A publication of the International Society for Horticultural Science

Chronica Horticulturae

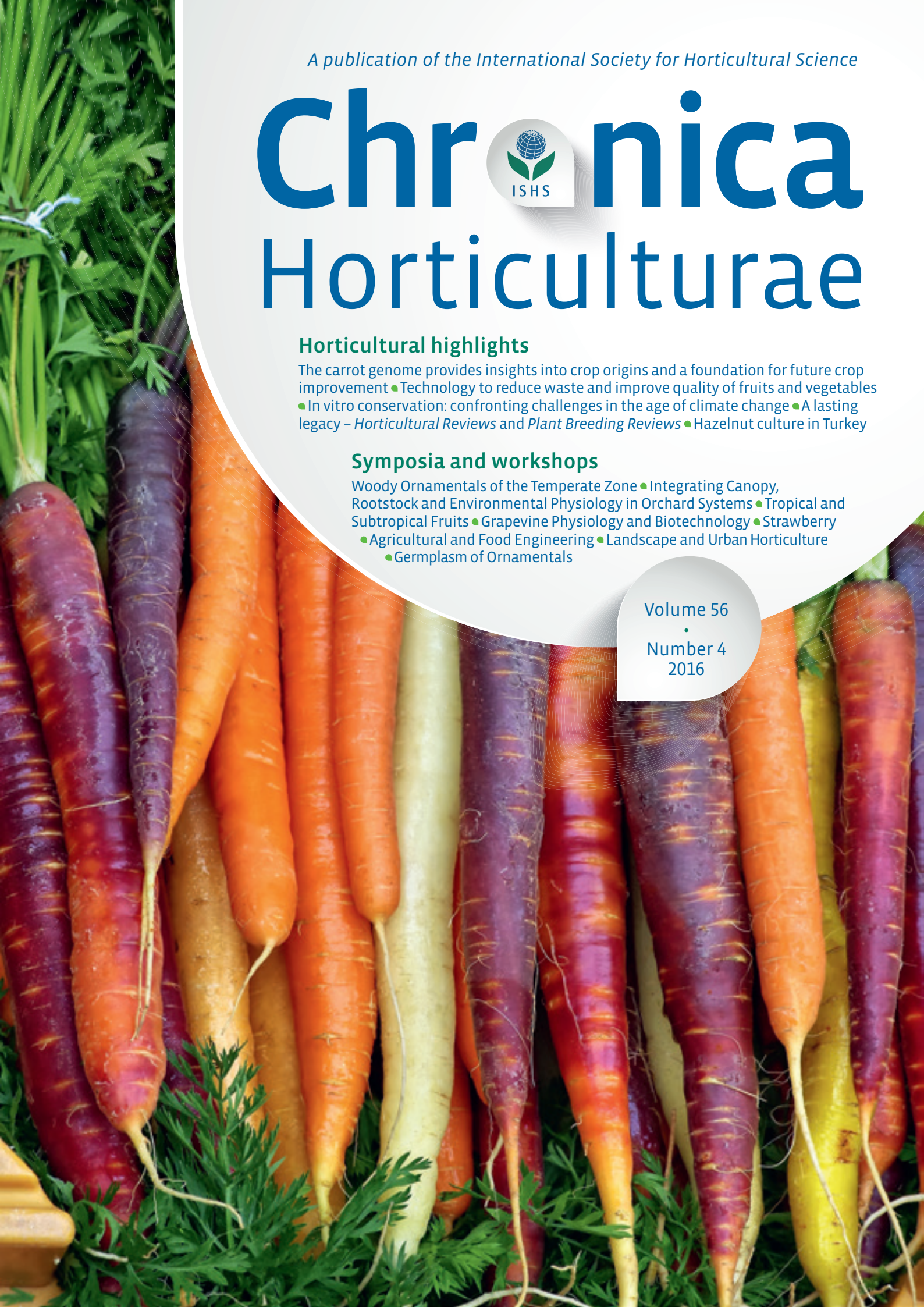
Horticultural highlights

The carrot genome provides insights into crop origins and a foundation for future crop improvement • Technology to reduce waste and improve quality of fruits and vegetables • In vitro conservation: confronting challenges in the age of climate change • A lasting legacy – *Horticultural Reviews* and *Plant Breeding Reviews* • Hazelnut culture in Turkey

Symposia and workshops

Woody Ornamentals of the Temperate Zone • Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems • Tropical and Subtropical Fruits • Grapevine Physiology and Biotechnology • Strawberry • Agricultural and Food Engineering • Landscape and Urban Horticulture • Germplasm of Ornamentals

Volume 56
•
Number 4
2016



Chronica Horticulturae

Chronica Horticulturae© Volume 56 – Number 4; December 2016;
ISSN: 0578-039X (print), 2506-9772 (electronic).

Published quarterly by the International Society for Horticultural Science, Leuven, Belgium. Lay-out and printing by Drukkerij Geers, 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**.

Editorial staff

Jill Stanley, Editor, **jill.stanley@plantandfood.co.nz**

Kelly Van Dijck, Associate Editor, **kelly.vandijck@ishs.org**

Peter Vanderborght, Associate Editor - Production & Circulation, **peter.vanderborght@ishs.org**

Membership and orders of *Chronica Horticulturae*

Chronica Horticulturae is provided to the Membership 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 in the **ActaHort CD-ROM** 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. ISHS members benefit from discounted submission fees. eJHS is available in print + online Open Access. Additional information can be viewed on **www.ishs.org/ejhs**.

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 Journal of Horticultural Science & Biotechnology, Journal of the American Pomological Society, Journal of the International Society for Mushroom Science, Fruits, Proceedings of the International Plant Propagators' Society, Journal of the Interamerican Society for Tropical Horticulture, Plant Breeding Reviews, Horticultural Reviews, etc.

Additional information can be viewed on the PubHort website **www.pubhort.org**.

Cover photograph: Carrots (Copyright: Bildagentur Zoonar GmbH/Shutterstock). See article p.8.

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

When dreams become reality...

Yves Desjardins, ISHS Board Member Responsible for Publications

Yves Desjardins

After much talking, discussing, consulting, planning, designing and programming, we are finally implementing many of the projects I have been presenting to you over the past few years during my first mandate as the ISHS Board member responsible for publications. You have certainly already noticed the style changes of the different publications of the Society. This is a concerted approach to align the visual identity of ISHS products and convey the professional image of the Society. *Acta Horticulturae* has benefited from this new look both outside and inside. Displaying the new visual signature of the ISHS logo, the new *Acta* covers are in my mind simply stunning. Indeed, just for fun, go to the *Acta Horticulturae* home page (www.ishs.org/acta-horticulturae) and have a look at the impressive pictures of the different *Acta* covers representing the diversity of our symposia topics. Conveners have selected images that bring fresh new life to the series. In addition to the cosmetic improvements, deeper changes have taken place. Indeed, we have revamped and streamlined the style of the *Acta* articles to give them a new modern look. The changes were made in the first place to hasten the review process and publish the proceedings of our symposia more rapidly. The new style improves the review and technical editing of the articles. Using the new eXtyles™ software, staff at the ISHS secretariat are now counting on a knowledgeable electronic assistant to help them in the review process. Our symposia editors no longer need to meticulously check for punctuation, capitals, spaces and abbreviations in references and spend long unproductive hours checking for bibliographic style compliance. The computer does it. The software recognizes authors and titles of references, compares them to their equivalent in the PubMed database, and replaces them with a formatted version according to ISHS publication guidelines. The only essential tasks the reviewers and editors have to do now, besides verifying the soundness of the research presented, is to check the concordance between references cited in-text and those included in the bibliography. This facilitates the review process considerably and contributes to speeding up publication.

Another behind the scenes project that demanded much planning from the secretariat is the new on-line abstract and manuscript submission system that we have named **ROSA**, an acronym for **R**esponsive **O**nline **S**ystem for ***A**cta Horticulturae* submission and review. Gone are the days when conveners would lose manuscripts, mix up review versions, or spend wasted time sorting and responding to mail with authors and reviewers. ROSA keeps all manuscripts on a central server accessible to the editors, designated associate editors, and reviewers. It allows for the easy transfer and flow of versions of manuscripts between authors and reviewers. Using the suggested timeline, a convener can now swiftly handle the abstract submission process, elaborate his scientific program, and review submitted manuscripts within about four months, before the opening of a symposium. To try out the system, I have "Guinea pigged" myself and have personally tested ROSA, while organizing the latest International Strawberry Symposium (ISS2016) in Québec City. I can testify that using ROSA, we were able to manage 300 abstracts, review 150 manuscripts using the different features of the system, and thanks to the collaboration of 85 dedicated reviewers, we were able to finalize the review process of all manuscripts before the meeting (see ISS2016 report in this issue). ROSA was invaluable in allowing exchanges between reviewers and authors, who responded quickly to requests for changes to the manuscripts. Alarms in the system also tell you when manuscript corrections are overdue and you can send reminders to reviewers or authors at the click of a button. Conveners will find this great new tool invaluable, because it not only saves time, but also saves lots of money.

Another achievement that occurred early in 2015 was the publication of our new peer-reviewed journal eJHS. Without a doubt, this journal is by far the nicest journal dedicated to horticultural science available on the market. The covers are once again astounding, with a picture highlighting a featured article in each volume. Thanks to the professional work of the editor-in-chief, Dr. Jens Wünsche, the journal is now gaining credence as the main vehicle for our members to publish peer-reviewed, impact factor articles. We are working hard to attract readership and notoriety to the journal and improve its citations and impact factor. While being relatively low at this stage, in a few years you will proudly brag that you have published your results in this journal.

At the same time, *Chronica Horticulturae*'s style and contents have been completely renewed for the best. Passing the helm to Dr. Jill Stanley after four years of intense work was a relief. I must say she took over the job with great professionalism and successfully steered the magazine in new directions. I can't wait to read the new issue for the excellent articles and reviews she has selected on many different topics. She has raised the publication standard of the magazine to a very high level indeed.

I am thus quite proud to see the different projects that were launched as ideas six years ago now successfully implemented. Thanks to the hard work and collaboration of the previous and present Board members, but mostly thanks to the ISHS staff, we have been able to put into action all these projects simultaneously, and bring them to good port and safe harbour.

However, the Board still has projects and development plans in its back pocket. One of them is to launch a journal focusing on tropical and subtropical horticulture. You will agree that the publication offer in this area of horticulture science was, until now, unfortunately rather poor. This is quite surprising, since horticulture in tropical and subtropical regions of the globe is growing at a rapid pace. For instance, many developing countries are relying on horticulture to improve their trade balance and foster economic growth, while reducing inequalities and poverty. The case of Mexico, Brazil and South Africa described by Hewett (2012) are good examples of how horticulture can stimulate growth and improve the quality of life of rural populations in developing areas. Another example of the growing opportunities for horticulture in the tropics are the strategic investments being made by a large corporation like Bayer CropScience in these regions, as it represents an area where horticulture will be growing rapidly in the next 20 years. To meet the high expectations for development of horticulture in these regions, considerable investment in research and new communication channels will be needed to share and disseminate advanced knowledge of horticulture science, hence a new ISHS journal.

I am thus proud to announce that ISHS has partnered with CIRAD and acquired a second peer-reviewed publication to add to its portfolio: the journal FRUITS. This partnership was created with the shared goal of making this journal "the" reference in the field of tropical and subtropical horticulture. FRUITS is already a well-known and respected journal. Owing to the work of its professional and dedicated editorial team at CIRAD, the journal has acquired a respectably high impact factor (1.013) for a horticulture journal. Moreover, being published until now by CIRAD, it had broad circulation in most higher education and research institutions from developing countries and the tropics. ISHS will take over the journal on 1st January 2017 and will jointly publish the journal with CIRAD during a transition period. The scope of the journal will be modified to focus on all horticulture crops grown in the tropics, including vegetables, fruits, spices, ornamentals and medicinal plants. It will not be publishing papers on Mediterranean climate crops anymore; these articles will be redirected to eJHS. To reflect the breadth and diversity of the topics covered by the journal, we will gradually change its name from FRUITS to the International Journal of Tropical and Subtropical Horticulture – Tropiculture. The editorial policy of the new journal will be modified to encompass the new reality and will include the following topics:

- Crop production and cropping systems including permaculture, agroforestry, interactions with the environment and sustainable cropping systems;
- Breeding, genetics and the release of genetic material adapted to tropical and subtropical environments;
- Management, storage and market supply of underutilized crops;
- Integrated management of pests and diseases;
- Health effects of tropical and subtropical horticultural species;
- Peri-urban and urban tropical crop production;
- Sustainable water and input use;
- Pertinent and documented experience in horticulture capacity building;
- Value chain development in developing countries;
- Seed science;
- Agricultural engineering.

We are in the process of putting together a representative international editorial board with associate editors from South America, Africa, Asia, Australia, Polynesia, Central America and the Caribbean. ISHS especially wishes to see this new journal become a hub for the publication of novel research and the promotion of research in the tropics. We are seeking the collaboration and support of international development agencies such as AVRDC, FAO, USAID, HortCRISP, CIDA, Von Humboldt foundation and others for the promotion of the journal. We will take advantage of our new technical editing capacity to publish the journal in a hybrid model with subscriptions, low-cost-page charges and fee-based open access. We want all researchers from developing countries to use this new vehicle to publish their research and disseminate their results throughout the tropics. We are especially inviting members of the ISHS Working Groups involved in tropical and subtropical crops to consider this new journal when publishing their results.

We hope you will appreciate the new developments taking place in your scientific Society. Publications are the core business of ISHS. One of the first goals of our Society is to facilitate the dissemination of knowledge and research advancements in the field of horticulture. The latest acquisition of FRUITS, which will become the International Journal of Tropical and Subtropical Horticulture – Tropiculture, is just one more step taken to serve the ISHS membership. I invite you to enthusiastically participate in this new venture.

References

Hewett, E.W. (2012). High-value horticulture in developing countries: barriers and opportunities. CAB Reviews *7* (*54*), 1–16.

Spotlight on Honoured ISHS Members

› Uygun Aksoy

› Prof. Uygun Aksoy during an invited speech on problems and potential in fresh fig production and trade at Uludağ Exporters' Assocation in Bursa, Turkey (September 2014).

Position or previous position

Full professor at Ege University, Faculty of Agriculture, Department of Horticulture, İzmir, Turkey; retired in April 2016

ISHS honour

Honorary Member since 2008

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

I grew up and was educated in Izmir, the third biggest city located on the western coast of Turkey. I come from a family closely related to agriculture. My grandfather was a farmer, my mother an agronomist (entomologist) and my father a veterinarian. I married my classmate, Bekir Aksoy, who was also a horticulturist and did his PhD on viticulture, and ran his family farm that he converted to organic. I married in 1977 and am a mother of two, a daughter and a son. I recently became a grandma.

In 2016, I wanted to make a change and asked for retirement from Ege University. I am now in a "transition period" working as a short-term consultant in FAO supported projects to develop organic farming in the Central Asian countries of Azerbaijan, Uzbekistan, Tajikistan and Kazakhstan. I also became a farmer, managing an olive grove and targeting the production of high quality olive oil.

I am one of the founders and ex-presidents of two NGOs: the Turkish Society for Horticultural Science and the Association on Organic Agriculture in Turkey. These activities helped me to widen my network, meet with young and diverse people and carry out training and development projects to disseminate the knowledge we have accumulated through research.

I love travelling and meeting with new people and cultures. My career helped me to travel both in Turkey and abroad. I had the opportunity to see places that ordinary tourists do not see, as in the case of valleys in the Atacama desert in Chile or rural areas in Tanzania or Azerbaijan. My hobbies include reading, watching movies, cooking and knitting. I am not good at sport, but I like swimming and benefit from the nice beaches in Izmir.

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

Coming from parents with an agricultural background, I liked nature and wanted to study agriculture, namely landscape architecture, which was a branch in the Department of Horticulture. However, by the time I finished school, I had decided to change my major to horticultural crops. I got a position at the Fruit Section at Ege University and continued my professional and academic career until 2016. My main research focus was figs and dried fruit. Because fig has been the pioneering crop in the development of organic agriculture in Turkey, I naturally entered into the field of organic production and contributed to its development. I was lucky to combine my personal wish for a more sustainable life/world with my professional career.

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

I finished my PhD in 1981, became an associate professor in 1987 and a full professor in 1995. I lectured mainly on postharvest handling of horticultural crops, and initiated courses on quality, guarantee systems and sustainable agri-food production at undergraduate and post-graduate levels. I was involved in various national and international research projects funded by the European Union Framework Projects, the World Bank, the Chilean Government and the International Center for Advanced Mediterranean Agronomic Studies (CIHEAM). During later years, I focused more on vocational training projects to disseminate the outcomes of our scientific work. I organized many national and international courses, symposia, congresses and seminars. Under the ISHS umbrella, I convened five symposia and am currently chairing the Scientific Committee of IHC2018. I also chaired the Scientific Committee of the 18th World Organic Congress held in Istanbul in 2014, organized under the International Federation of Organic Agriculture Movements (IFOAM). Currently, I am working as a short-term consultant in three FAO projects in Azerbaijan, Kazakhstan and Uzbekistan to develop organic agriculture. I lectured at the Mediterranean Agronomic Institutes in Chania, Greece (sustainable agriculture) for three years and in Bari, Italy (Mediterranean organic agriculture) for 15 years. I supervised 10 PhD and 21 MSc students at Ege University and 9 MSc students at the Mediterranean Agronomic Institute of Bari, Italy. I have published more than 250 scientific articles, mostly in international journals.

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

In my career, I started working on figs, an important crop in the Ege region. However, since Turkey was supplying 65% of the world dried fig trade, there were very few studies carried out in other countries. So, on the

› Working at the laboratory, in training and at social events. A) In the mycotoxin analysis lab during a short training offered at the Overseas Development Agency in UK (1988). B) Visiting Kew Gardens, the well-known botanical garden in southwest London, UK, during the blooming of rhododendrons (1998). C) Having dinner with Prof. Dr. Jung-Myung Lee and other colleagues after the annual meeting of the Korean Horticultural Society in Seoul, Korea (2002). D) With Vera, owner of the Integrezia Organic Fruit Farm, at the certificate ceremony of the training workshop on organic agriculture in Almaty, Kazakhstan (September 2016).

one hand, I had to be a pioneer, but at the same time I had to handle many unknown problems. I proposed to ISHS that I organize the First International Symposium on Figs in 1997. It was accepted and I convinced CIHEAM to organize an adhoc training for young scientists. This symposium gave birth to the ISHS Working Group on Figs in 1998 and since then the network has expanded as a result of regular symposia.

Another difficulty that I had to overcome was during my PhD. I gave birth to my son earlier than the expected date as a result of travelling through the rough roads among the fig orchards. It was a really challenging period, however, both my supervisor and my husband supported me so I was able to overcome the difficulties and was able to take care of my son as well as complete my research work as planned.

