchee, WA (United States of America): **XII International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems.** Info: Prof. Stefano Musacchi, Washington State University, TFREC, 1100 N. Western Ave., Wenatchee, WA 98801-1230, United States of America. Phone: (1)509-663-8181, Fax: (1)509-662-8714, E-mail: stefano.musacchi@wsu.edu E-mail symposium: info@2020orchardsystems.com Web: https://2021orchardsystems.com/

- July 27-28, 2021, Bogor, West Java (Indonesia): **II International Symposium on Tropical and Subtropical Ornamentals.** Info: Dr. Syarifah Iis Aisyah, Dept.of Agronomy and Horticulture, IPB, Jl. Meranti, Kampus IPB Darmaga, 16680 West Java Bogor, Indonesia. Phone: (62)2518629353, E-mail: syarifahiis@yahoo.com or Dr. Dewi Sukma, Department of Agronomy and Horticulture, Bogor Agricultural University, Jl. Meranti Kampus IPB Dramaga, 16680 Bogor, Indonesia. Phone: (62)-251-8629353, Fax: (62)-251-8629353, E-mail: dsukma70@yahoo.com E-mail symposium: tso2020indonesia@gmail.com Web: http://tso2020.ipb.ac.id
- August 15-18, 2021, Leuven (Belgium): **XIII International Controlled and Modified Atmosphere Research Conference - CaMa2021.** Info: Prof. Bart Nicolai, Flanders Centre for, Postharvest Technology, W. De Croylaan 42, 3001 Heverlee, Belgium. Phone: (32)16322375, Fax: (32)16322955, E-mail: bart.nicolai@biw.kuleuven.be or Dr. Maarten Hertog, BIOSYST-MeBioS, K.U. Leuven, de Croylaan 42 - bus 2428, B-3001 Heverlee, Belgium. Phone: (32)16322376, Fax: (32)16322955, E-mail: maarten.hertog@kuleuven.be Web: https://cama2020.org/
- August 22-27, 2021, Ghent (Belgium): **II International Symposium on Growing Media, Soilless Cultivation, and Compost Utilization in Horticulture.** Info: Dr. Bart Vandecasteele, ILVO, Plant Sciences Unit, B. Van Gansberghelaan 109, 9820 Merelbeke, Belgium. Phone: (32)92722699, E-mail: bart.vandecasteele@ilvo.vlaanderen.be E-mail symposium: info@growingmedia2021.com Web: www.growingmedia2021.com/
- August 30 - September 1, 2021, Truro, Nova Scotia (Canada): **XII International Vaccinium Symposium.** Info: Prof. Dr. David Percival, Dalhousie University, Department of Plant, Food, and Environmental Sciences, PO Box 550, Truro, NS B2N 5E3, Canada. Phone: (1)9028937852, Fax: (1)9028931404, E-mail: david.percival@dal.ca Web: http://www.Dal.ca/ivs
- September 5-8, 2021, Baoding, Hebei (China): **V International Jujube Symposium.** Info: Prof. Dr. Mengjun Liu, Research Center of Chinese Jujube, Agricultural University of Hebei, Baoding, Hebei, 71001, China. Phone: (86)312754342, Fax: (86)3127521251, E-mail: lmj1234567@aliyun.com Web: http://jujube.nssoft.net/
- September 14-17, 2021, Zlatibor (Serbia): **XII International Symposium on Plum and Prune Genetics, Breeding and Pomology.** Info: Dr. Darko Jevremovic, Kralja Petra I 9, 32000 Cacak, Serbia. Phone: (381)32321375, Fax: (381)32321391, E-mail: darkoj@ftn.kg.ac.rs E-mail symposium: plum2020@institut-cacak.org Web: https://www.plum2020.com
- September 20-26, 2021, Nara (Japan): **VII International Symposium on Persimmon.** Info: Prof. Dr. Keizo Yonemori, Faculty of Agriculture, Ryukoku University, 1-5 Yokotani, Seta Oe-cho, Otsu 520-2194, Siga, Japan. Phone: (81)775995695, Fax: (81)775995608, E-mail: keizo@agr.ryukoku.ac.jp or Prof. Dr. Satoshi Taira, Lab. of Pomology, Fac. of Agr., Yamagata University, Tsuruoka, Yamagata 997-8555, Japan. Phone: (81)235-282829, Fax: (81)235-282832, E-mail: staira@tds1.tr.yamagata-u.ac.jp E-mail symposium: 2020persimmon@gmail.com Web: http://kaki2020.jshs.jp
- September 20-24, 2021, Riva del Garda, Trento (Italy): **XIV International Symposium on Plant Bioregulators in Fruit Production.** Info: Dr. Fabrizio Costa, Via Mach 1, 38010 San Michele all'Adige, Trento, Italy. Phone: (39)0461615563, E-mail: fabrizio.costa@fmach.it Web: https://eventi.fmach.it/ISHS-2021
- September 24-26, 2021, Ohrid (North Macedonia): **VIII South-Eastern Europe Symposium on Vegetables and Potatoes.** Info: Prof. Dr. Gordana Popsimonova, Debarca 16, 1000 Skopje, North Macedonia. Phone: (389)70255878, E-mail: gpopsimonova@yahoo.com or Skender Kaciu, Univ. of Prishtina-Faculty of Agri., and Veterinary, Boulevar B.Clinton bb, 10000 Prishtina, Kosovo. E-mail: skenderkaciu@yahoo.com E-mail symposium: contact@ishs8.org Web: https://ishs8.org/
- September 27-30, 2021, Yalova (Turkey): **X International Symposium on Kiwifruit.** Info: Assoc. Prof. Arif Atak, Horticultural Central Research Institute, Department of Viticulture&Kiwifruit, 77102 Yalova, Turkey. Phone: (90)2268142520, Fax: (90)2268141146, E-mail: atakarif@gmail.com E-mail symposium: secretariat@kiwifruit2021.org Web: http://www.kiwifruit2021.org
- October 6-9, 2021, Toluca (Mexico): **V International Conference on Postharvest and Quality Management of Horticultural Products of Interest for Tropical Regions.** Info: Prof. Dr. Omar Franco Mora, Laboratory of Horticulture, Faculty of Agriculture, Universidad Autónoma del Estado de México, Toluca, México, 50140, Mexico. E-mail: franco_omar@hotmail.com E-mail symposium: convener@pqmhp2021.com Web: https://pqmhp2021.com/
- October 19-22, 2021, Nanjing (China): **V International Symposium on Biotechnology and Molecular Breeding in Horticultural Species.** Info: Jun Wu, Nanjing Agricultural University, College of Horticulture, Nanjing, Jiangsu, 210095, China. E-mail: wujun@njau.edu.cn or Prof. Dr. Shaoling Zhang, Nanjing Agricultural University, 1 Weigang, 210095 Nanjing, China. E-mail: nnzsl@njau.edu.cn Web: http://www.bmbh2020.org
- October 29-30, 2021, Kansas City, MO (United States of America): **XV International People Plant Symposium and II International Symposium on Horticultural Therapies.** Info: Dr. Candice Shoemaker, 2021 Throckmorton, Department of Hort, Forestry, Rec Res, Kansas State University, Manhattan, KS 66506, United States of America. Phone: (1)7855321431, Fax: (1)7855326849, E-mail: cshoemak@ksu.edu Web: http://ipps2020.org/
- October 31 - November 5, 2021, Stellenbosch (South Africa): **XI International Symposium on Grapevine Physiology and Biotechnology.** Info: Melané Vivier, Institute for Wine Biotechnology, Department of Viticulture and Oenology, Private Bag x1, Matieland, 7602, South Africa. Phone: (27)218083773, Fax: (27)218083771, E-mail: mav@sun.ac.za or Johan Burger, Stellenbosch University, Department of Genetics, Private Bag X1, Matieland, 7002 Stellenbosch, South Africa. E-mail: jtb@sun.ac.za Web: http://www.isgpb2020.com
- November 8-12, 2021, Montpellier (France): **I International Symposium on Reproductive Biology of Fruit Tree Species.** Info: Dr. Evelyne Costes, INRA UMR AGAP, 2, place Viala, 34060 Montpellier Cedex 1, France. Phone: (33)499612787, Fax: (33)499612616, E-mail: evelyne.costes@inrae.fr or Prof. Dr. Henryk Flachowsky, Pillnitzer Platz 3a, 01326 Dresden, Germany. E-mail: henryk.flachowsky@julius-kuehn.de Web: https://symposium.inrae.fr/reproductive-biologyfruittree/
- December 1-3, 2021, Bangkok (Thailand): **V Asia Symposium on Quality Management in Postharvest Systems.** Info: Prof. Dr. Varit Srilaong, Posth.Tech., School of Biores.&Technology, King Mongkut's Univ. of Technol.Thonburi, 126 Pracha-Uthid Road, Bangmod, Thungkru, Bangkok 10140, Thailand. E-mail: varit.sri@kmutt.ac.th E-mail symposium: asqp2021@kmutt.ac.th Web: http://www.asiapostharvest2021.kmutt.ac.th/
- December 14-17, 2021, Giarre, Catania (Italy): **VIII International Conference on Landscape and Urban Horticulture.** Info: Prof. Daniela Romano, Universitá de Catania, Dip. DOFATA, Via Valdisavoia 5, 95123 Catania, Italy. Phone: (39)095234306, Fax: (39)095234329, E-mail: dromano@unict.it or Dr. Francesca Bretzel, CNR, IRET Istituto di Ricerca sugli Ecosist, Via G. Moruzzi 1, Pisa 56124, Italy. Phone: (39)0506212485, Fax: (39)0506212473, E-mail: francesca.bretzel@cnr.it or Dr. Stefania Toscano, Via Valdisavoia 5, 95123 Catania(CT), Italy. Phone: (39)0954783303, E-mail: stefania.toscano@unict.it E-mail symposium: info@luh2021.it Web: https://www.luh2021.it/
- December 14-17, 2021, Catania (Italy): **III International Organic Fruit Symposium and I International Organic Vegetable Symposium**. Info: Prof. Dr. Ferdinando Branca, Di3A, Università di Catania, Via Valdisavoia 5, 95123 Catania, Italy. Phone:

(39)095234307, Fax: (39)095234329, E-mail: fbranca@unict.it or Dr. Alberto Continella, University of Catania, Via Valdisavoia 5, Catania, Italy. Phone: (39)095-234455, Fax: (39)095-234406, E-mail: acontine@unict.it or Dr. Alessandro Tribulato, via Valdisavoia, 5, 95123 Catania, Italy. Phone: (39) 095 234328, Fax: (39) 095 234329, E-mail: atribula@unict.it E-mail symposium: info@orghort2020.it Web: https://www.orghort2020.it/

Year 2022

- February 7-10, 2022, Bangalore (India): **International Symposium on Tropical and Subtropical Viticulture**. Info: Prof. Dr. Dilipraj Patil, Associate director of Research, MHREC, University of Horticultural Sciences, Udyanagiri, Bagalkot, 587104, India. E-mail: adrebagalkot@uhsbagalkot.edu.in or Dr. Girigowda Manjunatha, Officer In-charge, Bio-control laboratories, Directorate of Horticulture, University of Horticultural sciences, Bagal, Karnataka, 570020, India. Phone: (91)9916219697, E-mail: gmanjunath2007@gmail.com
- February 14-18, 2022, Stellenbosch (South Africa): **V International Symposium on Pomegranate and Minor Mediterranean Fruits**. Info: Prof. Dr. Olaniyi Fawole, Department of Botany and Plant Biotech, University of Johannesburg, Auckland Park Campus, South Africa. E-mail: olaniyi@sun.ac.za E-mail symposium: info@ishsstellenbosch.org Web: https://ishsstellenbosch.org/stellenbosch/
- March 6-10, 2022, San Juan (Argentina): **XVI International Symposium on Processing Tomato - XIV World Processing Tomato Congress**. Info: Dr. Luca Sandei, SSICA, Tomato Department, Viale f.Tanara 31/a, 43121 Parma (PR), Italy. Phone: (39) 0521795257, Fax: (39) 0521771829, E-mail: luca.sandei@ssica.it or Dr. Cosme A. Argerich, Instit. Nac. de Tecnol. Agro., C.C. Nro. 8, La Consulta, 5567 Mendoza, Argentina. Phone: (54)2622470304, Fax: (54)2622470753, E-mail: argerich.cosme@inta.gob.ar E-mail symposium: symposium@worldtomatocongress.com Web: http://www.worldtomatocongress.com
- March 13-18, 2022, Brena Baja (La Palma) & La Laguna (Tenerife) (Spain): **XIV International Protea Research Symposium**. Info: Prof. Dr. Juan Alberto Rodríguez Pérez, Àrea de Producción Vegetal, Universidad de La Laguna, Calle Dinamarca 29, 38300 La Orotava, Tenerife, Spain. Phone: (34)666695267, E-mail: jarodrip@ull.es Web: https://proteas2020.asocan.net
- March 28-31, 2022, João Pessoa, Paraíba (Brazil): **X International Congress on Cactus Pear and Cochineal**. Info: Mr. Mário Borba, 1571 Rio Grande do Sul Avenue, 58030021 João Pessoa-Paraíba, Brazil. E-mail: presidente@faepapb.com.br E-mail symposium: cactuscongress2022@faepapb.com.br Web: http://www.cactuscongress2022.com