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

I have many interesting experiences but a couple in particular spring to mind. Once, in the late 1990s, I had to attend a Codex Alimentarius meeting in Arusha, Tanzania. The travel agency could not arrange a flight for me. The previous week, I had to be in South Africa, so I decided to arrange the connection from Capetown to Arusha myself. I met a scientist from Tanzania and asked for his help. He told me to stay overnight in Dar-es-Salam and take a bus the next morning. I asked about the duration of the travel and everyone said that it would take 4-5 hours. The next morning I went to the bus station and took the bus. It broke down after 15 minutes and we had to change buses. Then I learned that it takes 11-12 hours of driving to reach Arusha. I could not change my plans at that stage, so I traveled through the forests and rural areas. I missed the meeting scheduled for that afternoon but it was a lifetime experience. Five years later I had to go to Arusha for an ISHS Board meeting. By then, floriculture had flourished around Arusha and there were direct flights daily from Amsterdam. Such is the impact of horticulture and trade!!

My second story occurred when I attended the International Horticultural Congress organized in Kyoto, Japan, in 1994. We were exchanging business cards with many participants including scientists from Japan. I had a suit with two pockets so I put my own business cards in one pocket and those that I received from others into the second one. As could be expected, I received many cards from Japanese colleagues. Prof. Amnon Erez from Israel posted a note and wanted to meet me. When we first met, he gave me his business card so I took a card out of my pocket, unfortunately from the wrong one and it was in Japanese. Prof. Erez saw at one glance and was astonished. He said “how clever you are! You have printed your business cards in Japanese for this meeting.” Actually it was not my business card but it belonged to a Japanese colleague. I was embarrassed but could not confess.

6. 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?

The younger generation should be aware of the fact that in the 1980s we did not have internet and we were receiving and sending all work information, such as submitting and requesting scientific papers, only by post.

› Prof. Yüksel Tüzel and Prof. Uygun Aksoy introducing plans for the 30th IHC 2018 during the ISHS General Assembly in Brisbane, Australia in August 2014.

Then fax machines were invented; what a luxury, but an expensive one. Sending applications to meetings (even in Europe) took nearly two weeks by post. Life was much slower. My PhD supervisor, Prof. Mehmet Dokuzoğuz, and Prof. Ruhinaz Gülcan, were ISHS members from our Department, and we were informed randomly through them. I decided to attend the International Congress held in Florence, Italy, in 1990. It gave me my first opportunity to envisage the world of horticulture and connect with so many other researchers. Later on, we founded the Turkish Horticultural Society in 1992 to fulfil scientific activities similar to those undertaken by ISHS, but locally. We also started organizing ISHS symposia in Turkey in 1992. The Ministry of Agriculture was paying the country membership dues, however, in the late 1980s they stopped paying them. The Turkish Horticultural Society decided to pay the ISHS dues and represent Turkey at the Council meetings. I attended the ISHS Council meeting in 1998 for the first time as the president of the Turkish Horticultural Society. During the elections for the ISHS Board, a few colleagues nominated me to stand, which was a surprise. There was an electricity cut, so we had to have a longer lunch break, during which time my friends convinced me. I was elected as the first woman on the Board and also the first member from a developing country.

ISHS's structure and principles helped us to develop similarly at the national level and since the foundation of the Turkish Horticultural Society in 1992, a congress has been organized every four years. The proceedings are published by the Turkish Horticultural Society and many symposia are held at intervals on special themes. Such a system provided a strong network among Turkish horticulturists who are actively participating in organising the International Horticultural Congress to be held in 2018 in Istanbul, Turkey.

Being a member of ISHS means you can get all the information about all horticulture-related activities at a world-wide level from the ISHS website and *Chronica Horticulturae*. Once you attend a symposium you become a part of the network and then look forward to the next event. These aspects made me keep my ISHS membership.

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

My advice to young people is to be an expert on time management. If you can plan and use your time efficiently, you can spare time for your family, science and fun. My second piece of advice is to become part of the professional networks, e.g. societies at national and international levels. If such networks do not exist, become part of initating one in your home country and then link with international counterparts. Scientific advances require intermingling of various fields of expertise and young scientists have to seek out this expertise, not only from their own institution but from all over the world.

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

In addition to the traditional topics, I believe more opportunities will arise in the future in the following fields: automation (sensors) throughout the whole chain, socio-economic and environmental sustainability and impact on human health. Horticultural production is today relatively more intensive than the other cropping systems, however, it is essential for our well-being. Intensification is inevitable and will increase in the future, but research and innovation on its social, economic and environmental impact will become more challenging. Consequently, horticultural knowledge and information systems need to be modified according to the local social demands and developments in technology.

Horticultural Science Focus

The carrot genome provides insights into crop origins and a foundation for future crop improvement

Philipp Simon, Massimo Iorizzo, Shelby Ellison, Douglas Senalik, Peng Zeng, Pimchanok Satapoomin, Jiaying Huang, Megan Bowman, Marina Iovene, Walter Sanseverino, Pablo Cavagnaro, Mehtap Yildiz, Alicja Macko-Podgórni, Emilia Moranska, Ewa Grzebelus, Dariusz Grzebelus, Hamid Ashrafi, Zhijun Zheng, Shifeng Cheng, David Spooner and Allen Van Deynze

Figure 1. Carrot color conditioned by segregation at the *Y* locus. A. A carrot population segregating at the *Y* locus, in a y_2y_2 background. All these carrots accumulate alpha- and beta-carotene as their predominant carotenoids like typical orange carrots grown today. Like today's carrots, the genotype of the darker orange carrots (upper left row) is $yy\ y_2y_2$. The genotype of pale orange carrots (upper right row and lower row) is $Y\_\ y_2y_2$ and they typically contain only 10-25% as much alpha- and beta-carotene as orange carrots. B. Slices of yellow carrots (yyY_2Y_2), which contain lutein, and white carrots ($Y\_\ Y_2Y_2$), which contain, at most, trace amounts of carotenoids, from a population segregating at the *Y* locus, in a Y_2Y_2 background.

Introduction

Vavilov (1951) placed the center of origin of cultivated carrot in Central Asia, and an analysis of molecular diversity in wild and cultivated carrots from around the world demonstrated that wild carrots from Central Asia were more similar to cultivated carrots (Iorizzo et al., 2013), confirming Vavilov's conclusions. Carrots may have been cultivated as a root crop in the Roman Empire, with extensive cultivation first recorded around 900 AD in Central Asia – Afghanistan in particular (Stolarczyk and Janick, 2011; Banga, 1963). Color has played an important role in the history of carrot domestication. The first Central Asian carrots were yellow or purple, and in the early 1500s, orange carrots were noted in still life paintings and some written accounts in Europe. Central Asian carrots spread first to the west beginning in the 900s, through the Middle East, North Africa, and then Europe; and to the east to South and North Asia (Banga, 1963). Orange carrots are grown globally today but yellow, purple, red, and white carrot land races, and some modern cultivars, are grown on a more limited scale in several parts of the world.

Carrot is among the top 10 vegetable crops globally and is a rich source of vitamin A, thanks to the popularity of orange carrots, which contain vitamin A precursors α- and β-carotene (Simon et al., 2009). The lutein in yellow carrots, anthocyanins in purple carrots, and lycopene in red carrots are also well-documented phytochemicals (Arscott and Tanumihardjo, 2010). Carrot is a diploid outcrossing crop and all carrot cultivars were open pollinated before the discovery of the first cytoplasmic male sterility (CMS) in carrot by Welch and Grimball (1947). The discovery of CMS in carrot triggered an expanded effort in carrot breeding and genetics, with the development of the first hybrid carrot cultivars and the first genes named in the 1960s. By the mid-1980s about 20 simply-inherited traits had been reported. Carrot is typically categorized as a cool season crop and most production is in temperate climates, but subtropical cultivars have been developed and have expanded the climate range of carrot production, especially since the 1970s (Simon, 2000).

Laying the foundation for sequencing the carrot genome

The sequencing of the carrot genome was an effort that formally began in 2012

and culminated with the publication and release of the genome in 2016 (Iorizzo et al., 2016). Financial support from eight seed companies (Bejo, Carosem, Monsanto, Nunhems, Rijk Zwaan (RZ), Sumika, Takii, and Vilmorin) provided funds to complete the project, and RZ also provided the DH1 carrot, both BAC (bacterial artificial chromosome) libraries and BAC end sequences of the sequenced carrot.

Several important tools that contributed to the sequencing project were developed before the project began. Genetic linkage maps provided critical information to arrange and confirm the order of superscaffolds and pseudomolecules generated by the assembly of DNA sequence, and to independently confirm that order. Linkage


B

maps were also essential to identify the candidate gene for the *Y* locus (Figure 1), which conditions carotenoid accumulation in the carrot tap root. These maps were generated from segregating populations developed from crosses made as early as 1989 to generate QTL maps for pigment accumulation and nematode resistance (Santos and Simon, 2002; Just et al., 2009) (Figure 2). Sequences for the carrot plastid (Ruhlman et al., 2006) and mitochondrial genomes (Robison and Wolyn, 2002; Iorizzo et al., 2012) had been published and contributed to confirmation of organellar genome sequence in this project. To verify the quality of the genome assembly, FISH (fluorescent in situ hybridization) (Iovene et al., 2008, 2011) and transcriptome sequence (Iorizzo et al., 2011) were used. Repetitive sequences account for a significant part of all eukaryotic genomes and previous research on MITEs (miniature inverted repeat transposable elements) (Grzebelus et al., 2006; Macko-Podgorni et al., 2013) provided a foundation to analyze their distribution in carrot and evolutionary trends.

Goals and key aspects of the carrot genome sequencing project

A full genome sequence provides the ultimate foundation to study genetics, gene function, and evolution of a species. The primary goal of the carrot genome project was to generate a high quality genome assembly, including characterization of repetitive sequences and annotation of genes. The carrot sequenced in this project was DH1, a doubled haploid Nantes type orange carrot (Figure 3). The full genome sequence generated will serve as the standard of comparison for future studies evaluating the breadth of diversity of *Daucus carota*. To begin to assess that breadth of genetic diversity, we resequenced 35 diverse cultivated and wild carrots and four other *Daucus* species in this study, and evaluated their phylogenetic relationships. Gene function works in concert with a multitude of variables that impinge on that function, including development and numerous abiotic and biotic variables in the environment, to generate the phenotypic variation of biology and agriculture. To begin to assess gene function in the carrot genome, we evaluated the transcriptome of 20 diverse plant tissues of vegetative, flowering, and stressed plants. We also utilized the carrot genome sequence to better understand the function of the *Y* gene, which regulates high carotenoid accumulation in carrots that have either yellow or orange storage roots, relative to the white wild type. To study molecular plant evolution at the genome-wide level, full genome sequence data are necessary, and relatively few full plant genome sequences are published, particularly in the Euasterid II clade. We compared 12 plant genomes to carrot and evaluated evidence for genome duplication and evolutionary relationships in this study.

Assembly and characterization of the carrot genome

Sequenced Illumina libraries of the DH1 genome included 3 paired end libraries (170-800 nt insert size) and 5 mate-pair libraries (2-40 kb insert size). End sequences of BAC (bacterial artificial chromosome) libraries of the DH1 genome provided additional paired end sequences spanning 148±70 kb. These paired end sequences, ranging from 170 nt to >200 kb, combined with a newly developed consensus linkage map using marker data from QTL studies noted earlier, were used to generate the *de novo* assembly of the carrot genome. Several tests were made to evaluate the correctness of the assembly sequence, including an evaluation of the assembled sequence with an 8-kb 454 library, additional BAC paired end sequences not previously used, and a new GBS SNP genetic map, to evaluate the assembly on a larger scale. Gene sequence of expressed genes (ESTs) and ultra-conserved genes were used to evaluate the assembly on a smaller scale. Over 99.7% of unassembled sequence reads aligned to the assembly, over 94% of the 454 library, additional BAC ends, ESTs, and ultra-conserved genes aligned to the genome assembly. GBS markers also aligned with high collinearly, confirming the accuracy of the assembly. In addition, FISH experiments were carried out to evaluate the consistency and coverage of assembly, focusing on repetitive sequences in chromosome-specific regions, subtelomeric regions, telomeres, and centromeres. These experiments indicated that the carrot genome assembly extends into the telomeric and subtelomeric regions of the genome, confirming high coverage of the assembly. Based upon the assembly statistics, combined with corroborating studies to evaluate correctness of that assembly, the carrot genome assembly is among the most complete published, based upon both coverage and length of sequence contiguity. A total of 60 superscaffolds anchored with SNP markers mapped on the nine carrot chromosomes accounting for 85% of the carrot genome. One superscaffold on chromosome 4 spans 85% of that chromosome, and one recombination event occurs roughly every 388 kb.

Repetitive DNA sequences, including mobile elements (MEs) and large clusters of tandem repeats (TRs), typically account for a significant part of eukaryotic genomes, and carrot is no exception. MEs typically occupy 20-40% of plant genome assemblies and in carrot they account for 46% of the assembled genome. Most carrot MEs (98%) are transposable elements, and given their abundance, the distribution of carrot ME insertion sites was evaluated. Over half were found to be near (<2 kb), or in genes, distributed in a random pattern. Large clusters of TRs were observed in FISH studies in carrot telomeres, using a telomere-specific probe that hybridizes to all telomeres, and a centromere-specific probe that hybridizes to all centromeres in the carrot genome. A third probe was prepared to hybridize to a TR that forms a knob only on chromosome 1, called CL80. To expand our evaluation of repetitive DNA sequences beyond carrot to the other *Daucus* species, 106 paired end reads were also generated for *D. syrticus*, a species closely related to carrot, and to four more distantly related species (Arbizu et al., 2014a, b) – *D. aureus*, *D. guttatus*, *D. littoralis*, and *D. pusillus*. Interestingly, an evaluation of *D. syrticus* sequences revealed that the carrot centromeric repeat was highly abundant in this species; however, the CL80 repeat was not present. In two of the more distantly related species, *D. guttatus* and *D. littoralis*, FISH analysis revealed that the centromere repeat

Figure 2. A carrot population segregating at both the Y_2 locus and one of the anthocyanin (*P*) loci. The *Y* locus is not segregating, *yy*. Carrots with orange color or absence of anthocyanins are homozygous recessive for the y_2y_2 or *pp* loci, respectively; yellow or purple carrots indicate the presence of at least one dominant Y_2 or *P* allele, respectively.

sequence found in carrot was absent, while the CL80 repeat was highly represented in subtelomeric and pericentromeric regions of most of these chromosomes. This redistribution and repurposing of repetitive sequences among *Daucus* species provides an interesting foundation for future research.

Characterization of the carrot genome identified 32,000 genes, based on comparison of genes annotated in the genomes of other plants, of which 98.7% were observed in the carrot transcriptome. Putative gene functions were assigned and aligned to catalogued plant proteins.

Carrot diversity

Genetic diversity in cultivated and wild carrots provides the heritable variation necessary to drive future crop improvement, and provides insights into crop domestication. For the carrot genome sequencing project, 35 diverse wild and cultivated carrots were resequenced, among which 1.3×10^6 SNPs were identified, and 49,365 SNPs were selected for phylogenetic and cluster analysis. As in previous studies with 3,202 SNPs (Iorizzo et al., in press), Central Asia and the Middle East were found to be primary centers of carrot domestication. The allelic constitution of eastern cultivated carrots (Asian carrots, so-named because they originated east of Central Asia) was more similar to that of Central Asia wild carrots than western cultivated carrots (European, North African, and Middle Eastern carrots), likely reflecting more intensive breeding in western cultivated carrots.

As was observed in previous studies, the genetic diversity of cultivated carrots, mostly open pollinated cultivars, was only slightly lower than that of wild carrots, suggesting a relatively limited bottleneck during carrot domestication. Comparing wild carrot with eastern cultivated accessions, five carrot chromosomes had genomic regions with high levels of population differentiation (F_{ST}), indicating that genomic regions on these chromosomes include genes for domestication traits.

Carrot genome evolution

Carrot is a member of the Euasterid II clade which also includes lettuce and sunflower, as well as other *Apiaceae* like celery, coriander and parsnip. To study the evolution of the carrot genome, the whole genome sequence of carrot and 12 other plants were compared, to identify orthologous genes – genes in different species that evolved from a common ancestral gene during speciation. Analysis of sequence divergence in ortholog sequences estimated the time frame in which Euasterids II diverged from Rosids, Ericales, and Euasterids I to be ~113, ~101, and ~90.5 million years ago, respectively, whereas carrot diverged from lettuce ~72 million years ago. Whole genome duplications, reflected in multiple blocks of syntenic genes, play a significant role in plant evolution. Two such duplications, or possibly a duplication and a triplication, occurred in the evolution of carrot. In addition to whole genome duplications, lineage-specific duplications expanded the representation of some gene families but not others. As a result, relative to other plants, the carrot genome, for example, contains few genes in the MADS transcription factor family, which plays an important role in the development of reproductive organs, and few genes in most classes of resistance genes involved in plant-pathogen introductions. In contrast, the carrot genome contains an expanded set of zinc-finger genes involved in several important biological processes including morphogenesis and symbiosis. Mechanisms by which plant genomes compensate for relative over- and under-represented gene families are not well understood so carrot may serve as a model for studying these mechanisms.

A candidate gene for carotenoid accumulation

While wild carrot tap roots accumulate little or no carotenoids, the first cultivated carrots were yellow, or purple and yellow, while most modern carrots are orange. The *Y* and *Y2* genes condition carotenoid accumulation, and the genotypes of white, yellow, and orange carrots are *Y_Y2_*, *y y Y2_*, and *y y y2 y2*, respectively (Buishand and Gabelman, 1979). The sequencing of the carrot genome provided an opportunity to identify candidate genes for the *Y* gene. Using two mapping populations segregating for the *Y* gene (*YyY2Y2* and *Yyy2y2*), fine-mapping identified a 75-kb region of chromosome 5 harboring the *Y* gene. None of the eight predicted genes in this region had a role in isoprenoid biosynthesis. Three predicted genes had synonymous SNPs but one gene, DCAR_032551, had a 212-nt insertion in its second exon in both mapping populations. That insertion creates a frame-shift mutation, which co-segregated with the *Y* allele phenotype, and with differential gene expression patterns. A survey of diverse wild carrots and white cultivated carrots revealed no samples with the *Y* inser-

tion, and all but two diverse orange carrots surveyed were homozygous for the insertion. Those two exceptional orange carrots were heterozygous for the insertion, and another nonsynonymous allele, a 1-nt insertion in the second exon that also causes a frameshift mutation, was noted. An evaluation of LD (linkage disequilibrium) in the genomic region bearing the *Y* gene found increased LD and reduced nucleotide diversity in *yy* carrots, indicating this region was under selection. The discovery of two different *y* alleles indicates that the *yy* high pigment phenotype was selected more than once.

How might the *Y* gene function?