- April 18-21, 2022, Murcia (Spain): **III International Symposium on Beverage Crops**. Info: Rocio Gil Muñoz, Avda Ntra Sra de la Asunción N24, 30520 Jumilla, Spain. E-mail: mariar.gil2@carm.es or Prof. Dr. Encarna Gómez-Plaza, Universidad de Murcia, Fac. Veterinaria, Dep. Tecnología Alimentos, Campus Espinardo, 30071 Murcia Murcia, Spain. Phone: (34) 868887323, E-mail: encarna.gomez@um.es or Prof. Dr. Cristina Garcia-Viguera, Phytochemistry and Healthy Foods Lab, Dept Food Science Technoloy CEBAS-CSIC, Campus Espinardo 25, Espinardo, 30100 Murcia, Spain. Phone: (34) 968396200, Fax: (32)9686213, E-mail: cgviguera@cebas.csic.es Web: https://www.bevcrops21.es/
- May 23-26, 2022, Pula (Croatia): **VIII International Symposium on Edible Alliums**. Info: Smiljana Goreta Ban, Institute of Agriculture and Tourism, Department of Agriculture and Nutrition, Karla Huguesa 8, 52440 Porec, Croatia. E-mail: smilja@iptpo.hr
- May 29 - June 2, 2022, Limassol/Lemesos (Cyprus): **VI International Symposium on Postharvest Pathology: Innovation and Advanced Technologies for Managing Postharvest Pathogens**. Info: Assist. Prof. Nikolaos Tzortzakis, Dept. Agricultural Sciences, Biotechnology, Food Science, Cyprus University of Technology, 3036, Lemesos, Cyprus. Phone: (35)7 25002280, Fax: (35)7 25002838, E-mail: nikolaos.tzortzakis@cut.ac.cy Web: http://web.cut.ac.cy/postharvestpathology2021/
- May 30 - June 3, 2022, Naoussa (Greece): **X International Peach Symposium**. Info: Prof. George Manganaris, Anexartisias 57, PAREAS Building, P.O. Box 50329, 3603 Lemesos, Cyprus. Phone: (357)25002307, Fax: (357)25002804, E-mail: george.manganaris@cut.ac.cy or Dr. Athanassios Molassiotis, Pomology lab, Faculty of Agriculture, AUTH, 54 124 Thessaloniki, Greece. Phone: (30)2310 998882, Fax: (30)2310 998882, E-mail: amolasio@agro.auth.gr Web: https://www.fruitsciences.eu/peach2021
- June 12-15, 2022, Cordoba (Spain): **XV International Asparagus Symposium**. Info: Juan Gil, Plaza de la oca, 1, 2-1, Córdoba, Spain. E-mail: juan.gil@uco.es Web: https://www.ias2022.com/
- June 19-24, 2022, Davis, CA (United States of America): **VIII International Symposium on Almonds and Pistachios**. Info: Dr. Louise Ferguson, 2037 Wickson Hall, Plant Sciences Department Mail Stop II, UC Davis 1 Shields Ave. Davis CA 95616, United States of America. Phone: (1) 559 737 3061, Fax: (1) 530 752 8502, E-mail: lferguson@ucdavis.edu or Dr. Thomas M. Gradziel, Department of Pomology, University of California, 1 Shields Avenue, Davis, CA 95616-8683, United States of America. E-mail: tmgradziel@ucdavis.edu or Bruce Lampinen, Dept of Plant Sciences, University of California, 1 Shields Avenue, Davis, CA 95616, United States of America. E-mail: bdlampinen@ucdavis.edu Web: https://ucanr.edu/sites/Almond_Pistachio_2021/
- NEW August 14-20, 2022, Angers (France): **XXXI International Horticultural Congress: IHC2022**. Info: Dr. François Laurens, INRA, Centre d'Angers, 49071 Beaucouzé, France. Phone: (33)2 41 22 56 00, Fax: (33)2 41 22 57 55, E-mail: francois.laurens@inrae.fr E-mail: symposium: info@ihc2022.org Web: https://www.ihc2022.org/