In an analysis of the carrot transcriptome, 925 genes were co-expressed with the candidate for the *Y* gene, DCAR_032551, and gene expression in the isoprenoid pathway was especially enriched. Earlier research had also demonstrated that genes in this pathway are expressed in orange, yellow, and white carrot storage roots (e.g. Just et al., 2007). The functioning of the isoprenoid pathway in orange roots may, on first consideration, be surprising, because carotenoids have no known function in roots. However, downstream products of the pathway beyond carotenoids, such as abscisic acid and strigolactones, are critical for root growth and response to abiotic stress. With that in mind, it is the accumulation of carotenoids in yellow and orange carrot storage roots that is unusual, rather than carotenoid biosynthesis itself. While analysis of expression confirmed overexpression of several genes in the MEP (methylerythritol phosphate) and carotenoid pathways in *yy* plants, genes in the monoterpenoid biosynthetic portion of pathway, in contrast, were generally underrepresented in *yy* orange and yellow carrots. Volatile monoterpenoids account for a significant portion of the flavor of raw carrots, so it might be speculated that yellow and orange carrots are less flavorful than white carrots, but that has not been observed (Surles et al., 2004), suggesting additional regulation of monoterpenoid biosynthesis.

While the DCAR_032551 gene is not a biosynthetic gene in the isoprenoid pathway, it does have a homolog in the *Arabidopsis* genome, *pel* (PSEUDO-ETIOLATION IN LIGHT). Mutants of the *pel* gene have a defective response to light in leaves and stems (Ichikawa et al., 2006), but without a known function. Aspects of the *Y* gene are reminiscent of the *cop/det* photomorphogenic repressor genes of Arabidopsis, in which seedlings grown in the dark lack the typical characteristics of etiolation (elongated hypocotyls and cotyledons; chlorosis). Instead, they resemble light-grown seedlings in overall morphology, plastid differentiation, and carotenoid accumulation, including a transcriptome pattern of light-regulated genes comparable to that for seedlings grown in light (Lau and Deng, 2012). Given the similarity between the COP/DET mutant phenotype, referred to as de-etiolated, the similar transcriptome pattern observed with the *Y* gene, and physiological studies in carrot demonstrating ectopic chloroplast differentiation in roots exposed to light (Fuentes et al., 2012), the *Y* gene function resembles de-etiolation in the carrot tap root. The extent to which this similarity holds up will be revealed as the function of the *pel* gene in Arabidopsis and the *Y* gene in carrot are studied in more detail.

Figure 3. DH1, the carrot used to sequence the genome.

Applications of the carrot genome

The sequencing of the carrot genome provides a foundation for additional studies in plant evolution, especially as more Euasterid II plant genomes are sequenced, and as comparative genomic and FISH studies involving tandem repeats are pursued. The carrot genome sequence has already served as a valuable resource in clarifying the phylogeny of the genus *Daucus* and close relatives (Arbizu et al., 2014a, b). Similarly, insights into the phenotypic signatures of carrot domestication can be associated with selection for specific genes with access to the genome sequence. Several immediate applications are already being pursued with the development of molecular markers closer to, or in, genes under selection in breeding programs for more simply inherited traits, or in applying GWAS (genome-wide association study) approaches to select complex traits in carrot. The identification of candidate genes will provide a deeper understanding of traits. A more extensive catalog and intensive understanding of the carrot transcriptome is also already growing, given the release of the carrot genome. In 2008, only 600 DNA nuclear sequences were at NCBI for *Daucus*, and 5350 for all *Apiaceae*; whereas in 2014, those numbers had risen to 30,855 sequences for *Daucus*, and 54,000 for all *Apiaceae* (Iorizzo et al., in press). The carrot genome sequencing project, in combination with additional genomic analysis in other *Apiaceae*, has increased those numbers to 92,674 and 121,068 today. Whole genome sequencing and resequencing projects will certainly continue to enrich the genomic resources available to plant scientists working with the *Apiaceae*, and with other plants.

Acknowledgements

The authors appreciate the financial support of the carrot industry and the following vegetable seed companies: Bejo, Carosem, Monsanto, Nunhems, Rijk Zwaan (RZ), Sumika, Takii, and Vilmorin, with additional thanks to RZ for providing DH1, BAC libraries, and BES. Shelby Ellison was supported by the National Science Foundation under Grant No. 1202666. Marina Iovene thanks the projects RGV-FAO (D.M. 3824) for partial financial support and PONa3_00025-BIOforIU for funding the acquisition of a fluorescence microscope. Alicja Macko-Podgórni, Emilia Moranska, Ewa Grzebelus, and Dariusz Grzebelus were supported by the Polish National Science Center, project no. 2012/05/B/NZ9/03401 and the statutory funds for science granted by the Polish Ministry of Science and Higher Education to the Faculty of Biotechnology and Horticulture, Univ. of Agric. in Krakow. The authors thank Holly Ruess for assembly and annotation of the plastid genome and Rob Kane for support in development of plant materials.

› Philipp Simon

› About the authors

Philipp Simon is a USDA, ARS Research Geneticist and Professor of Horticulture at the University of Wisconsin, Madison, Wisconsin, USA. His research in vegetable genetics and breeding has focused on carrot improvement and development of breeding tools. He has developed widely used germplasm, co-led the carrot sequencing project with Allen Van Deynze, and collected carrot, *Allium*, and other vegetable germplasm in 10 collecting expeditions. http://vcru.wisc.edu/simon/, e-mail: philipp.simon@ars.usda.gov

Massimo Iorizzo, Plants for Human Health Institute, Department of Horticultural Science, North Carolina State University, Kannapolis, North Carolina, USA, e-mail: miorizz@ncsu.edu

Shelby Ellison, Department of Horticulture, University of Wisconsin-Madison, Madison, Wisconsin, USA, e-mail: slrepinski@wisc.edu

Douglas Senalik, Vegetable Crops Research Unit, US Department of Agriculture-Agricultural Research Service, and Department of Horticulture, University of Wisconsin-Madison, Madison, Wisconsin, USA, e-mail: Douglas.Senalik@ars.usda.gov

Peng Zeng, Beijing Genomics Institute-Shenzhen, Shenzhen, China, e-mail: zengpeng@genomics.cn

Pimchanok Satapoomin, Kasetsart University, Thailand, e-mail: faaspns@ku.ac.th

Jiaying Huang, Beijing Genomics Institute-Shenzhen, Shenzhen, China, e-mail: 1584030896@qq.com

Megan Bowman, Van Andel Research Institute Grand Rapids, Michigan, USA, e-mail: megan.bowman@vai.org

Marina Iovene, Institute of Biosciences and Bioresources, National Research Council, Bari, Italy, e-mail: marina.iovene@ibbr.cnr.it

Walter Sanseverino, Sequentia Biotech, Bellaterra, Barcelona, Spain, e-mail: wsanseverino@sequentiabiotech.com

Pablo Cavagnaro, National Scientific and Technical Research Council (CONICET), Facultad de Ciencias Agrarias, Universidad Nacional de Cuyo, Cuyo, Argentina, and Instituto Nacional de Tecnología Agropecuaria (INTA), Estación Experimental Agropecuaria La Consulta, La Consulta, Argentina, e-mail: pablocavagnaro@hotmail.com

Mehtap Yildiz, Department of Agricultural Biotechnology, Faculty of Agriculture, Yuzuncu Yil University, Van, Turkey, e-mail: mehtapyildiz@gmail.com

Alicja Macko-Podgórni, Institute of Plant Biology and Biotechnology, University of Agriculture in Krakow, Krakow, Poland, e-mail: mackoa@ogr.ar.krakow.pl

Emilia Moranska, Institute of Plant Biology and Biotechnology, University of Agriculture in Krakow, Krakow, Poland, e-mail: ejozefowicz88@gmail.com

Ewa Grzebelus, Institute of Plant Biology and Biotechnology, University of Agriculture in Krakow, Krakow, Poland, e-mail: grzebeluse@ogr.ur.krakow.pl

Dariusz Grzebelus, Institute of Plant Biology and Biotechnology, University of Agriculture in Krakow, Krakow, Poland, e-mail: dgrzebel@ogr.ar.krakow.pl

Hamid Ashrafi, Department of Horticultural Science, North Carolina State University, Raleigh, North Carolina, USA, e-mail: hamidashrafi@ncsu.edu

Zhijun Zheng, Beijing Genomics Institute-Shenzhen, Shenzhen, China, e-mail: zhengzhijun01@126.com

Shifeng Cheng, Beijing Genomics Institute-Shenzhen, Shenzhen, China, e-mail: chengshf@genomics.cn

David Spooner, Vegetable Crops Research Unit, US Department of Agriculture-Agricultural Research Service, and Department of Horticulture, University of Wisconsin-Madison, Madison, Wisconsin, USA, e-mail: David.Spooner@ars.usda.gov

Allen Van Deynze, Seed Biotechnology Center, University of California, Davis, Davis, California, USA, e-mail: avandeynze@ucdavis.edu

› References

Arbizu, C., Ruess, H., Senalik, D., Simon, P.W., and Spooner, D.M. (2014a). Phylogenomics of the carrot genus (*Daucus*, Apiaceae). Amer. J. Bot. *101*, 1666–1685.

Arbizu, C., Ruess, H., Senalik, D., Simon, P.W., and Spooner, D.M. (2014b). Morphometrics of *Daucus* (Apiaceae): a counterpart to a phylogenomic study. Amer. J. Bot. *101*, 2005–2016.

Arscott, S.A., and Tanumihardjo, S.A. (2010). Carrots of many colors provide basic nutrition and bioavailable phytochemicals acting as a functional food. Compr. Rev. Food Sci. Food Saf. *9*, 223–239.

Banga, O. (1963). Main Types of the Western Carotene Carrot and Their Origin (Zwolle, The Netherlands: W.E.J. Tjeenk).

Buishand, J.G., and Gabelman, W.H. (1979). Investigations on the inheritance of color and carotenoid content in phloem and xylem of carrot roots (*Daucus carota* L.). Euphytica. *28*, 611–632.

Fuentes, P., Pizarro, L., Camilo Moreno, J., Handford, M., Rodriguez-Concepcion, M., and Stange, C. (2012). Light-dependent changes in plastid differentiation influence carotenoid gene expression and accumulation in carrot roots. Plant Mol. Biol. *79*, 47–59.

Grzebelus, D., Yau, Y.-Y., and Simon, P.W. (2006). Master: a novel family of PIF/Harbinger-like transposable elements identified in carrot (*Daucus carota* L.). Mol. Genet. Genomics *275*, 450–459.

Ichikawa, T., Nakazawa, M., Kawashima, M., Iizumi, H., Kuroda, H., Kondou, Y., Tsuhara, Y., Suzuki, K., Ishikawa, A., Seki, M., Fujita, M., Motohashi, R., Nagata, N., Takagi, T., Shinozaki, K., and Matsui, M. (2006) The FOX hunting system: an alternative gain-of-function gene hunting technique. Plant J. *48*, 974–985.

Iorizzo, M., Senalik, D.A., Grzebelus, D., Bowman, M., Cavagnaro, P.F., Matvienko, M., Ashrafi, H., Van Deynze, A., and Simon, P.W. (2011). De novo assembly and characterization of the carrot transcriptome reveals novel genes, new markers, and genetic diversity. BMC Genomics *12*, 89.

Iorizzo, M., Grzebelus, D., Senalik, D., Szklarczyk, M., Spooner, D., and Simon, P.W. (2012). Against the traffic: the first evidence for mitochondrial DNA transfer into the plastid genome. Mobile Genet. Elements *2*, 1–6.

Iorizzo, M., Senalik, D.A., Ellison, S.L., Grzebelus, D., Cavagnaro, P.F., Allender, C., Brunet, J., Spooner, D.M., Van Deynze, A., and Simon, P.W. (2013). Genetic structure and domestication of carrot (*Daucus carota* subsp. *sativus*) (Apiaceae). Amer. J. Bot. *100*, 930–938.

Iorizzo, M., Ellison, S., Senalik, D., Zeng, P., Satapoomin, P., Bowman, M., Iovene, M., Sanseverino, W., Cavagnaro, P., Yildiz, M., Macko-Podgórni, A., Moranska, E., Grzebelus, E., Grzebelus, D., Ashrafi, H., Zheng, Z., Cheng, S., Spooner, D., Van Deynze, A., and Simon, P.W. (2016). A high-quality carrot genome assembly reveals new insights into carotenoid accumulation and asterid genome evolution. Nature Genet. *48*, 657–666.

Iorizzo, M., Ellison, S., Van Deynze, A., Stoffel, K., Ashrafi, H., Iovene, M., Cavagnaro, P., Cheng, S., Zheng, P., Zheng, Z., Senalik, D., Spooner, D., and Simon, P.W. Recent advances in carrot genomics. Acta Hortic. (in press).

Iovene, M., Grzebelus, M.E., Carputo, D., Jiang, J., and Simon, P.W. (2008). Major cytogenetic landmarks and karyotype analysis in carrot and other Apiaceae. Amer. J. Bot. *95*, 793–804.

Iovene, M., Cavagnaro, P.F., Senalik, D., Buell, C.R., Jiang, J., and Simon, P.W. (2011). Comparative FISH mapping of *Daucus* species (Apiaceae family). Chromosome Res. *19*, 493–506.

Just, B.J., Santos, C.A.F., Fonseca, M.E.N., Boiteux, L.S., Oloizia, B.B., and Simon, P.W. (2007). Carotenoid biosynthesis structural genes in carrot (*Daucus carota*): isolation, sequence-characterization, single nucleotide polymorphism (SNP) markers and genome mapping. Theor. Appl. Genet. *114*, 693–704.

Just, B.J., Santos, C.A., Yandell, B.S., and Simon, P.W. (2009). Major QTL for carrot color are positionally associated with carotenoid biosynthetic genes and interact epistatically in a domesticated x wild carrot cross. Theor. Appl. Genet. *119*, 1155–1169.

Lau, O.S., and Deng, X.W. (2012).The photomorphogenic repressors COP1 and DET1: 20 years later. Trends Plant Sci. *17*, 584–593.

Macko-Podgorni, A., Nowicka, A., Grzebelus, E., Simon, P.W., and Grzebelus, D. (2013). *DcSto*: carrot *Stowaway*-like elements are abundant, diverse, and polymorphic. Genetica *141*, 255–267.

Robison, M.M., and Wolyn, D.J. (2002). Complex organization of the mitochondrial genome of petaloid CMS carrot. Mol. Genet. Genomics *268*, 232–239.

Ruhlman, T., Lee, S.B., Jansen, R.K., Hostetler, J.B., Tallon, L.J., Town, C.D., and Daniell, H. (2006). Complete plastid genome sequence of *Daucus carota*: implications for biotechnology and phylogeny of angiosperms. BMC Genomics *7*, 222.

Santos, C., and Simon, P.W. (2002). Some AFLP amplicons are highly conserved DNA sequences mapping to the same linkage groups in two F_2 populations of carrot. Genet. Molec. Biol. *25*, 195–201.

Simon, P.W. (2000). Domestication, historical development, and modern breeding of carrot. Plant Breed. Rev. *19*, 157–190.

Simon, P.W., Pollak, L.M., Clevidence, B.A., Holden, J.M., and Haytowitz, D. (2009). Plant breeding for human nutritional quality. Plant Breed. Rev. *31*, 325–392.

Stolarczyk, J., and Janick, J. (2011). Carrot: history and iconography. Chron. Hortic. *51* (2), 13–18.

Surles, R.L., Ning Weng, Simon, P.W., and Tanumihardjo, S.A. (2004). Carotenoid profiles and consumer sensory evaluation of specialty carrots (*Daucus carota* L.) of various colors. J. Agric. Food Chem. *52*, 3417–3421.

Vavilov, N.I. (1951). The origin, variation, immunity and breeding of cultivated plants. Chronica Botanica *13*, 1–366.

Welch, J.E., and Grimball, E.L. (1947). Male sterility in carrot. Science *106*, 594.

Technology to reduce waste and improve quality of fruits and vegetables

Marie Shrestha, Sonja Guttmann and Markus von Bargen

Introduction

Millions of tons of vegetables and fruits are harvested and then distributed throughout Europe every year. However, fruits and vegetables are mostly highly perishable foods and are especially susceptible to changing environmental conditions after harvest such as temperature and humidity. An innovative technology, based on the principle of ultrasonic humidification/disinfection, was tested to evaluate whether it had potential to reduce waste and improve quality of fruit and vegetables along the entire supply chain. Ultrasonic humidification relies on the generation of ultrasonic waves in so-called piezoelectric transducer units located at the base of the humidifier's water tub. These transducers convert electrical energy into mechanical energy, and subsequently generate ultrasonic waves, which produce very fine aerosols for air humidification. During operation of the transducer, the surrounding water carries the ultrasonic vibrations to the water-air interface above. The constant compression and decompression of the water column above the transducer causes cavitation in close proximity to the water surface. Thus intersecting capillary waves are formed, from which very fine water vapour droplets (the aerosols) with a very small diameter are separated in the wave peak. The size of the water droplets depends on the ultrasonic frequency used. In order to achieve the desired droplet size of 1-3 µm, a frequency of 1.7 MHz is required. These micro-droplets are then injected through a pipe system out of the humidifier in an air stream. Because of the adiabatic cooling effect, the surrounding temperature is reduced, resulting in an effective cooling system that utilises very little energy.

The market potential of this technology has been demonstrated in real-scale case studies within the FRESH-DEMO EU-project (H2020; grant agreement N°634699). Peaches and nectarines were transported using a permanent ultrasonic humidification, from harvest in Italy to a supermarket in The Netherlands, and this system was compared with conventional non-humidified products. After delivery to the supermarket, samples of each product were transported to a laboratory in the north of Germany where different analyses were performed to determine the effect of the ultrasonic humidification/disinfection technology on the quality and shelf-life of the fruit.

Figure 1. The effect of ultrasonic humidification on quality of nectarines after transportation from Gobbi Dino to Roosendaal and storage for 15 days at 5°C. Treatments were: conventional (left) in which boxes of fruit were maintained at 5°C, relative humidity (RH) of approx. 80%; humidified (right) in which boxes of fruit were maintained at 5°C, RH of 96% using ultrasonic humidification; and humidified and acidifier treated (centre) in which boxes were held in the same conditions as the humidified treatment but also received a natural acidifier application prior to transportation.

Materials and Methods

Three batches of peaches (Pesche Pia IT-P. Bianca 1^A) and nectarines (Pesche Noci IT-P. Bianca 1^A) were purchased from Gobbi Dino (north of Italy) and were packed into 54 boxes of 7 kg each. The fruit were harvested, packaged and transported 1314 km to a supermarket in Roosendaal.

Boxes of fruit were transported for 4 days under one of three different sets of conditions. The first set of boxes had ultrasonic humidification (5°C; 96% relative humidity) applied, a second set were treated after harvest and packaged with a natural acidifier based on citric acid for 15 minutes and transported under the same ultrasonic humidification, whereas the control set were harvested, packaged and conventionally transported at similar temperatures and a relative humidity of approximately 80%.

After delivery, the fruit were stored at 5°C to simulate the temperature of the average consumer's fridge. Control fruit were stored without humidification, whereas the fruit that received the humidification treatment during transport were stored on arrival with humidification for 15 days. Pictures were taken of each box on a daily basis. The appearance (mould growth, decay formation) and the weight of the boxes was monitored every three days until end of storing time (day 15). Sensory analyses (taste, flavour, decay, colour, softness, and obvious differences from the control fruit) were conducted once a week (day 1, day 8 and day 15) with fruit from different boxes.

Directly after delivery and after storage day 15, one box of each treatment was delivered to a laboratory in Bremen to analyse soluble solids concentration and vitamin C content

Evolution of weight loss [%]	C	H	HD
after 15 days for peaches	5.08	2.46	3.15
after 15 days for nectarines	7.01	3.52	2.93

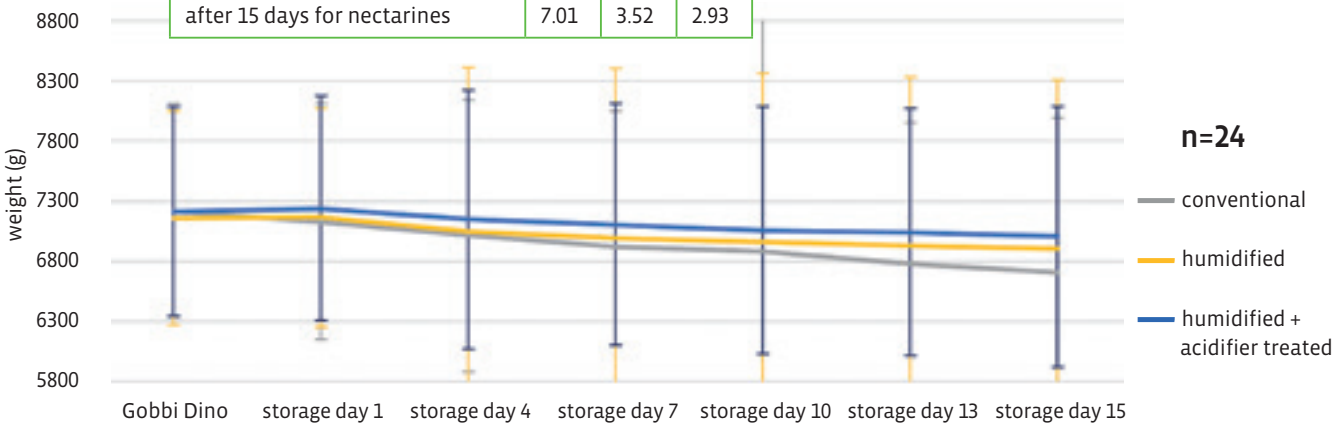


Figure 2. The effect of humidification on the weight of boxes of nectarines during the supply chain from harvest, including transportation from Gobbi Dino to Roosendaal and storage for 15 days at 5°C. Treatments were: conventional (C) in which boxes of fruit were maintained at 5°C, relative humidity (RH) of approx. 80%; humidified (H) in which boxes of fruit were maintained at 5°C, RH of 96% using ultrasonic humidification; and humidified and acidifier treated (HD) in which boxes were held in the same conditions as the humidified treatment but also received a natural acidifier application prior to transportation. Eight boxes per treatment were measured. The percent weight loss after 15 days for both peaches and nectarines is shown in the inset table. Error bars represent the standard errors of the mean.

of the fruit (HPLC – internal method of accredited laboratory 'Handelslabor Hofmann GmbH'), and to ttz Bremerhaven to measure the hydration, the pH, the total polyphenol content (according to LFBG 47.00-10[1]) and the microbiological load (total viable counts, and mould and yeast counts 100 g^{-1}) of the fruit.

Results

Directly after delivery, the peaches and nectarines in all treatments were similar in appearance. However, the ultrasonic humidification during storage after arrival in Roosendaal significantly affected the quality of peaches and nectarines. Figure 1 shows that the humidified (centre photo) and humidified and acidifier treated (right photo) nectarines were more intense in colour and were more homogeneous in skin appearance than the fruit in the control treatment. The conventionally-transported and stored nectarines (left photo) in the control treatment had less intense colour and there was greater decay and sulcate areas on the skin surface.

Fruit that were transported and stored in humidified conditions had a longer shelf-life by 2-4 days and were better in appearance than the fruit in the control treatment. Mould spoilage appeared approximately 3 days earlier on conventionally treated fruit than fruit receiving ultrasonic humidification along the supply chain.

The weight of the peach and nectarine boxes was constant along the supply chain from the starting point in Italy until arrival in Roosendaal and day 1 of storage (Figure 2 – example shown for nectarines).

During post-transportation storage, the boxes gradually started to lose weight. The boxes from the control treatment lost on average 6.1% of their weight from harvest to end of shelf-life (after 15 days). However, the

[1] L 47.00-10 2008-12 Bestimmung des Gesamt-Polyphenolgehaltes in Tee; Colorimetrisches Verfahren mit Folin-Ciocalteu-Reagenz (nach DIN ISO 14502-1).

Table 1. The effect of humidification on soluble solids concentration, vitamin C content and total polyphenol content of peaches and nectarines after transportation from Gobbi Dino to Roosendaal and subsequent storage for 15 days at 5°C. Treatments were: conventional, in which boxes of fruit were maintained at 5°C, relative humidity (RH) of approx. 80%; humidified, in which boxes of fruit were maintained at 5°C, RH of 96% using ultrasonic humidification; and humidified and acidifier treated in which boxes were held in the same conditions as the humidified treatment but also received a natural acidifier application prior to transportation. Four fruit were assessed per treatment.

	Soluble solids concentration (° brix) Standard deviation 0.5-1.5		Vitamin C content (mg 100 g^{-1}) Standard deviation 1.5-3.0		Total polyphenol content (mg g^{-1} drying substance) Standard deviation 0.2-0.4	
Nectarines	**Day 1**	**Day 15**	**Day 1**	**Day 15**	**Day 1**	**Day 15**
Conventional	9.5	10.3	6.0	8.9	1.5	1.5
Humidified	10.6	11.0	6.5	9.9	1.4	1.5
Humidified + acidifier	9.4	10.4	6.6	11.2	1.5	1.6
Peaches	**Day 1**	**Day 15**	**Day 1**	**Day 15**	**Day 1**	**Day 15**
Conventional	12.7	13.9	6.2	8.6	1.6	1.6
Humidified	13.0	13.0	6.5	9.8	1.6	1.6
Humidified + acidifier	13.8	13.3	5.9	9.0	1.5	1.5

boxes transported and stored with humidification lost on average 3.0% (standard deviation: 0.38%) from harvest to end of shelf-life (after 15 days), although this was statistically not significant (Table in Figure 2).
The water content of the nectarines in the control treatment decreased 11.7% along the supply chain and storage (measured by calculating fruit dry matter content at different points along the chain). The water content of the nectarines in the humidified treatments decreased on average 3.9±1.9% along the supply chain and storage. For peaches, a decrease of 1.5%±0.0% in water content was detected for the control fruit, whereas peaches from the humidified treatments displayed an increase in water content of 5.9±1.3%.
Constant pH values were documented for all peaches (around 4.5±0.15) and all nectarines (around 3.9±1.5) throughout the supply chain and storage.
Evaluation of soluble solids concentration, vitamin C content and total polyphenol content during storing time of 15 days for peaches and nectarines are shown in Table 1. No significant difference between soluble solids concentration or total polyphenol content among the treatments for peaches as well as for nectarines was detected.
For vitamin C content, all values increased during storage time by approximately 3 g 100 mg^{-1} (around 50% increase during storing). The greatest change in vitamin C content was detected for nectarines held in the humidification treatment with the addition of acidifier (Table 1) with an increase of 4.4 mg 100 g^{-1} (around 70%).
There was considerable variation in microbiological counts within each treatment and therefore there was no significant difference among them.
No difference in sensory characteristics of both peaches or nectarines among treatments were observed on arrival at Roosendaal. On storage days 8 and 15, the peaches and nectarines in the humidified treatments demonstrated better sensorial characteristics, better appearance in terms of intensity in colour and more typical taste and flavour than the fruit in the control treatment.

Discussion

Ultrasonic humidification of peaches and nectarines along the supply chain and during storage led to high quality products during shelf-life, which was increased by up to 4 days, less weight loss and superior taste and flavour compared to control fruit.
End users will profit by extended shelf-life as well as improved taste and flavour, whereas the impact for the seller will be waste reduction combined with improved hydration and minimized weight loss. Considering these advantages for end users and sellers, this technology has been identified as an easy to handle technology with a significant effect on product quality along the complete supply chain.
The ultrasonic humidification technology also provides the opportunity to add a natural acidifier as an innovative solution to reduce waste and to maintain the quality of peaches and nectarines during transport and storage. The ultrasonic humidification technology is easy to implement at each step of the supply chain (from harvest to display in the supermarket).

Ultrasonic humidification technology leads to positive benefits for end users, retailers and the environment.

Acknowledgments

This study was performed within the framework of the FRESH-DEMO project, funded under the Horizon 2020 research and innovation programme - Contract number 634699.

› Marie Shrestha

› Sonja Guttmann

› Markus von Bargen

› About the authors

Mrs. Marie Shrestha is team leader of the international project group at ttz Bremerhaven - BILB. She has an MSc in Food Technology and has over 8 years experience in management of European and national research projects in the area of food technology and bioprocess, with a focus on plant proteins, food processing by-product valorisation and active and intelligent packaging. E-mail: MShrestha@ttz-bremerhaven.de

Mrs. Sonja Guttmann is project manager of national and international projects at ttz Bremerhaven - BILB. She has a Dipl. Ing. in Biotechnology and has over 8 years experience in management of European and national research projects in the area of food technology, with a focus on ultrasonic humidification technology. E-mail: SGuttmann@ttz-bremerhaven.de

Mr. Markus von Bargen is technical leader at ttz Bremerhaven – BILB. He has a BA and, with more than 14 years of experience in the implementation of applied technical developments, he is leading the development of ultrasonic humidification technology. E-mail: MvonBargen@ttz-bremerhaven.de

In vitro conservation: confronting challenges in the age of climate change

Sutthinut Soonthornkalump

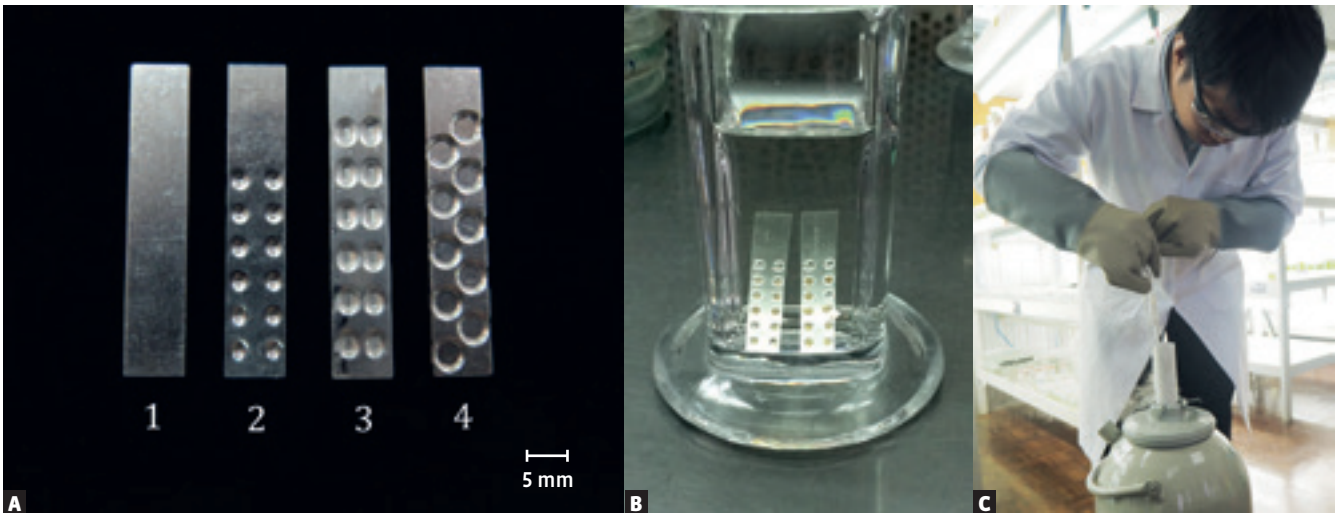


Figure 1. A) Various types of aluminum cryo-plate: A1) plain cryo-plate, A2) typical cryo-plate, A3) oblong-well cryo-plate, A4) broad-well cryo-plate; B) PVS2 treatment of encapsulated protocorms of P. niveum on aluminum cryo-plate; C) Immersion of plant material into liquid nitrogen tank. (Photos by S. Soonthornkalump).

Climate change is affecting security of food production because of severe fluctuations in the world's weather. Many rare and endemic species are threatened by climate change. In situ conservation on its own cannot guarantee the survival of many endangered plant species. Therefore, in order to achieve the goal of conservation, simultaneous ex situ and in situ conservation is needed. Knowledge of plant micropropagation is very useful for developing several techniques for short/medium and long term conservation, such as slow growth storage and cryopreservation. These methods have already been applied to conserve many rare, endemic plants, including valuable medicinal plants in Thailand.

Introduction

The average atmospheric temperature has increased over the past two centuries, and climate change is assumed to be one of the causes of serious problems relating to world ecological systems and biodiversity (Reed, 2012). Experts claim that climate change cannot be halted within the next few years. The Aichi biodiversity target was launched at the Convention on Biological Diversity (CBD) in Nagoya, Japan, in 2010, as part of the strategic plan for biodiversity in 2000-2020. One of the actions to achieve the strategic goal was to promote sustainable use of plants, in order to safeguard biodiversity (CBD, 2010). Therefore, conservation processes for plants need to be implemented as soon as possible. Since in vitro techniques were first developed several decades ago, many branches of plant biotechnology, including conservation, have been integrated. Tissue culture systems are very useful to assist in protecting and maintaining the germplasm of various plant species and cultivars. This technique has some advantages compared to conventional propagation methods, for example, high multiplication rates, freedom from pathogens, small area requirement, low labor costs, and maintenance of genetic stability (Engelmann, 1991a). Tissue culture techniques are continuously being improved, particularly for conservation purposes (Sarasan et al., 2006).

There are two major in vitro storage methods: short/medium term and long term conservation (Engelmann, 1991a). Slow growth storage is the most popular for short/medium term storage. It involves the restriction of growth rates and employs routine culture techniques. In contrast, cryopreservation has been developed for long term conservation of viable biological materials in ultra-low temperatures, and this technology has developed rapidly in the last few years (Taji et al., 2002). This article outlines recent techniques of in vitro conservation and their applications for sustainable use.

Short/medium term conservation versus long term conservation

Short/medium term storage involves maintenance of in vitro plant materials in growth-limiting conditions without incurring tissue injury during the intervals between subcultures (Engelmann, 1991a). This method employs routine tissue culture techniques, combined with some physiological conditions (FAO, 2014). The use of low temperature in culture conditions is usually combined with a reduction in light intensity (Rao, 2004). Supplements of sugar-substituted additives (e.g. mannitol), plant growth retardants (e.g. abscisic acid (ABA)), anti-gibberellic acid agents (anti-GA) and increased sugar concentrations are commonly found to improve success, depending on the plant species (Lambardi and Ozudogru, 2013). Temperature can affect growth rate, for example, de Carvalho et al. (2014) found that reducing the temperature to 10°C reduced in vitro growth rate and resulted in 100% survival after in vivo acclimatization of ornamen-

■ Table 1. Comparison of essential factors of short/medium and long term in vitro conservation (Modified from Engelmann, 1991a, b).

Techniques	Factors	Description
Short/medium term conservation	Temperature	• Treatment of low temperature combined with low light intensity can suppress growth rate. However, cold sensitivity of some species needs to be taken into account.
	Culture medium	• Reduced nutrition and sugar content can reduce growth and also increase the intervals between subcultures. • Supplement of osmoprotectants, such as mannitol or increased sugar concentrations, can improve conservation of plant material in low temperatures. • Growth retardants, such as ABA and anti-GA, can be used to reduce growth. • Other substances, such as activated charcoal, can also be used to limit browning and chlorophyll degradation.
	Physiology stage of explant	• After transfer, the explant can be stored to avoid necrosis and phenolic compound production.
	Culture vessel	• Type of vessel affects gaseous exchange, the risk of contamination and can save space.
	Gaseous environment	• Decreased oxygen content or reduced atmospheric pressure of the culture chamber can limit growth without the need for low temperature (Hassan, 2004).
	Encapsulation	• This technique, known as synthetic seed, is achieved by coating plant material with alginate hydrogel, which can then be stored at low temperatures or using cryopreservation (Rai et al., 2009).
	Desiccation	• Gradual dehydration with ABA pretreatment can increase dehydration tolerance and prolong the period of storage at room temperature.
Long term conservation	Plant material	• Explants (such as shoot tips) should be small, have a dense cytoplasm with a few vacuoles and a high nucleus/cytoplasm ratio. Young and vigorous tissue could have a higher survival rate than aging material.
	Preculture	• Several cryoprotectants, such as sucrose, mannitol, sorbitol, DMSO, polyethylene glycol, can be applied to increase cell membrane integrity. Concentration and preculture period are factors that have to be determined in this step. • Cold acclimatization can increase freezing tolerance and survival rate in some temperate species (Palva et al., 2001).
	Freezing	• Various types of freezing procedures can be performed, such as ultra-rapid, rapid and slow freezing. Programmable freezing instruments can improve precision and reproducible freezing conditions. • The use of an aluminum plate results in extremely high freezing rates that avoid ice crystallization during the freezing step (Sekizawa et al., 2011).
	Storage	• Storage duration in liquid nitrogen is theoretically unlimited. The storage chamber should be protected from natural radiation, because it may lead to mutation.
	Thawing	• The immersion of cryovials containing samples in water at 40°C is frequently used to avoid recrystallization in plant tissue after freezing. • High concentrations of sucrose (1 M sucrose) are beneficial when using the aluminum plate (Yamamoto et al., 2011).
	Post-treatment	• For optimal conditions after thawing, osmoprotectants must be eliminated by rinsing, dilution or diffusion, to reduce their toxicity. • Low concentrations of nutrients are used within the culture medium after treatment, to prevent osmotic shock. • Dark conditions can prevent the effects of photooxidation. • Supplements of suitable phytohormones in the culture medium can also enhance recovery rate. • Addition of antioxidants also reduces or prevents browning effects (Antony et al., 2013)
	Viability assessment	• In case regrowth is very slow, some chemical supplements are commonly used, such as fluorescein diacetate (FDA) and 2,3,5-triphenyltetrazolium chloride (TTC). However, the disadvantage is that this is a destructive method. Volatile hydrocarbon production, which can be analyzed by chromatography, is considered to be a non-destructive method.

tal bromeliad (*Acanthostachys strobilacea*). Manipulation of the gaseous environment by overlaying mineral oil extended subculture intervals from 6 to 24 months in *Bacopa monnieri,* the Indian medicinal plant (Sharma et al., 2012). Synthetic seed treatment of the valuable medicinal orchid, *Dendrobium nobile*, resulted in storage for up to 60 days of the encapsulated protocorm-like bodies (PLBs) (Mohanty et al., 2013).