Symposia at IHC2022:

- NEW August 14-20, 2022, Angers (France): **International Symposium on Breeding and Effective Use of Biotechnology and Molecular Tools in Horticultural Crops**. Info: Dr. Vincent Gerardus Maria Bus, Plant and Food Research, Private Bag 1401, Havelock North 4157, New Zealand. Phone: (64)69758946, Fax: (64)69758881, E-mail: vincent.bus@ plantandfood.co.nz or Dr. Mathilde Causse, INRA-GAFL, BP 94, 84143 Montfavet Cedex, France. E-mail: mathilde.causse@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s1-breeding-and-effective-use-of-biotechnology-and-molecular-tools-in-horticultural-crops/
- NEW August 14-20, 2022, Angers (France): **International Symposium on Conservation and Sustainable Use of Horticultural Genetic Resources**. Info: Dr. Tiziana Ulian, Wellcome Trust Millennium Building, Wakehurst, RH17 6TN West Sussex Ardingly, United Kingdom. E-mail: t.ulian@kew.org or Dr. Raphael Morillon, Station CIRAD de Roujol, Station CIRAD de Roujol, 97170 Guadeloupe Petit Bourg, Guadeloupe. Phone: 590386162, E-mail: raphael.morillon@cirad.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s2-conservation-and-sustainable-use-of-horticultural-genetic-resources/
- NEW August 14-20, 2022, Angers (France): **International Symposium on Quality Seeds and Transplants for Horticultural Crops**. Info: Prof. Dr. Daniel Leskovar, 1619 Garner Field Rd., Texas A&M AgriLife Research, Texas AM Univeristy, Uvalde Texas 78801, United States of America. Phone: (1)830-278-9151, Fax: (1)830-278-1570, E-mail: daniel.leskovar@ agnet.tamu.edu or Prof. Dr. Olivier Leprince, 42 rue Georges Morel, 49070 Beaucouzé, France. E-mail:

olivier.leprince@agrocampus-ouest.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s3-quality-seeds-and-transplants-for-horticultural-crops/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on In Vitro Technology and Micropropagated Plants**. Info: Dr. Sandra Correia, Department of Life Sciences, University of Coimbra, Calcada Martim de Freitas, 3000-456 Coimbra, Portugal. Phone: (351)239240700, Fax: (351)239240701, E-mail: sandraimc@uc.pt or Prof. Dr. Stefaan Werbrouck, University Gent, Department Applied Biosciences, Valentin Vaerwyckweg 1, 9000 Gent, Belgium. Phone: (32)9 244 88 59, Fax: (32)9 242 42 79, E-mail: stefaan.werbrouck@ugent.be E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s4-in-vitro-techniques-and-micropropagated-plants/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Innovations in Ornamentals: from Breeding to Market**. Info: Dr. Johan Van Huylenbroeck, ILVO- Plant Sciences Unit, Applied genetics & breeding, Caritasstraat 39, 9090 Melle, Belgium. Phone: (32) 9-2722862, Fax: (32) 9-2722901, E-mail: johan.vanhuylenbroeck@ilvo.vlaanderen.be or Dr. Fabrice Foucher, UMR IRHS, Centre INRA, BP 60057, 49071 Beaucouze, France. E-mail: fabrice.foucher@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s5-innovations-in-ornamentals-from-breeding-to-market/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Innovative Technologies and Production Strategies for Sustainable Controlled Environment Horticulture**. Info: Assoc. Prof. Youssef Rouphael, University of Naples, Via Università 100, 80055 Portici(Napoli), Italy. E-mail: youssef.rouphael@unina.it or Dr. Jean-Charles Michel, L'Institut Agro - Agrocampus Ouest, 2 rue Le Notre, 49045 Angers, France. Phone: (33)241225422, Fax: (33)241225553, E-mail: jean-charles.michel@agrocampus-ouest.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s6-innovative-technologies-and-production-strategies-for-sustainable-controlled-environment/