In contrast, the mainstream method for long term storage is cryopreservation, which is the storage of living plant material under extremely low temperatures (lower than -130°C) so that the stored material survives and can regrow after thawing (Day and Stacey, 2007). The principle of cryopreservation is the control and/or avoidance of intracellular ice crystallization by reducing water content in plant cells without cell injury (Benson, 2000). There are six important

Table 2. Comparison of advantages and disadvantages of short/medium term and long term in vitro conservation.

Type of in vitro conservation	Advantages	Disadvantages
Short/medium term in vitro conservation	• No need for special equipment and easy to set up (Engelmann, 1991b). • Optimal stage of orthodox seed, recalcitrant seed, bulk and large weight seed can be stored using in vitro collection (Engelmann, 1998). • Phytosanitary control of technique provides ability to transport germplasm nationally and internationally (FAO, 2014).	• Laborious, high cost of maintenance and genetic alteration may occur over time (Sarasan et al., 2006). • In vitro conditions may induce oxidative stress and senescence (Thakur et al., 2015).
Long term conservation by cryopreservation	• Unlimited storage period (Engelmann, 1991a). • Low cost maintenance and minimal space requirement (Kaczmarczyk et al., 2011). • Provides possibility to store chilling-sensitive or recalcitrant species (Sershen, et al., 2012).	• Sophisticated instruments are often necessary (e.g. liquid nitrogen dewar, aluminum cryocane, cryovial) (Taji et al., 2002). • If not detected, the depletion of liquid nitrogen could lead to the loss of all samples (FAO, 2014).

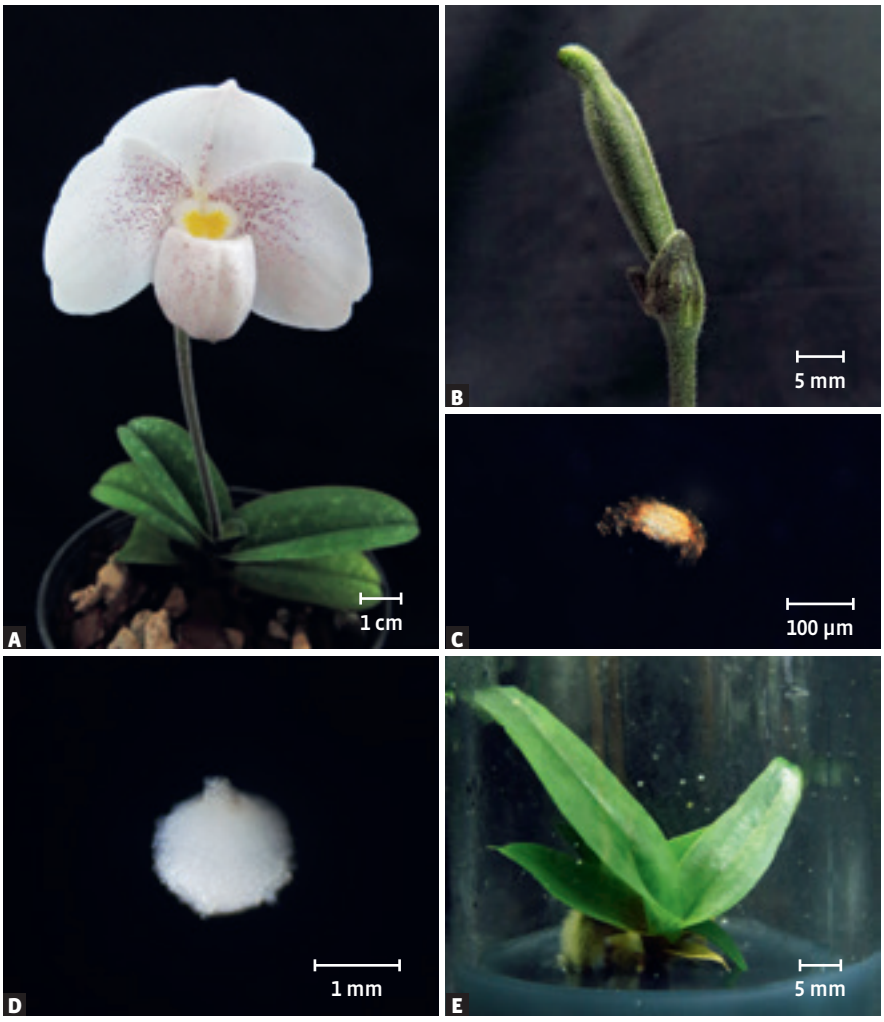


Figure 2. A) Morphological characters and seed development of *Paphiopedilum niveum* plant and flower, B) Five-month-old capsule, C) Seed contained embryo, D) Four-month-old protocorm cultured in darkness, E) Six-month-old plantlet. (Photos by S. Soonthornkalump).

steps in most protocols; preculture, osmoprotection, dehydration, freezing in liquid nitrogen (LN), rapid warming and regrowth (Sakai and Engelmann, 2007). Since the 1960s, the average number of publications on cryopreservation has been increasing every year (Pritchard, 2002). Several procedures have been developed, with a range of modifications, such as controlled rate of cooling, vitrification-based methods and dehydration-based methods (Kaczmarczyk et al., 2012).

Currently, vitrification-based and dehydration-based methods are popular. The difference between the protocols is the dehydration process. The vitrification-based method was developed in the 1980s using concentrated plant vitrification solutions (PVS) (Sakai and Engelmann, 2007), such as PVS1, PVS2 and PVS3, of which PVS2 is the most commonly used (Kami, 2012). In order to mitigate toxicity of PVS and enhance viability of the sample, it is necessary to determine the optimal incubation time for each species and material type. The dehydration-based method involves evaporative desiccation using a sterile air flow or by placing the sample over silica gel (Sherlock et al., 2005). This method is simple and does not use toxic chemicals, however, the dehydration period is longer. Some plant species exhibit high mortality after being exposed to PVS, in which case dehydration-based cryopreservation should be used.

Cryopreservation technology is developing continually. One of the newest techniques is the aluminum cryo-plate method, which was developed by a Japanese scientific team from the Genetic Resources Center, National Agriculture and Food Research Organization (NARO). An aluminum cryo-plate is a small aluminum plate with various sized wells on the upper side (Figure 1A) (Sekizawa et al., 2011). This equipment acts as a plant material holder and reduces injury and loss of plant material during the cryopreservation process (Figure 1B). The first successful report of the use of a cryo-plate was by Yamamoto et al. (2011), who used a cryo-plate as part of the vitrification technique, and called it the V cryo-plate method. This method combines the advantages of vitrification and droplet-vitrification. Encapsulation vitrification is not a very complex process and there is no need to use special equipment (Reed, 2008). The use of aluminum foil as part of droplet-vitrification facilitates uniformly rapid thermal exchange (Vujović et al., 2011). The use of cryo-plates also results in very high cooling and

Figure 3. A) *Vanda coerulea* was hand pollinated by QBG staff, B) Tissue culture training of villagers using low-cost laminar air flow cabinet, C) Orchid flasks on wooden shelves, D) Dr. Santi Watthana (second from the left) and QBG staff instructed the basics of orchid biology to the villagers, E) Flowers of the reintroduced *V. coerulea*. (Photos by Dr. S. Watthana).

warming rates. Moreover, cryo-plates are useful in transferring plant material in the steps of loading solution (LS) and PVS2 (Sekizawa et al., 2011). Aluminum cryo-plates have also been applied as part of a dehydration technique, named D-cryo-plate (Matsumoto et al., 2015). This method resulted in 87% regrowth of Japanese persimmon shoot tips. Recently, the aluminum cryo-plate was adapted for use with a new desiccator called drying beads, and the resultant regrowth rates for bamboo orchids (*Arundina graminifolia*) were higher than the same material desiccated on silica gel (Cordova II and Thammasiri, 2016).

During the first steps of cryopreservation, i.e. excision and desiccation, an induced oxidative burst can lead to tissue browning in some plant species (Roach et al., 2008). Lipoic acid, glutathione (GSH), glycine betaine, polyvinylpyrrolidone (PVP), vitamin E and vitamin C have been reported to give rise to antioxidant activity, which reduces oxidative stress in plant cryopreservation (Uchendu et al., 2010a, b). This article focuses on vitamin C, which is an antioxidant that is frequently included as a supplement in cryopreservation. Vitamin C plays an important role in the ascorbate-glutathione cycle by preventing extreme reduction and oxidation (Foyer and Noctor, 2011). Normally, high accumulation of ascorbate can be found in apoplastic fluid, which acts as a cell membrane defender (Pedreira et al., 2004). A low concentration of vitamin C (0.005%) controlled browning of Cavendish banana (Ko et al., 2009). The addition of vitamin C (0.5 mg L^{-1}) alone increased the regrowth rate of post-cryopreserved blackberry shoot tips more than the combined addition of vitamin C and vitamin E (Uchendu et al., 2010b).

A possible side effect of multiplication medium containing plant hormones or of very long term culture is somaclonal variation (SV) (Bairu et al., 2011; Wang et al., 2011). SV is a serious concern because the point of conservation programmes is to preserve genetic integrity. SV has been classified into two types: heritable and epigenetic (Skirvin et al., 1994). Heritable variation can be stable in either sexual or asexual propagation, whereas epigenetic variation is unstable even in asexual propagation (Bairu et al., 2011). Epigenetic alteration was detected as the instability of epigenetic mechanism and activation of transposon elements (Kaeppler and Phillips, 1993). Although genetic stability is one of the most important necessities for in vitro conservation (Taji et al., 2002), SV can be an important tool for crop improvement in many cases (Lestari, 2006). Therefore, protocols have been developed that detect genetic modification. Flow cytometry is used to determine the DNA content, which indicates the ploidy level and genome size (Fernández et al., 2003). Molecular marker techniques, such as RAPD (Martín and González-Benito, 2005), AFLP (Chuang et al., 2009), RAPD with ISSR (Fatima et al., 2013), and AFLP with MSAP (Tiwari et al., 2013), are very useful to verify genetic stability.

Figure 4. A) Cut flowers of *Curcuma* hybrids; B) Young inflorescence of *C. angustifolia* found in the local market during the early rainy season; C) Cut flowers of *Smithatris supraneanae* (erect inflorescense) and *Globba* spp. (pendulous inflorescence) used as an offering during the Buddhist Lent in Saraburi province, Central Thailand; D) Rhizomes, young shoot and young inflorescence of many ginger species often used in Thai cuisine. (Photos by Dr. T. Puangpairote and S. Soonthornkalump).

The essential factors to be determined (Table 1) and the advantages and disadvantages (Table 2) of different in vitro conservation techniques have been summarized.

Application of in vitro conservation for human well-being: a case study in Thailand

Thailand is considered to be one of the richest centres of biodiversity in the world, with more than 15,000 plant species distributed within the country. In recent years, the area of forest has decreased from 70 to 33% of the total land area (CBD, 2016). Many issues, such as fluctuations in climate, deforestation, environmental pollution, disturbance from human activities and introduction of invasive alien species (Office of Natural Resources and Environmental Policy and Planning, 2014), have contributed to an urgent need to halt the loss of biodiversity. Plant tissue culture is very useful for the conservation and preservation of plant species. Rare, endemic and valuable medicinal plants, such as orchids and zingiberaceous plants, have been stored using in vitro techniques. Some organizations and conservation projects play an important role in Thailand, such as the Royal Initiative of Her Royal Highness Princess Maha Chakri Sirindhorn (RSPG); the Queen Sirikit Botanic garden (QBG); the National Research Council of Thailand (NRCT); the Department of Biology, Faculty of Science, Prince of Songkla University (PSU); and the Department of Plant Science, Faculty of Science, Mahidol University (MUSCPL).

Several orchids in Thailand were considered to be endangered, such as *Paphiopedilum* spp. and *Dendrobium cruentum,* which are Thai native orchids listed in Appendix I of the Convention of International Trade in Endangered Species of Wild Fauna and Flora (CITES). Therefore, suitable micropropagation protocols need to be developed in order to conserve these orchids. *Paphiopedilum niveum*, endemic to southern Thailand, is considered particularly important because it is an endangered species on the red list of the International Union for Conservation of Nature (IUCN). This species had previously been identified for developing protocols for seed germination (Figure 2) and indirect somatic embryogenesis (Kaewubon et al., 2010). In addition, the first successful protocol was developed to conserve *P. niveum* (Chairoek et al., 2016). The authors reported that the highest survival rate (29.6%) of callus of *P. niveum* after cryopreservation resulted from using encapsulation vitrification.

The Orchid Seed Stores for Sustainable Use (OSSSU) project aims to store orchid seeds from around the world and construct a database of orchid families, seed production and suitable germination media. This project is a collaboration among an international network of orchid seed biotechnologists from 16 countries, including Thailand. The Department of Plant Science, Faculty of Science, Mahidol University (MUSCPL), is the project partner and coordinator in Thailand. They aim to conserve orchid seeds from diverse habitats within Thailand and develop in vitro production protocols to support their sustainable use. Their protocols for desiccating orchid seeds and storing them in a freezer at -20°C have been described on the OSSSU website (OSSSU, 2016). Seed from twenty-eight Thai native orchids have been successfully stored in the freezer at -20°C using this method (Thammasiri, 2011).

Figure 5. A) Observation of rare and endangered plants in their natural habitat; B) *Alpinia nigra,* threatened Thai edible ginger; C) Flowers of resurrection ginger (*Kaempferia rotunda*); D) One-year-old *Nepenthes ampullaria* stored in slow growth culture conditions; E) In vitro collection of rare and endemic species; F) The author presenting ex vitro acclimatization technique at a plant tissue culture workshop. (Photos by Dr. T. Jenjittikul and S. Soonthornkalump).

The blue vanda conservation project is a collaboration between the QBG and the villagers of Baan Pong Krai, Chiang Mai province. In 2008 this project resulted in the reintroduction of blue vanda (*Vanda coerulea*) from tissue culture to the wild (Figure 3). Villagers were instructed on the basic principles of plant tissue culture by staff from Ramkhamhaeng University and QBG. Currently, the Pongyeang Subdistrict Administrative Organization (PSAO) has provided supporting funds to construct a local plant tissue culture laboratory so that the villagers can produce orchids using in vitro culture. This project has been promoted to the public on several occasions. Moreover, this village is being publicized as the blue vanda village for ecotourism. These activities have provided a new income stream for many Baan Pong Krai villagers. Villagers are far more aware of the importance of conservation because of encouragement from QBG and financial support from PSAO (Watthana and Keeratikornkul, 2016).

Thailand is a key location in the geographical distribution of the ginger family (*Zingiberaceae*), with more than 300 species found in Thailand (Larsen and Larsen, 2006). Species within *Zingiberaceae* have a wide range of uses including those relating to Thai tradition, cuisine and medicinal use (Figure 4). Some ginger species were developed for horticultural use and have now become popular in the marketplace, e.g. Siam tulip (*Curcuma alismatifolia*) and torch ginger (*Etlingera elatior*). However, many species are also rare or endangered. Therefore, in order to conserve ginger germplasm, an in vitro collection of gingers was established in the plant tissue culture laboratory at MUSCPL. Some species were included in a plant improvement project, supported by the National Research Council of Thailand (NRCT) and the Plant Genetic Conservation Project under the RSPG. For instance, *Alpinia nigra*, or "Nor Kala", is a rare edible ginger, which is usually used as a spice, medicine or indigenous vegetable (Figure 5B). It is an important ingredient in Tod Man Nor Kala, the signature dish of Ko Kret subdistrict in Nonthaburi province, 20 km north of Bangkok. Its habitat has been decreased by property development. Shoot tips of *A. nigra* were cryopreserved using the vitrification method, resulting in a regrowth rate of 27% (Rungjindamai et al., 2010). Tissue culture has also been used to multiply the fragrant flower species of *Hedychium*. QBG has promoted its cultivation for perfume production. These activities

demonstrate positive cooperation between local people and the governing sector, which in turn is positive for sustainable use and conservation of threatened plant species.

My experience in the field of in vitro conservation

In 2009, I shifted my research field from marine science to plant science for my masters degree. I was interested in micropropagation and tissue culture. I decided to focus on improvement of wild ginger species that had potential to become new ornamentals. My masters thesis involved using in vitro mutagenesis to improve some ornamental characters of the resurrection ginger (*Kaempferia rotunda*) (Figure 5C), and was supported by a grant from the National Research Council of Thailand. This research involved chromosome doubling and gamma irradiation to make tetraploid and variegated leaf mutants, and was a good opportunity to assist my supervisor in making progress in the RSPG project. During the project, I had the opportunity to undertake field trips to collect plant material for the in vitro plant collection at MUSCPL. I also assisted in a workshop on plant tissue culture and helped maintain the in vitro collection of rare and endangered plant species (Figure 5).

When I started my PhD research, I decided to focus on micropropagation and cryopreservation of *Paphiopedilum*, the Venus slipper orchid. All species in this genus are considered to be endangered. This includes *Paphiopedilum niveum*, which was recently evaluated by IUCN as endangered because the wild population is threatened as a result of loss of habitat and plant collection by poachers. Meanwhile, there was no efficient protocol to conserve this germplasm. The Department of Biology, Faculty of Science, Prince of Songkla University, have already established protocols for micropropagation of *P. niveum* (Kaewubon et al., 2010; Kaewubon and Meesawat, 2014; Chairoek et al., 2015). The first protocol for *P. niveum* callus cryopreservation was presented by colleagues at the First International Symposium on Tropical and Subtropical Ornamentals (Chairoek et al., 2016). However, I intend to develop the novel protocol of cryopreservation further by using aluminum cryoplates for *P. niveum*, whilst taking measures to ensure genetic stability (Figure 1C). This could lead to the development of conservation of other *Paphiopedilums* species in the future.

Acknowledgements

The author would like to gratefully thank the graduate school, Prince of Songkla University, for financial support, and also thank Assoc. Prof. Dr. Upatham Meesawat, his supervisor, for reviewing this article. He especially thanks Assoc. Prof. Dr. Kanchit Thammasiri, Assist. Prof. Dr. Ngarmnij Chuenboonngarm, Assist. Prof. Dr. Thaya Jenjittikul, and Dr. Shin-ichi Yamamoto, for their encouragement and helpful suggestions. He is also very grateful to Dr. Santi Watthana and all his *colleagues* from PSU and MUSCPL for their friendly help and for providing information and photos that were used in this article.

› Sutthinut Soonthornkalump

› About the author

Sutthinut Soonthornkalump is a PhD candidate from the Department of Biology, Faculty of Science, Prince of Songkla University, Thailand. He has concentrated on plant micropropagation for in vitro breeding and conservation purposes. He is passionate about tissue culture of carnivorous plants, orchids and exotic ornamentals. He has been inspired by a poem of Prof. Rapee Sagarik, who is the Thai orchid "father": "Conservation and development are the same things. A mind of love is inclined to conserve, which then would lead to a natural development." These words have become his motto and working guideline. Sutthinut won an ISHS award for the best student poster presentation at the I International Symposium on Tropical and Subtropical Ornamentals, which was held in Krabi Province, Thailand, from 7-9 March 2016.

› References

Antony, J.J.J., Keng, C.L., Mahmood, M., and Subramaniam, S. (2013). Effects of ascorbic acid on PVS2 cryopreservation of *Dendrobium* Bobby Messina's PLBs supported with SEM analysis. Appl. Biochem. Biotechnol *171*, 315–329.

Bairu, M.W., Aremu, A.O., and Van Staden, J. (2011). Somaclonal variation in plants: causes and detection methods. Plant Growth Regul *63*, 147–173.

Benson, E.E. (2000). Special symposium: in vitro plant recalcitrance do free radicals have a role in plant tissue culture recalcitrance? In Vitro Cell Dev Biol Plant. *36*, 163–170.

CBD. (2010). The Strategic Plan for Biodiversity 2011-2020 and the Aichi Biodiversity Targets. http://www.cbd.int/decision/cop/?id=12268.

CBD. (2016). Thailand-Country profile. https://www.cbd.int/countries/?country=th (Accessed June 2016).

Chairoek, S., Thammasiri, K., and Meesawat, U. (2015). Optimization of protocorm-like bodies tissue culture and clonal propagation conditions for endangered lady's slipper orchid (*Paphiopedilum niveum* (Rchb.f.) Stein). Pak. J. Biotechnol *12* (2), 105–114.

Chairoek, S., Thammasiri, K., and Meesawat, U. (2016). Cryopreservation of *Paphiopedilum niveum* (Rchb.f.) Stein calli using encapsulation-vitrification and vitrification methods. Paper presented at I International Symposium on Tropical and Subtropical Ornamentals (Krabi Province, Thailand: ISHS).

Chuang, S.J., Chen, C.L., Chen, J.J., Chou, W.Y., and Sung, J.M. (2009). Detection of somaclonal variation in micro-propagated *Echinacea purpurea* using AFLP marker. Sci Hortic-Amsterdam *120* (1), 121–126.

Cordova II, L.B., and Thammasiri, K. (2016). Cryopreservation on a cryo-plate of *Arundina graminifolia* protocorms, dehydrated with silica gel and drying beads. Cryoletters *36* (2), 68–76.

Day, J.G., and Stacey, G.N. (2007). Cryopreservation and Freeze-Drying Protocols, 2nd edn (Totowa, NJ: Human Press).

de Carvalho, V., dos Santos, D.S., and Nievola, C.C. (2014). In vitro storage under slow growth and *ex vitro* acclimatization of the ornamental bromeliad *Acanthostachys strobilacea*. S. Afr. J. Bot. *92*, 30–43.

Engelmann, F. (1991a). In vitro conservation of tropical plant germplasm - a review. Euphytica *57*, 227–243.

Engelmann, F. (1991b). In vitro conservation of horticultural species. Acta Hortic. *298*, 327–334. http://dx.doi.org/10.17660/ActaHortic.1991.298.40

Engelmann, F. (1998). In vitro germplasm conservation. Acta Hortic. *461*, 41–47. http://dx.doi.org/10.17660/ActaHortic.1998.461.2

FAO. (2014). Genebank: Standards for Plant Genetic Resources for Food and Agriculture (Rome: FAO).

Fatima, N., Ahmad, N., and Anis, M. (2013). An improved in vitro encapsulation iprotocol, biochemical analysis and genetic integrity using DNA based molecular markers in regenerated plants of *Withania somnifera* L. Ind Crops Prod. *50*, 468–477.

Fernández, A.B., Sánchez-Moreiras, A.M., and Coba de la Peña, T. (2003). Flow cytometry principles and instrumentation. In Handbook of Plant Ecophysiology Techniques, M.J. Reigosa Roger, ed. (Dordrecht: Kluwer Academic Publishers), p.21–34.

Foyer, C.H., and Noctor, G. (2011). Ascorbate and glutathione: the heart of the redox hub. Plant Physiol *155*, 2–18.

Hassan, N.S. (2004). Storage of in vitro banana shoot cultures at low temperature or under mineral oil layer. Int. J. Agri. & Biol. *6* (*2*), 303–306.

Kaczmarczyk, A., Turner, S.R., Bunn, E., Mancera, R.L., and Dixon, K.W. (2011). Cryopreservation of threatened native Australian species-what have we learned and where to from there? In Vitro Cell Dev Biol Plant. *47*, 17–25.

Kaczmarczyk, A., Funnekotter, B., Menon, A., Phang, P.Y., Al-Hanbali, A., Bunn, E., and Mancera R.L. (2012). Current issues in plant cryopreservation. In Current Frontiers in Cryobiology, I.I. Katkov, ed. (Rijeka, Croatia: Intech), p.417–438.

Kaeppler, S.M., and Phillips, R.L. (1993). Tissue culture-induced DNA methylation variation in maize. Proc Natl Acad Sci USA 90, 8773–8776.

Kaewubon, P., Sangdam. S., Thammasiri, K., and Meesawat, U. (2010). Plant regeneration through somatic embryogenesis from callus-derived PLBs of tropical slipper orchid (*Paphiopedilum niveum* (Rchb.f.) Pfitz.). Floriculture Ornamental Biotech. *4* (*special issue 1*), 29–35.

Kaewubon, P., and Meesawat, U. (2014). Histological analysis of somatic embryogenesis induced in tropical lady's slipper orchid (*Paphiopedilum niveum*). Acta Hortic. *1025*, 231–236. http://dx.doi.org/10.17660/ActaHortic.2014.1025.33

Kami, D. (2012). Cryopreservation of plant genetic resources. In Current Frontiers in Cryobiology, I.I. Katkov, ed. (Rijeka, Croatia: Intech), p.439–456.

Ko, W.H., Su, C.C., Chen, C.L., and Chao, C.P. (2009). Control of lethal browning of tissue culture plantlets of Cavendish banana cv. formosana with ascorbic acid. Plant Cell Tiss Organ Cult. *96*, 137–141.

Lambardi, M., and Ozudogru, E.A. (2013). Advances in the safe storage of micropropagated woody plants at low temperature. Acta Hortic. 988, 29–42. http://dx.doi.org/10.17660/ActaHortic.2013.988.2

Larsen, K., and Larsen, S.S. (2006). Gingers of Thailand (Chiang Mai, Thailand: Queen Sirikit Botanic Garden).

Lestari, E.G. (2006). Review: in vitro selection and somaclonal variation for biotic ad abiotic stress tolerance. Biodiversitas *7* (*3*), 297–301.

Martín, C., and González-Benito, M.E. (2005). Survival and genetic stability of *Dendranthema grandiflora* Tzvelev shoot apices after cryopreservation by vitrification and encapsulation-dehydration. Cryobiology *51*, 281–289.

Matsumoto, T., Yamamoto, S., Fukui, K., Rafique, T., Engelmann, F., and Niino, T. (2015). Cryopreservation of persimmon shoot tips from dormant buds using the D cryo-plate technique. The Horticulture Journal *84* (*2*), 106–110.

Mohanty, P., Nongkling, P., Das, M.C., Kumaria. S., and Tandon, P. (2013). Short-term storage of alginate-encapsulated protocorm-like bodies of *Dendrobium nobile* Lindl.: an endangered medicinal orchid from North-east India. Biotech *3*, 235–239.

Office of Natural Resources and Environmental Policy and Planning. (2014). Thailand: National report on the implementation of the convention on biological diversity. (Bangkok, Thailand: Integrated Promotion Technology Co., Ltd.).

OSSSU. (2016) OSSSU protocols. http://osssu.org/main/protocols-english.html (Accessed June 2016).

Palva, E.T., Welling, A., Tähtiharju, S., Tamminen, I., Puhakainen, T., Mäkelä, P., Laitinen, R., Li, C., Helenius, E., Boije, M., Aspegren, K., Aalto, O., and Heino, P. (2001). Cold acclimation and development of freezing and drought tolerance in plants. Acta Hortic. *560*, 277-284. http://dx.doi.org/10.17660/ActaHortic.2001.560.53

Pedreira, J., Sanz, N., Peña, M.J., Sánchez, M., Queijeiro, E., Revilla, G., and Zarra, I. (2004). Role of apoplastic ascorbate and hydrogen peroxide in the control of cell growth in pine hypocotyls. Plant Cell Physiol. *45* (*5*), 530–534.

Pritchard, H.W. (2002). Editorial cryopreservation and global warming! CryoLetters *23*, 281–282.

Rai, M.K., Asthana, P., Singh, S.K., Jaiswal, V.S., and Jaiswal, U. (2009). The encapsulation technology in fruit plants - a review. Biotechnol Adv. *27*, 671–679.

Rao, N.K. (2004). Plant genetic resources: advancing conservation and use through biotechnology. Afr J. Biotechnol *3* (*2*), 136–145.

Reed, B.M. (2008). Plant Cryopreservation: a Particle Guide (New York: Springer).

Reed, D.H. (2012). Impact of climate change on biodiversity. In Handbook of Climate Change Mitigation, W.Y. Chen, J. Seiner, T. Suzuki, and M. Lackner, eds. (Switzerland: Springer International Publishing), p.506–530.

Roach, T., Ivanova, M., Beckett, R., Minibayeva, F.V., Green, I., Pritchard, H.W., and Kranner, I. (2008). An oxidative burst of superoxide in embryonic axes of recalcitrant sweet chestnut seeds as induced by excision and desiccation. Physiol. Plantarum, *133*, 131–139.

Rungjindamai, C., Thammasiri, K., Chuenboongarm, N., and Jenjittikul, T. (2010). Cryopreservation of *Alpinia nigra* (Gaertn.) Burtt by vitrification-based technique. Thai Journal of Botany *2* (*special issue*), 151–154.

Sakai, A., and Engelmann, F. (2007). Vitrification, encapsulation-vitrification and droplet-vitrification: a review. Cryoletters *28* (*3*), 151–172.

Sarasan, V., Cripps, R., Ramsay, M.M., Atherton, C., McMichen, M., Prendergast, G., and Rowntree, J.K. (2006). Conservation in vitro of threatened plants-process in the past decade. In Vitro Cell Dev Biol Plant. *42*, 206–214.

Skirvin, R.M., McPheeters, K.D., and Norton, M. (1994). Sources and frequency of somaclonal variation. HortScience *29* (*11*), 1232–1237.

Sekizawa, K., Yamamoto, S., Rafique, T., Fukui, K., and Niino, T. (2011). Cryopreservation of in vitro-grown shoot tips of carnation (*Dianthus caryophyllus* L.) by vitrification method using aluminium cryo-plates. Plant Biotechnology *28*, 401–405.

Sershen, Varghese, B., Pammenter, N.W., and Berjak, P. (2012). Cryo-tolerance of zygotic embryos from recalcitrant seeds in relation to oxidative stress – a case study on two amaryllid species. J. Plant Physiol. *169*, 999–1011.

Sharma, N., Satsangi, R., Pandey, R., Singh, R., Kaushik, N., and Tyagi, R.K. (2012). In vitro conservation of *Bacopa monnieri* (L.) using mineral oil. Plant Cell Tiss Organs. *111*, 291–301.

Sherlock, G., Block, W., and Benson, E.E. (2005). Encapsulation-dehydration cryopreservation protocol using silica gel as the desiccant. Cryoletters *26* (*1*), 45–54.

Taji, A., Kumar, P., and Lakshmanan, P. (2002). In Vitro Plant Breeding. (New York: Food Products Press).

Thakur, S., Tiwari, K.L., and Jadhav, S.K. (2015). In vitro approaches for conservation of *Asparagus racemosus* Willd. In Vitro Cell Dev Biol Plant. *51*, 619–625.

Thammasiri, K. (2011). Ex situ conservation of Thai orchid species. Paper presented at 20th World Orchid Conference (Singapore).

Tiwari, J.K., Saurabh, S., Chandel, P., Singh, B.P., and Bhardwaj, V. (2013). Analysis of genetic and epigenetic variation in in vitro propagated potato somatic hybrid by AFLP and MSAP marker. Electron J Biotechn. http://dx.doi.org/10.2225/vol16-issue6-fulltext-9

Uchendu, E.E., Muminova, M., Gupta, S., and Reed, B.M. (2010a). Antioxidant and anti-stress compounds improve regrowth of cryopreserved *Rubus* shoot tips. In Vitro Cell Dev Biol Plant. *46*, 386–393.

Uchendu, E.E., Leonard, S.W., Traber, M.G., and Reed, B.M. (2010b). Vitamins C and E improve regrowth and reduce lipid peroxidation of blackberry shoot tips cryopreservation. Plant Cell Rep. *29*, 25–35.

Vujovića, T., Sylvestre, I., Ružića, D., and Engelmann, F. (2011). Droplet-vitrification of apical shoot tips of *Rubus fruticosus* L. and *Prunus cerasifera* Ehrh. Sci Hortic. *130*, 222–228.

Wang, W., Zhao, X., Pan, Y., Zhu, L., Fu, B., and Zhikang, L. (2011). DNA methylation changes detected by methylation-sensitive amplified polymorphism in two contrasting rice genotypes under salt stress. J Genet Genomics *38*, 419–424.

Watthana, S., and Keeratikornkul, A. (2016). Blue vanda village. http://www.qsbg.org/Database/Article/Image/vijai.pdf (in Thai). (Accessed June 2016).

Yamamoto, S., Fukui, K., and Niino, T. (2011). A new cryopreservation method for vegetatively propagated plant genetic resources using aluminum cryo-plates. Paper presented at: Research Highlights for 2011 (FY 2011) (Ibaraki, Japan: National Institute of Agrobiological Sciences).

History

A lasting legacy – *Horticultural Reviews* and *Plant Breeding Reviews*

Ian Warrington and Irwin Goldman

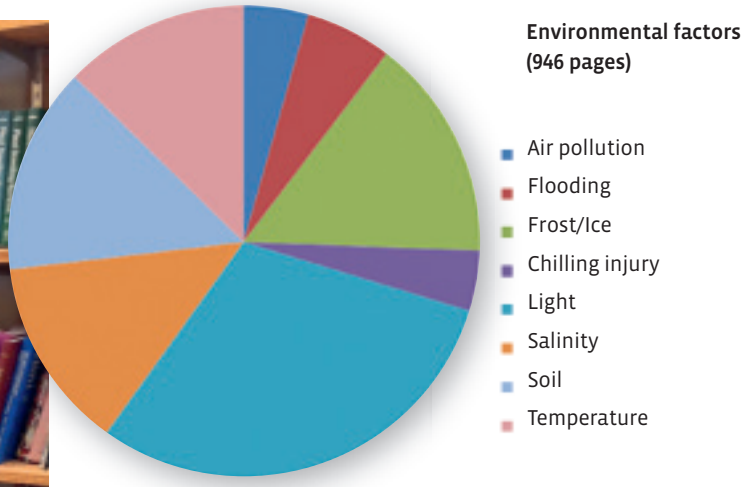


Figure 1. The impacts of environmental factors on the growth and development of many horticultural crops have been extensively covered in a number of reviews in *Horticultural Reviews*.

› Jules Janick standing in front of an impressive lineup of *Horticultural Reviews* and *Plant Breeding Reviews* on his bookcase.

Horticultural Reviews and the partnership publication, *Plant Breeding Reviews*, are widely recognised as being premier publications in horticultural science literature globally. Both were established under the initiative of Prof. Jules Janick – *Horticultural Reviews* in 1979 and *Plant Breeding Reviews* in 1983 – having identified a niche for such publications amongst a wealth of other scientific journals at that time, none of which specialised in review articles of significant length and depth in the various fields of horticultural science.

Horticultural Reviews

There have now been 44 volumes of *Horticultural Reviews* published over the past 37 years, comprising 347 review articles and 18,936 pages in aggregate. Many of the major fruit, berry, nut, vegetable and ornamental species have been covered in significant review articles (Table 1). A number of other species have been included as an integral part of other reviews. The species coverage includes those grown in temperate, sub-tropical and tropical regions of the world.

Within and across many of these crops, *Horticultural Reviews* covers many different aspects of crop management, including both pre- and postharvest, and field and protected cultivation (Table 2). Reviews on disease and pest management have also been included (over 700 pages of content), with almost equal coverage of insect and mite pests (213 pages), fungi (246 pages) and viruses (200 pages), with less coverage afforded to bacteria and nematodes. The impacts of different mineral elements on various horticultural crops have also received attention with particular coverage of the importance of nitrogen (176 pages) and calcium (166 pages). Given the critical importance of many environmental factors on plant growth, flowering, fruiting and fruit/vegetable/flower quality, it is not surprising that there has been inclusion of a significant number of reviews covering the impacts of light, temperature, salinity, and freeze injury (Figure 1) as well as carbon dioxide and water (Table 2) on plant growth and development.

Horticulture embraces many different areas of plant science and botany, and reviews have been included on many different disciplines within plant physiology, such as flowering, carbohydrate metabolism, photosynthesis and ethylene biosynthesis (Table 3), along with many areas of botany, such as taxonomy, systematics, morphology and classification. Specific attention has been given to the roles of plant growth regulators, especially auxins, gibberellins and ethylene on crop growth and development.

These reviews have been prepared by over 700 contributors from many parts of the world.

Plant Breeding Reviews

There have now been 40 volumes of *Plant Breeding Reviews* published over the past 33 years, comprising 316 review articles and

■ Table 1. Main horticultural crops included in reviews in *Horticultural Reviews*.

Temperate fruit		
Almond	Fig	Nectarine
Apple	Grape	Olive
Apricot	Kiwifruit	Peach
Avocado	Loquat	Pear
Cherry	Melon	Pomegranate
Citrus	Navel orange	
Others: feijoa, lemon, mandarin, orange, passion fruit, pawpaw, persimmon		
Berryfruit		
Blackberry	Currants	Red bayberry
Blueberry	Elderberry	Strawberry
Bramble	Lingonberry	
Cranberry	Raspberry	
Others: barberry, bilberry, black currant, gooseberry, mulberry		
Nuts		
Chestnut	Macadamia	Pecan
Others: filbert (hazelnut), walnut		
Tropical fruit		
Banana	Caper bush	Jujube
Ber	Date palm	Lychee
Cactus	Jojoba	Mango
Others: cacao, cherimoya, coconut palm, coffee, custard apple, durian, longan, mangosteen, papaya		
Vegetables		
Allium	Cowpea	Pumpkin
Aroids	Eggplant	Sorghum
Asparagus	Garlic	Squash
Aubergine	Horseradish	Sweet potato
Bean	Lettuce	Tomato
Bitter gourd	Mung bean	Watermelon
Capsicum pepper	Pepper (*Piper*)	
Cassava	Potato	
Others: adzuki bean, beet, broccoli, Brussels sprouts, cabbage, carrot, cauliflower, celeriac, celery, chicory, cucumber, *Dioscorea* (yam), leek, okra, onion, parsley, parsnip, taro		
Ornamentals		
Amaryllidaceae	Cut flowers	*Leucadendron*
Aroids	Daylily	*Leucospermum*
Artemisia	*Dieffenbachia*	Orchid
Banksia	Dogrose	Protea
Carnation	Foliage plants	Rose
Chrysanthemum	Heliconia	Tulip
Others: *Agapanthus*, anthurium, azalea, bedding plants, begonia, belladonna, *Caladium*, *Clivia*, *Colocasia*, cotoneaster, *Cyrtanthus*, Easter lily, geranium, *Hippeastrum*, *Lycoris*, *Narcissus*, *Nerine*, *Scadoxus*		
Other (mushrooms, spices, herbs, tree species)		
Agaracus	Ginseng	Palms
Black pepper	Gourds	*Salix*
Chayote	Mushrooms	Stone pine
Datura	Nightshades	Tea
Ginger	Opium poppy	
Others: *Alocasia*, hawthorne, henbane, myrrh, oil palm		

■ Table 2. Main horticultural management practices included in reviews in *Horticultural Reviews*.