NEW ■ August 14-20, 2022, Angers (France): **II International Symposium on Greener Cities: Improving Ecosystem Services in a Climate-Changing World (GreenCities2022)**. Info: Dr. Vivian Loges, Univ.Federal Rural de Pernambuco, Rua José Bezerra de Albuquerque 38a, Recife, 54315-580, Brazil. Phone: (51)8134624552, Fax: (51)8133206250, E-mail: vloges@yahoo.com or Mr. Philippe Faucon, 22 rue de l'Arsenal, 17300 Rochefort, France. Phone: (33)546991701, E-mail: p.faucon@critt-horticole.comE-mailsymposium:sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s7-greencities2022/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Advances in Vertical Farming**. Info: Eri Hayashi, 6-2-1 Kashiwanoha, Kashiwa 277-088, Japan. E-mail: ehayashi@npoplantfactory.org or Prof. Dr. Leo F.M. Marcelis, Wageningen University, Horticulture & Product Physiology, Droevendaalsesteeg 1, 6708 PB Wageningen, Netherlands. Phone: (31)317485675, E-mail: leo.marcelis@wur.nl E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s8-advances-in-vertical-farming/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Urban Horticulture for Sustainable Food Security (UrbanFood2022)**. Info: Dr. Kathrin Specht, Arndtstrasse 15, 10965 Berlin, Germany. E-mail: kathrin.specht@ils-forschung.de or Dr. Kevin Morel, 16, rue Claude Bernard, 75231 Paris, France. E-mail: kevin.morel@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s9-urban-horticulture-for-sustainable-food-security/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Value Adding and Innovation Management in the Horticultural Sector**. Info: Dr. David Neven, FAOB605, Viale delle Terme di Caracalla, 00153 Rome, Italy. E-mail: david.neven@fao.org or Dr. Syndhia Mathé, Direction régional CIRAD Afrique Centrale, BP 2572, Yaounde, Cameroon. E-mail: syndhia.mathe@cirad.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s10-value-adding-and-innovation-management-in-the-horticultural-sector/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Adaptation of Horticultural Plants to Abiotic Stresses**. Info: Dr. Fulai Liu, Department of Plant & Environmental Science, University of Copenhagen, Hoeibakkegaard Alle 13, 2630 Taastrup, Denmark. Phone: (45)35333392, Fax: (45)35333478, E-mail: fl@plen.ku.dk or Dr. Bénédicte Wenden, INRA - UMR BFP - 71 avenue Edouard Bourlaux, 33882 Villenave d'Ornon Cedex, France. Phone: (33)557122549, E-mail: benedicte.wenden@inrae.frE-mailsymposium:sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s11-adaptation-of-horticultural-plants-to-abiotic-stresses/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Water: a Worldwide Challenge for Horticulture.** Info: Brunella Morandi, Università di Bologna, Viale Fanin 44, 40127 Bologna, Italy. E-mail: brunella.morandi@unibo.it E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s12-water-a-worldwide-challenge-for-horticulture/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Plant Nutrition, Fertilization, Soil Management**. Info: Assist. Prof. Lee Kalcsits, Washington State University, WSU-TFREC, Wenatchee, WA 98801, United States of America. Phone: (1)5096638181, E-mail: lee.kalcsits@wsu.edu or Assist. Prof. Patrice Cannavo, Agrocampus Ouest, Unité de Recherche EPHor, 2 rue André Le Notre, 49045 Angers, France. E-mail: patrice.cannavo@agrocampus-ouest.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s13-plant-nutrition-fertilization-soil-management/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Sustainable Control of Pests and Diseases**. Info: Prof. Lucia Zappala, viale tirreno, 31, 95123 Catania, Italy. E-mail: lzappala@unict.it E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s14-sustainable-control-of-pests-and-diseases/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Agroecology and System Approach for Sustainable and Resilient Horticultural Production**. Info: Prof. Dr. Maria Claudia Dussi, Universidad Nacional del Comahue, Facultad de Ciencias Agrarias, CC 85 (8303) Cinco Saltos, Rio Negro-Patagonia, Argentina. Phone: (54) 299 9 5719365, E-mail: mcdussi@yahoo.com or Dr. Sylvaine Simon, INRAE Gotheron, 460 Chemin de Gotheron, 26320 Saint-Marcel-lès-Valence, France. Phone: (33)432722206, Fax: (33)475588626, E-mail: sylvaine.simon@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s15-agroecology-and-system-approach-for-sustainable-and-resilient-horticultural-production/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Innovative Perennial Crops Management**. Info: Dr. Sara Serra, Washington State University, Department of Horticulture, Pullman, WA 99164, United States of America. E-mail: sara.serra@wsu.edu or Dr. Pierre-Eric Lauri, UMR SYSTEM, INRA, Place Pierre Viala, 34060 Montpellier, France. Phone: (33)499613054, E-mail: pierre-eric.lauri@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s16-innovative-perennial-crops-management/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Integrative Approaches to Product Quality in Fruits and Vegetables**. Info: Alyson Mitchell, Department of Food Science Technology, UC Davis, 1 Shields Ave, Davis CA 95616, United States of America. Phone: (1)5303046618, E-mail: aemitchell@ucdavis.edu or Dr. Nadia Bertin, UR 1115 PSH, INRA, Domaine St Paul, 228 route de l'aérodrome, Site

Agroparc, 84914 Avignon, France. Phone: (33)0432722324, E-mail: nadia.bertin@inrae.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s17-integrative-approaches-to-product-quality-in-fruits-and-vegetables/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Precision and Digital Horticulture in Field Environments**. Info: Dr. Sindhuja Sankaran, Washington State University, P.O. Box 641020, Pullman Washington 99164, United States of America. Phone: (1)5093358828, E-mail: sindhuja.sankaran@wsu.edu or Prof. David Rousseau, Université d'Angers, 62 Avenue Notre Dame du Lac, 49000 Angers, France. Phone: (33)638291612, E-mail: david.rousseau@univ-angers.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s18-precision-and-digital-horticulture-in-field-environments/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Advances in Berry Crops**. Info: Dr. Susan McCallum, The James Hutton Institute, Errol Road, Invergowrie, DD2 5DA Dundee, Scotland, United Kingdom. E-mail: susan.mccallum@hutton.ac.uk or Dr. Béatrice Denoyes, 71 avenue Edouard Bourlaux, 33882 Villenave d'Ornon, France. E-mail: beatrice.denoyes@inrae.fr E-mail symposium: sciences@ihc2022.org Web: www.ihc2022.org/symposia/s19-advances-in-berry-crops/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on the Vitivinicultural Sector: Which Tools to Face Current Challenges**. Info: Prof. Dr. Ahmet Altindisli, Ege University, Faculty of Agriculture, Department of Horticulture, 35100 Bornovaİzmir, Turkey. Phone: (90)2323882622, Fax: (90)2323881865, E-mail: ahmet.altindisli@gmail.com or Assoc. Prof. Benjamin Bois, CRC - UMR Biogeosciences, 6 Boulevard Gabriel, 21000 DIJON, France. Phone: (33)662605225, E-mail: benjamin.bois@u-bourgogne.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s20-the-vitivinicultural-sector-which-tools-to-face-current-challenges/