Irrigation	Anti-transpirants Deficit irrigation Drip irrigation Roots
Fruit and vegetable management	Fruit thinning Grafting Girdling Harvesting Pest management Pruning Rootstocks Replant management Yield determinants
Plant propagation	Asexual embryogenesis Cryopreservation In vitro/tissue culture Seeds and seed germination
Greenhouses	CO_2 enrichment Crop management Design Energy use efficiency Nutrient film technique Pest management
Postharvest technologies	MA and CA storage Packaging Quality evaluation

■ Table 3. Physiological processes covered in reviews in *Horticultural Reviews*.

Flowering and fruiting	Abscission Alternate bearing Juvenility Parthenocarpy Pollination Photoperiod Vernalisation
Plant processes	Anthocyanin synthesis Carbohydrate metabolism Cell walls and membranes Circadian rhythms Cold hardiness Dormancy Gravitropism Metabolism Photosynthesis Respiration Volatile synthesis
Postharvest	Disorders Senescence

15,392 pages in aggregate. Each volume has included an average of nearly eight reviews, with several volumes devoted to specific topics such as long term selection (Vol. 24), raspberry breeding (Vol. 32), and the U.S. National Plant Germplasm System (Vol. 7). One of the most impressive features of this collection of review articles is that they were authored by more than 700 scientists from around the world, comprising what is certainly the largest collection of review articles and perspectives from plant breeders over a 33 year period.

Plant Breeding Reviews includes up-to-date reviews on plant breeding and genetics of all types of crops by both traditional and molecular methods. These reviews help breeders, scientists, policy makers, students, and others understand the genetic basis of key world crops and help in the preservation of crop genetic resources. In addition, the reviews provide detailed analysis of key concepts and approaches in plant breeding, serving as a repository for the latest thinking on scientific methods in the field. The emphasis of the series is on methodology, a fundamental understanding of crop genetics, and specific applications to major crops. Recent reviews have covered state-of-the-art topics such as association mapping in plant breeding, epigenetics and its influence on genotype and environment, development of synthetic hexaploids in wheat, nutritional enhancement of staple food crops, prospects of transgenic vegetables, doubled haploid breeding, and use of interspecific periclinal chimeras in cultivar development. Dozens of critical reviews of breeding approaches for many of the world's most important economic crops appear in the pages of *Plant Breeding Reviews*, providing what is probably the single largest source of such information in any publication (Table 4). *Plant Breeding Reviews* also includes the most complete and comprehensive discussions of key plant breeding topics, such as heritability and estimation of genetic variances, which far exceed what one would be able to assemble from plant breeding textbooks or journal articles.

On certain topics, *Plant Breeding Reviews* contains a series of chapters that, taken together, form an incredibly important and unique body of work. For example, on the subject of maize breeding, *Plant Breeding Reviews* contains detailed information on anther culture, apomixis, biotic resistance, doubled haploid breeding, utilization of exotic germplasm, selection for reduced foliar diseases, selection for oil and protein concentration, honeycomb breeding designs, hybrid breeding, breeding for insect resistance, long term selection, male sterility, marker-assisted selection, overdominance, quantity and quality of storage proteins, recurrent selection, tolerance to acid soils,

■ Table 4. Main economic crops included in *Plant Breeding Reviews*.

Fruit, nut and berry crops	Vegetable crops	Agronomic, forest, tree and shrub crops	
Almond	Amaranth	Alfalfa	Rubber
Apple	Bean	Barley	Sesame
Banana	Table beet	Cassava	Soybean
Blackberry	Carrot	Coffee	Spelt
Black walnut	Chili pepper	Cotton	Sugarcane
Blueberry	Cucumber	Cowpea	Triticale
Cactus	Eggplant	Douglas fir	Wheat
Chestnut	Garlic	Durum wheat	White clover
Currant	Lettuce	Fescue	Wild rice
Gooseberry	Melon	Guayule	
Grapefruit	Mushroom	Maize	
Loquat	Snap pea	Oat	
Papaya	Potato	Oil palm	
Plantain	Rutabaga	Peanut	**Flower crops**
Raspberry	Sweet corn	Pearl millet	
Strawberry	Sweet potato	Perennial ryegrass	Chrysanthemum
Sweet cherry	Tomato	Rice	Rose

■ Table 5. Many notable international horticultural scientists and plant breeders have been included in dedications written by their peers in either *Horticultural Reviews* or in *Plant Breeding Reviews* over the past 38 years.

Dedications in *Horticultural Reviews*			Dedications in *Plant Breeding Reviews*
Bailey, Liberty Hyde	Hess, Charles E.	Ryugo, Kay	Bliss, Frederick A.
Beach, Spencer A.	Hummer, Kim E.	Sansavini, Silviero	Bringhurst, Royce S.
Bukovac, Martin J.	Kader, Adel A.	Sedgely, Margaret	Brewbaker, James L.
Campbell, Carl W.	Kamemoto, Haruyuki	Sherman, Wayne B.	Coyne, Dermot E.
Cantliffe, Daniel J.	Kester, Dale E.	Simon, Philipp W.	Daubeny, Hugh A.
Clark, John R.	Looney, Norman E.	Smock, Robert M.	Gabelman, Warren H.
Cummins, James N.	Magness, John R.	Sperling, Calvin R.	Jahn, Margaret, M.
De Hertogh, August A.	Maynard, Donald N.	Spiegel-Roy, Pinhas	Jennings, Derek
Dennis, Frank G. Jr	Mitchell, Cary A.	Stevens, M. Allen	Munger, Henry M.
Faust, Miklos	Mizrahi, Yosef	Thompson, Maxine M.	Peloquin, Stanley J.
Finn, Chad E.	Moore, James N.	Warrington, Ian J.	Ryder, Edward J.
Ferguson, A. Ross	Possingham, John V.	Weiser, Conrad J.	Vuylsteke, Dirk R.
Goldman, Irwin L.	Pratt, Charlotte, S.	Whitaker, Thomas W.	Weinberger, John H.
Hackett, Wesley P.	Proebsting, Edward L. Jr.	Wittwer, Sylvan H.	Zohary, Daniel
Halevy, Abraham H.	Rick, Charles M. Jr.	Yang, Shang Fa	

transposable elements, unreduced gametes, and selection for yield. One can also use *Plant Breeding Reviews* to examine how selection for resistance to a particular pest, such as nematodes, is approached from a range of different crop species, including separate reviews on apple rootstocks, banana, plantain, coffee, cowpea, raspberry, soybean, and sweet potato.

Special features

A special element of both *Horticultural Reviews* and *Plant Breeding Reviews* has been the dedicatory chapters included within many of the volumes, which are comprised of descriptive biographies of key individuals involved in horticultural science, plant breeding and genetics. These included seminal figures associated with plant breeding such as Norman E. Borlaug (Vol. 28), Glenn Burton (Vol. 3), Donald Duvick (Vol. 14), Jack Harlan (Vol. 8), Henry Jones (Vol. 1), Ernest Sears (Vol. 10), and George Sprague (Vol. 2). A complete list of dedicatory honourees relevant to the breeding of horticultural crops is shown in Table 5.

Similarly, 45 internationally renowned horticultural scientists, past or present, have been recognised with dedicatory chapters in *Horticultural Reviews*, covering North America, Europe, Asia and Australasia (Table 5).

Both of these *Reviews* include extensive cumulative indexes which make it easy to search for specific topics. In *Horticultural Reviews* there are 33 double column pages dedicated to the index while in *Plant Breeding Reviews* there are more than 42 single spaced pages with thousands of entries on every conceivable plant breeding topic.

The editors of these two publications are each supported by small editorial advisory boards who help identify topics that are worthy of review and potential contributors for such subjects, as well as assist with refereeing responsibilities.

Concluding comments

Both *Horticultural Reviews* and *Plant Breeding Reviews* have become essential reading for horticultural scientists, botanists, agronomists and plant scientists in general. These two review journals have provided timely reviews on many different areas that are highly topical to horticultural science in particular and to many other areas of plant science as well. The coverage of topics has been extensive and reflects the interests and specialities of Prof. Janick who, throughout his career has shown an acute interest and application to many different areas of plant science that are relevant to horticulture, including plant breeding.

Future volumes will no doubt contain updates to reviews that were published 30 to 40 years ago. Advances have been made in our understanding of the various plant sciences associated with horticultural science, and new technologies have evolved. The emergence of new areas such as robotics, controlled environment farming and of the various “omics” (genomics, proteomics, etc.) will, no doubt, also be the subject of future reviews.

Prof. Janick retired as editor of both publications in 2016. He leaves a lasting legacy that will endure for years to come.

› An invitation

The publication of an authoritative review in a specialised area of scientific endeavour is often the highlight of a professional career. You, together with your colleagues and students, are invited to submit a review to either of these publications. Reviews should be between 30 and 100 double-spaced pages (which translate into 15-50 printed pages). Manuscripts can be submitted at any time. Guidelines will be provided on request. Enquiries and submissions should be made as follows:

Horticultural Reviews
To Prof. Ian Warrington
at ianjw@xtra.co.nz

Plant Breeding Reviews
To Prof. Irwin Goldman
at ilgoldma@wisc.edu

› Ian Warrington

› Irwin Goldman

› About the authors

Ian Warrington is an Emeritus Professor at Massey University in New Zealand. His previous research interests focussed mainly on the responses of a range of horticultural, agronomic and forest species to different environmental factors, mainly light and temperature. Those studies involved research under both controlled environment and field conditions. Following an active research career, he became CEO of The Horticulture and Food Research Institute of New Zealand (HortResearch) (1995-2002) and Deputy Vice-Chancellor (Vice President) of Massey University (2002-2010). He has been heavily involved with publishing during his career – earlier to co-edit authoritative books on kiwifruit and apples, along with a number of volumes of *Acta Horticulturae* and, more recently, he was the editor of the *Journal of the American Pomological Society*. He is a Fellow and an Honorary Member of the ISHS.
E-mail: ianjw@xtra.co.nz

Irwin Goldman is Professor and Chair of the Department of Horticulture at the University of Wisconsin-Madison. His program focuses on breeding and genetics of cross pollinated vegetable crops, primarily carrot, onion, and table beet. Together with his students, his research has included investigations of vegetable crops and human health, recurrent selection for culinary traits and secondary metabolites, and efficiencies for breeding of biennial crops. His program has released numerous inbred lines, open pollinated cultivars, and genetic stocks of carrot, onion, and beet. Recently, he has been part of a team that developed the Open Source Seed Initiative to foster the sharing of crop germplasm worldwide. Goldman has also served in a number of administrative roles at Wisconsin, including Vice Dean and Interim Dean of the College of Agricultural and Life Sciences.
E-mail: ilgoldma@wisc.edu

The world of Horticulture

Hazelnut culture in Turkey

Şahin Anıl, Haydar Kurt, Aysun Akar and Çiğdem Bulam Köse

IHC2018 ISTANBUL
XXX. INTERNATIONAL HORTICULTURAL CONGRESS
12-16 AUGUST 2018
ISTANBUL / TURKEY
www.ihc2018.org

Figure 1. Hazelnut growing regions of Turkey: red areas are considered to be the 'essential hazelnut growing provinces' (Ordu, Giresun and Trabzon); green areas are the 'new production areas'; pink areas were included as hazelnut growing regions in 2015; others are not important to the hazelnut industry.

Introduction

The history of hazelnut culture dates back 5000 years, and its origin spans from Caspian Sea shores to China, which includes northern Anatolia and the Caucasus. Historical documents record that hazelnut was growing in northern Turkey's Black Sea coastal area approximately 2500 years ago, and it has been transported to many other countries during the last six centuries.

Hazelnuts have a very distinguished place in human health and nutrition by being one of the most important ingredients of the chocolate industry. They have properties that contribute to healthy diets by decreasing cholesterol, and they contain high quality vegetal fat (64.2%), protein (16.5%), carbohydrate (14%), rich minerals (phosphorous, iron and calcium), and vitamins (A, B_1, B_2, B_6, C and E).

Particularly over the last 600 years hazelnut has an unparalleled tradition and an essential place in Turkish horticulture because of export-driven production and its use as a raw material in the food industry. Around 700,000 ha in Turkey is devoted to hazelnut culture, but because of the alternate bearing habit of hazelnut, average annual production fluctuates between 450,000 and 650,000 t, which accounts for 70% of the world's total (Table 1). Turkey is the world leader and dominates world markets in hazelnut production and export. These facts show that hazelnut has indeed had a very impressive heritage and a unique position in Turkey.

Around 4 million people are directly or indirectly involved in hazelnut production, and about 400,000 families solely depend on it. No other crop in Turkey has such large numbers of people reliant on it. The Black Sea region has very suitable ecological and geographical conditions for the best quality hazelnut culture.

Almost all hazelnut plants are bushy in form and have been derived from *Corylus avellana* L. × *Corylus maxima* Mill. It is not known exactly when some of the hazelnut orchards in the eastern Black Sea region were established but the area is considered to be the "first standard region" for hazelnut and they have been growing there for centuries (Ordu, Giresun, Trabzon provinces, Figure 1).

The growing area of hazelnut in Turkey is located between the latitudes of 40-41° N and the longitudes of 37-42°E in the Black Sea region along a 60-km wide coastal strip and at an altitude of 750 m. This area is the most suitable with respect to ecological conditions for hazelnut (Köksal, 2002). Within this area, the eastern Black Sea was the first location where hazelnut was cultivated, but over time hazelnut cultivation has spread to the middle and western Black Sea. This is considered to be the new production area and has now exceeded the production in its natural growing region (Ayfer et al., 1986; Bostan, 1997).

According to the statistical records, hazelnut production is found in 33 provinces to some extent, however, 95% of the total production occurs in the Sakarya, Giresun, Düzce, Samsun and Trabzon provinces (Figure 1).

Hazelnut is considered to be a strategic crop for the eastern Black Sea because it is the only income generating occupation for many people in this region. It is too challenging to grow other crops in this area because of the sloping land, high rainfall and high humidity. Hazelnuts, with their bushy habit, also help to control erosion in this region (Figure 2).

Figure 2. A) A typical hazelnut orchard planted on sloping land, showing the multiple trunks and bushy habit of the trees. B) A hazelnut orchard established as single trees on sloping land at the Hazelnut Research Institute.

Figure 3. A hazelnut cluster approaching harvest maturity.

Figure 4. A young hazelnut tree just before harvest.

Table 1. Hazelnut planted area (ha), production amount (t) and average yield (kg ha^{-1}) for the last five years (Anonymous, 2015).

Years	Area (ha)	Production (t)	Yield (kg ha^{-1})
2011	696,964	430,000	620
2012	701,407	660,000	940
2013	702,144	549,000	780
2014	702,144	450,000	640
2015	702,628	646,000	910

Table 2. Export quantity (t), value ($US) and average price ($US kg^{-1}) for hazelnut kernels from Turkey for the last five years. Source: Black Sea Exporters Union (KİB).

Years	Export		
	Amount (t)	Export revenue ($US)	Average price ($US kg^{-1})
2011	243,766,392	1,759,162,313	7.22
2012	265,743,996	1,802,462,907	6.78
2013	274,657,461	1,767,276,552	6.43
2014	252,528,337	2,314,253,067	9.2
2015	240,137,287	2,827,316,418	11.77

The majority of hazelnuts produced in Turkey are used in processing; 70% are used in the chocolate industry, 20% for pie and candy making, and only 10% are sold as an unprocessed product.

Harvest, drying and postharvest handling

Hazelnut harvest in Turkey takes place between August and September, and growers generally pick clusters by hand. From the first week of August, growers observe the hazelnut clusters to predict harvest time (Figures 3 and 4). Fruit drying has been carried out traditionally in natural conditions using solar energy. This causes some difficulties and defects in quality, especially in humid seasons. Research has been carried out to develop artificial drying systems to overcome this problem, however, outcomes from those efforts have not yet been widely put into practice.

The blending process (separating kernels from the husks) is carried out using machines and can last until October, depending upon the region and precipitation. Hazelnuts store very well, and, in Turkey, can easily be stored in traditional warehouses for up to two years.

Marketing and exports

Turkey has a lot of expertise in marketing hazelnuts, either as unprocessed products or processed products (of which there are at least 48 different types), in local and especially in export markets. There are over 300 companies specialised in storing and marketing

Figure 5. Sun dried natural hazelnuts ready for marketing.

Figure 6. Hazelnut kernels ready for processing.

hazelnut and its products. About 60 of these companies export more than one million $US in value annually. There are around 200 hazelnut processing enterprises, of which 25 have integrated facilities.

Today, in addition to accounting for 75% of the world production (around 580,000 t), Turkey is the top exporter of hazelnuts and hazelnut products, with 240,000-270,000 t kernels exported (85% of the world export) (Table 2). This represents between 1.7 and 2.8 billion $US revenue annually for the last five years. Turkey exports its hazelnuts to more than 50 countries. The EU countries account for 85% of export destinations. Within that, approximately 50% goes to Germany, followed by Italy, France, The Netherlands and the UK. Outside the EU, Switzerland is the number one importer, using hazelnut products in their famous chocolate industry.

Both the natural nuts and kernels must pass very strict physical and chemical quality and hygiene control measures (Figures 5 and 6), and end products are packed mechanically. Product diversification is a high priority for the future, and new enterprises with sophisticated infrastructure are being encouraged because this development promotes consumption and increased exports of hazelnut products.

Important cultivars

There are 16 traditional commercial hazelnut cultivars in the country. In addition to these old cultivars obtained from natural hybridization, the Hazelnut Research Institute has developed three new cultivars and four candidate cultivars through intensive breeding programmes using selection from a very rich biodiversity and subsequent crossing (Anonymous, 2016). Currently, the following cultivars are being utilised: 'Tombul', 'Palaz', 'Çakıldak', 'Foşa', 'Mincane', 'Kalınkara', 'Uzunmusa', 'Kan', 'Kargalak', 'Cavcava', 'Sivri', 'İncekara', 'Acı', 'Kuş', 'Yuvarlak Badem', 'Yassı Badem', 'Okay 28', 'Giresun Melezi' and 'Allahverdi'.

Properties of some outstanding hazelnut cultivars (short descriptions)

There have been various publications characterizing Turkish hazelnut genetic resources, cultivars and breeding types, published in Turkish and in English (Ayfer et al., 1986; Çalışkan and Çetiner, 1997; Balık et al., 2016). Short descriptions of some very important Turkish hazelnut cultivars are given below.