NEW ■ August 14-20, 2022, Angers (France): **XII International Symposium on Banana: Celebrating Banana Organic Production**. Info: Mr. Walter Ocimati, Bioversity International, Plot 106, Katalima Road, P.O. Box 24384, 256 Kampala, Uganda. Phone: (256)414286213, Fax: (256)414286949, E-mail: w.ocimati@cgiar.org or Dr. Thierry Lescot, CIRAD, RU GECO, Persyst Department, Boulevard de la Lironde, TA B26/PS4, 34398 Montpellier, France. Phone: (33)467615666, Fax: (33)467615821, E-mail: thierry.lescot@cirad.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s21-international-symposium-on-banana-celebrating-banana-organic-production/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Natural Colorants from Plants**. Info: Dr. Riikka Räisänen, Craft Studies P.O. Box 8, 00014 University of Helsinki, Finland. E-mail: riikka.raisanen@helsinki.fi or Ms. Anne de La Sayette, ARRDHOR - CRITT Horticole, 22 rue de l'Arsenal, 17300 Rochefort, France. Phone: (33)546991701, E-mail: arrdhor@wanadoo.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s22-natural-colorants-from-plants/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Postharvest Technologies to Reduce Food Losses**. Info: Gustavo Teixeira, Av. José Adriano Arrobas Martins, 210, 14.883-298 Jaboticabal São Paulo, Brazil. E-mail: teixeiragha@yahoo.com.br or Dr. Florence Charles, Universite d'Avignon, 301 rue Baruch de Spinoza, BP 21239, cedex 9, 84916 Avignon, France. Phone: (33)4.90.84.22.08, E-mail: florence.charles@univ-avignon.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s23-post-harvest-technologies-to-reduce-food-losses/

NEW ■ August 14-20, 2022, Angers (France): **IX International Symposium on Human Health Effects of Fruits and Vegetables - FAVHEALTH2022**. Info: Dr. Emmanuel Geoffriau, Agrocampus Ouest - IRHS, Institute Research Horticulture Seeds, 2, rue le Notre, 49045 Angers, France. Phone: (33)241225431, E-mail: emmanuel.geoffriau@agrocampus-ouest.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s24-horticulture-for-nutrition-and-food-security-health-and-well-being/

NEW ■ August 14-20, 2022, Angers (France): **International Symposium on Medicinal and Aromatic Plants: Domestication, Breeding, Cultivation and New Perspectives**. Info: Dr. Emmanuel Geoffriau, Agrocampus Ouest - IRHS, Institute Research Horticulture Seeds, 2, rue le Notre, 49045 Angers, France. Phone: (33)241225431, E-mail: emmanuel.geoffriau@agrocampus-ouest.fr E-mail symposium: sciences@ihc2022.org Web: https://www.ihc2022.org/symposia/s25-medicinal-and-aromatic-plants-domestication-breeding-cultivation-and-new-perspectives/

For updates logon to www.ishs.org/symposia

› Available issues of *Acta Horticulturae*

Available numbers of *Acta Horticulturae* (print). In addition any *Acta Horticulturae* title is also available in the electronic **e-Acta Horticulturae** format for online access or on USB-drive. To order *Acta Horticulturae* or for more information on price and availability, including tables of content, please check out the 'publications' page at **www.ishs.org** or go straight to **www.actahort.org**

Acta Number	Acta Title	Price (EUR)
1312	III Asian Horticultural Congress	135
1311	VI International Symposium on Applications of Modelling as an Innovative Technology in the Horticultural Supply Chain - Model-IT 2019	125
1310	VI International Symposium on Fig	67
1309	IX International Strawberry Symposium	230
1308	II International Symposium on Fruit Culture along Silk Road Countries	93
1307	XV EUCARPIA Symposium on Fruit Breeding and Genetics	108
1306	II International Symposium on Moringa	82
1305	III International Symposium on Growing Media, Composting and Substrate Analysis	124
1304	IX International Peach Symposium	87
1303	XIII International Pear Symposium	125
1302	II International Symposium on Vegetable Grafting	76
1301	XIII International Asparagus Symposium	67
1300	XI International Workshop on Sap Flow	63
1299	XXX International Horticultural Congress IHC2018: VII International Symposium on Tropical and Subtropical Fruits, Avocado, II International Symposium on Jackfruit and Other Moraceae and II International Symposium on Date Palm	108
1298	I International Symposium on Botanical Gardens and Landscapes	145
1297	XXX International Horticultural Congress IHC2018: V International Symposium on Plant Genetic Resources and International Symposium on Applied Functional Molecular Biology	150

For an updated list of all titles (in print, USB-drive or e-Acta Horticulturae format) logon to www.actahort.org