'Tombul'

This is the most important hazelnut cultivar grown in Turkey, and is particularly common in the Giresun province. It was selected by farmers from a natural hazelnut population during very old times. It represents the image of "Turkish hazelnut" because of its very high quality and it is extremely well-known in international markets. It has an alternate bearing tendency, however, stable, high yields are possible if good orchard management techniques are followed. Mature nuts are well rounded and have a tidy shape, and its name comes from this physical appearance. Fruit length is approximately 18 mm, width is 17 mm, and kernel ratio is 50-52%.

The nut flesh of 'Tombul' is white and bright. Nut size: 16.6 mm; kernel size: 12.6 mm; nut weight: 1.8 g; kernel weight: 1.0 g; nut/kernel ratio: 54.4%; protein content: 17.1%; fat content: 59.8%; harvest date: 10-15 August (Figures 7-9).

'Sivri'

This is another very important traditional cultivar. Although it can be found in almost the entire hazelnut region, it is most commonly produced in the Giresun province. This cultivar is highly productive but it is sensitive to drought, and as a result, there is unacceptably high pre-harvest fruit drop in dry seasons. Nut size: 17.1 mm; kernel size: 13.2 mm; nut weight: 2.0 g; kernel weight: 1.0 g; nut/kernel ratio: 49.9%; protein content: 17.6%; fat content: 60.9%; harvest date: 10-15 August (Figure 10).

'Çakıldak'

This is a standard cultivar that is widespread in the Ordu province. It is also known as 'Delisaya' in the western Black Sea region and is produced in quite large quantities. It is quite tolerant to late spring frosts because it has very late bud burst compared with other cultivars. It adapts to almost all ecological conditions and has a very high yield and large nut size. However, the flavour is not so good. Nut size: 17.6 mm; kernel size: 13.8 mm; nut weight: 2.1 g; kernel weight: 1.2 g; nut/kernel ratio: 55.8%; protein content: 17.6%; fat content: 59.4%; harvest date: 20-25 August (Figure 11).

Figure 7. Husks of the cultivar 'Tombul'.

Figure 8. Dried nuts of the cultivar 'Tombul'.

Figure 9. Kernels of the cultivar 'Tombul'.

Figure 10. Nuts of the cultivar 'Sivri'.

Figure 11. Dried nuts of the cultivar 'Çakıldak' ready to sell.

Figure 12. The attractive nuts of the cultivar 'Foşa'.

Figure 13. Dried nuts of the cultivar 'Palaz'.

Figure 14. 'Okay 28' (left) and 'Giresun Melezi' (right) hazelnut cultivars, developed through cross-breeding by the Hazelnut Research Institute.

Figure 15. 'Allahverdi' hazelnuts at a local market.

'Foşa'

This is a large and attractive hazelnut cultivar mainly grown in the Trabzon vicinity. Its shell is reddish-brown and 17.9 mm wide. Nut size: 17.4 mm; kernel size: 12.6 mm; nut weight: 1.7 g; kernel weight: 0.8 g; nut/kernel ratio: 50-53%; protein content: 18.6%; fat content: 58.3%; harvest date: 15-20 August (Figure 12).

'Palaz'

This is commonly grown in the Ordu and Samsun provinces, and can be easily distinguished by its tick-leaf tissue and long, split husk. Its main defect is that it is sensitive to many diseases and pests. Nut size: 17.5 mm; kernel size: 13.7 mm; nut weight: 2.1 g; kernel weight: 1.1 g; nut/kernel ratio: 51.4%; protein content: 17.4%; fat content: 61.0%; harvest date: 10-15 August (Figure 13).

Recently released cultivars

'Okay 28'

This cultivar was developed in a breeding programme undertaken by the Hazelnut Research Institute by crossing 'Tombul' × 'Kargalak' cultivars, and was registered in 2012. Productivity and nut/kernel ratio are high. Bud burst is one week later than 'Tombul', which is important for late spring frosts. Nut size: 20.1 mm; kernel size: 15.4 mm; nut weight: 2.9 g; kernel weight: 1.5 g; nut/kernel ratio: 54.6%; protein content: 16.8%; fat content: 61.3%; harvest date: 15-20 August (Figure 14).

'Giresun Melezi'

This is another hybrid of 'Tombul' × 'Kargalak' developed through cross-breeding by the Hazelnut Research Institute, and registered in 2012. Nut size: 19.4 mm; kernel size: 13.9 mm; nut weight: 2.4 g; kernel weight: 1.2 g; nut/kernel ratio: 51.7%; protein content: 20.4%; fat content: 58.5%; harvest date: 15-20 August (Figure 14).

'Allahverdi'

This was selected by the Hazelnut Research Institute from the natural hazelnut populations of the Black Sea region, and registered in 2015. Bud burst is 15 days later than 'Tombul' which means it is more likely to escape late spring frosts. Compared with 'Tombul', 'Allahverdi' has more male flowers, pollination lasts one week longer, the empty fruit ratio is lower and the yield is double. It has light alternate bearing, and low sensitivity to drought, frost, diseases and pests. Nut size: 17.2 mm; kernel size: 12.2 mm; nut weight: 1.8 g; kernel weight: 0.8 g; nut/kernel ratio: 49.3%; protein content: 19.5%; fat content: 58.0%; harvest date: 10-15 August (Figure 15).

Research and development activities

The first institution responsible for hazelnut research and development in Turkey was the Hazelnut Research Institute, which was established in 1936 in the Giresun province. This institute undertakes R&D activities on cultivar development, improving growing techniques and orchard management, plant health, harvest and postharvest technologies, socio-economic aspects of hazelnut industry, and extension & training.

Other institutions dealing with hazelnut research and innovation include:

- Black Sea Regional Research Institute of the Ministry of Food, Agriculture and Livestock in Samsun province;

- Plant Protection Central Research Institute of the Ministry of Food, Agriculture and Livestock in Ankara;
- Marmara Research Centre of the Turkey Scientific and Technological Research Council;
- Agricultural Faculty of Ondokuz Mayıs University in Samsun province;
- Agricultural Faculty of Ordu University in Ordu province; and
- Agricultural Faculty of Ankara University.

Titles of reports of some important research projects undertaken and published by the Hazelnut Research Institute between 1998 and 2014:

- Report of hazelnut genetic resources project (1998);
- Hazelnut cultivar development by cross-breeding (1999);
- Yield trials for new hazelnut cultivar candidates obtained from selection studies (1999);
- Studies on the relationships between carbohydrate metabolism and alternate bearing tendency with respect to pruning and fertilization (1999);
- The establishment of a data base for production, production costs and marketing of hazelnut in Turkey (2006);
- Economic analysis of hazelnut producing holdings in Giresun, and determination of growing and marketing problems (2012);
- Development of new hazelnut cultivars through selections from 'Tombul' hazelnut populations in Giresun and Trabzon provinces (2012);
- Determination of the effects of rejuvenation pruning on the yield and quality at old hazelnut orchards (2013);
- The impact assessment of research and development programmes on the hazelnut industry (2013);
- Determination of the farmers' behaviours to the agricultural insurance implementations, issues and suggestions in the eastern Black Sea region (2014);
- Socio-economic analysis of new hazelnut strategy (2014).

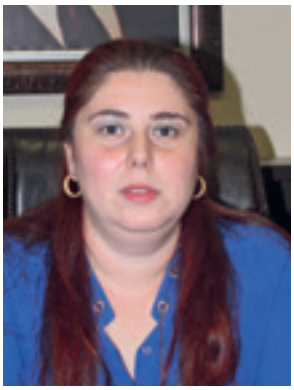
New R&D challenges

- Determining new suitable crossing parents that have high tolerance to biotic and/or abiotic stresses, and developing stress-tolerant cultivars with advanced breeding methods such as marker-assisted selection;
- Development of new cultivars with no alternate bearing (or very little), high yields, and superior quality, using innovative breeding techniques including mapping, marker-assisted selection, and transformation;
- Improving fruit set and nut/kernel ratio and decreasing empty nut ratio through pollination and fertilization studies;
- Developing innovative methods for mass propagation of hazelnut saplings with reasonable cost;
- Improving mechanical harvest and fruit drying techniques;
- Improving postharvest technologies;
- Implementation of CIS and Remote Sensing technologies to more accurately estimate total production, and forecast biotic and abiotic stresses.

› Şahin Anil

› Haydar Kurt

› Aysun Akar



› Çiğdem Bulam Köse

› About the authors

Sahin Anil is an associate professor in Horticultural Sciences at the General Directorate of Agricultural Research and Policy (GDAR). He is a senior researcher in pomology and research manager of horticulture, and has been serving for more than 42 years at the Ministry of Food, Agriculture and Livestock of Turkey. He was Deputy Director General of GDAR between November 1995 and September 1996 and between February and November 1999; and Department Head of Horticultural Research between May 2003 and March 2005 and between September 2010 and August 2011. Dr. Anil has been Country Contact Person, Governing and Management Board member and Work Package leader in EU funded ERANET projects, namely ARIMNet and CORE ORGANIC, for the last eight years. Currently, he is a Ministerial Advisor located at the GDAR. He is a member of the International Society for Horticultural Science (ISHS). E-mail: sanil@tagem.gov.tr

Haydar Kurt has a PhD degree in hazelnut growing techniques. He worked at the Hazelnut Research Institute from 2000 to 2001 as research staff, between 2001 and 2004 as Deputy Director, and from 2004 to 2005 as Acting Director. Since 2010, he has been working at the General Directorate of Agricultural Research (GDAR) as the coordinator of Nut Crops Research programme. E-mail: hkurt@tagem.gov.tr

Aysun Akar is a hazelnut specialist. She has worked as an extension researcher at Giresun Provincial Directorate of the Ministry of Food, Agriculture and Livestock. She was deputy director of the Hazelnut Research Institute between 2014 and 2016. Since August 2016, she has been the director of the Hazelnut Research Institute. She is also an active researcher, leading some of the research projects such as "Selection of pollinizers for new hazelnut cultivars". In 2014-2015, she was the leader of the project "Quality changing in hand and machine combed out samples of 'Tombul', 'Palaz' and 'Kalınkara' hazelnut cultivars during storing period". She is currently continuing her studies on genetics and breeding of hazelnut. E-mail: aysun.akar@tarim.gov.tr

Çiğdem Bulam Köse has been working in the Plant Health Department of the Hazelnut Research Institute since 2006. She is currently serving as the deputy Director of the Institute. Her specialty is hazelnut pests. E-mail: cigdem.kose@tarim.gov.tr

› References

Anonymous. (2015). Turkey Statistical Council (TÜİK) and the Black Sea Exporters Union (KİB) records.

Anonymous. (2016). Hazelnut Research Institute. http://arastirma.tarim.gov.tr/findik.

Ayfer, M., Uzun, A., and Baş, F. (1986). Turkish Hazelnut Varieties (in Turkish) (Ankara, Turkey: Black Sea Hazelnut Exporters Union), pp.95.

Balık, İ.H., Balık, S.K., Beyhan, N., and Erdoğan, V. (2016). Turkish Hazelnut Cultivars (in Turkish and English) (Trabzon, Turkey: Hazelnut Promotion Group).

Bostan, S.Z. (1997). The problems and solutions in Turkey hazelnut industry (in Turkish). Ondokuz Mayıs University Agricultural Faculty Magazine *12* (2), 127–133.

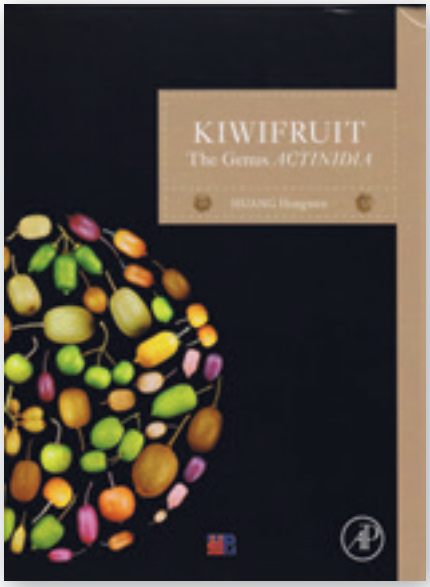
Çalışkan, T., and Çetiner, E. (1997). Characterization studies on some hazelnut cultivars and types. Acta Hortic. *445*, 1–11. https://doi.org/ 10.17660/ActaHortic.1997.445.1

Köksal, A.İ. (2002). Turkish Hazelnut Cultivars (in Turkish) Ankara, Turkey: University of Ankara, Faculty of Agriculture), pp.136. ISBN 975-92886-0-5.

› 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



Huang, Hongwen. (2016). Kiwifruit: The Genus *Actinidia* (Academic Press (an imprint of Elsevier Inc.)), pp.334. ISBN 978-0-12-803066-0 (hardcover). $236.95. http://store.elsevier.com/Kiwifruit/Hongwen-Huang/isbn-9780128030660/

Kiwifruit is one of the few new fruit to be commercialised over the past century – others being macadamia, avocado and blueberry. Much of the early commercial development of this crop occurred in New Zealand, particularly during the latter half of the 20th century, and production rapidly followed into other countries around the world, including Italy, France, Greece, Chile, Japan and the USA. These developments were based on a very limited range of germplasm and almost entirely on one cultivar, 'Hayward'.

The origin of kiwifruit is, in fact, China, which has a rich diversity of species within the genus *Actinidia*. However, access to germplasm and understanding of the diversity of this genus outside of China has been very limited until recently. Further, the successful commercialization of kiwifruit in other countries has resulted in Chinese fruit growers and scientists being more aware of the value of this germplasm within China, along with the opportunity to establish a commercial industry within that country. Accordingly, both scientific and commercial activities have accelerated over the past 30-40 years. Nonetheless, much of the information that has resulted from such developments has been published mainly in Chinese and has been difficult to access elsewhere.

'Kiwifruit: The Genus *Actinidia*' has, for the first time, summarised in English much of the published scientific knowledge secured on this crop in China, along with details about the Chinese industry. It includes references to research elsewhere in the world, especially in New Zealand and in Italy. The book is authored by Professor Hongwen Huang, Director, Wuhan Botanical Garden, Chinese Academy of Sciences, Wuhan, China, in association with 14 other contributors from a number of other research institutes and universities across the country.

The book is presented in eight chapters: Systematic and Genetic Variation of *Actinidia*; Species; Natural Distribution of Genus *Actinidia*; Domestication and Commercialization of *Actinidia*; Biology, Genetic Improvement, and Cultivar Development; Main Cultivars in Commercial Production; Cultivation and Management; and Harvest and Storage.

The real value of this text is the comprehensive information that is presented on the different *Actinidia* taxa, their distributions, the relationships between them and their commercial potential (Chapters 1, 2 and 3). This includes detailed discussion about the taxonomic and nomenclatural changes that have recently occurred (and will no doubt continue to occur in this extensive genus).

Chapter 1 provides an excellent presentation about the challenges involved in the taxonomic treatment of the genus. It includes very good summaries of previous attempts at classification of species and of the revisions that have recently occurred. Topics such as ploidy variation, pollen characteristics, flower morphology and sex variation (all *Actinidia* taxa are functionally dioecious) and the evolution of particular species are very well covered.

Chapter 2 in particular is richly illustrated with color photographs showing details of the vegetative, floral and fruit characteristics of each of 106 species and varieties within the genus, and detailed maps showing their current distribution within China. Chapter 3 further develops the information about species distribution by defining, in detail, the ecological characteristics of each of the regions where the species are located naturally. This information would have been enhanced had some photographs been included showing the *Actinidia* germplasm in these natural locations (noting that three such images are included later in the text in Chapter 5). Chapter 6, which describes in detail characteristics of main cultivars that are currently used in commercial production, is also very informative in that it includes descriptions of those involved within the industry in China (which differ somewhat from those used in other countries). This section, too, is well illustrated with excellent color photographs.

The other chapters involving domestication, commercialization and the management of commercial crops, although important, are of less value than the chapters outlined above. More detailed information on those topics is available from other countries in more comprehensive texts on the pre- and postharvest management of this crop. Nonetheless, the information is valuable in that it provides detail of production practices in

China, including information about some of the pests and diseases that are not present in other kiwifruit-producing countries.
Overall the text is very well presented with rich augmentation using many color photographs, colored graphs and a large number of tables. It is well laid out and there are few errors. Translation into English from Chinese has been well managed and the text is mostly easy to read. There are, nonetheless, some issues that should be addressed in any revision: single and not double quotes should be used around cultivar names such as 'Hayward'; the key shown in many of the maps (starting with Figure 2.122, page 131) is not explained until page 185; words such as monsoon (not moonson – pages 181, 182), talk instead of stalk (pages 130, 132 and elsewhere) and maritime (not marital, pages 181, 182) need to be corrected; "plum blooming rain significance" (page 178) is not understood; Vc (chapter 2) and VC (chapter 6) should be standardised. The excellent color photographs of the different species shown on the cover and on pages 218 and 224 would be considerably enhanced if a key was included naming the different species. Finally, the index needs to be arranged in alphabetical order and not date order within each family name. The current order does not follow accepted scientific convention.
This text is essential reading for anyone involved with the science and management of kiwifruit. In many of the topics covered, it greatly adds to prior knowledge about this genus and provides valuable information about the industry in China. It is also a valuable text for those involved with the breeding of other fruit species and with interests in plant ecology, taxonomy and botany.
A previous version of this text was published in China in 2014 as "The Genus *Actinidia*: A World Monograph" by the Scientific Press, Beijing. The 2016 version includes some additional material, such as descriptions of the latest cultivars from New Zealand and, aside from the different title, has different page numbers.

Reviewed by Ian Warrington, Massey University, Palmerston North, New Zealand

› New titles

Gröning, G. (2016). From Dangast to Colorado Springs. Irma Franzen-Heinrichsdorff 1892-1983. Notes on the Life and Work of the First Woman Graduate in Landscape Architecture. CGL-Studies, Volume 24, translated by H. Kaal (Munich, Germany: AVM-edition), pp.166. ISBN 978-3-95477-061-8 (hardcover). € 49.90. www.avm-edition.de

Evans, K., ed. (2016). Achieving Sustainable Cultivation of Apples (Cambridge, UK: Burleigh Dodds Science Publishing), pp.460. ISBN 978-1-78676-032-6 (hardback). £220.00. https://shop.bdspublishing.com/checkout/Store/bds/Detail/WorkGroup/3-190-52574
A 20% discount will be received by entering the code "ISHS20" when ordering through https://shop.bdspublishing.com/checkout/Store/bds/Detail/WorkGroup/3-190-52574

Mattoo, A. (ed.) (2016). Achieving Sustainable Cultivation of Tomatoes (Cambridge, UK: Burleigh Dodds Science Publishing), pp.400. ISBN 978-1-78676-040-1 (hardback). £190.00. https://shop.bdspublishing.com/checkout/Store/bds/Detail/WorkGroup/3-190-52948
A 20% discount will be received by entering the code "ISHS20" when ordering through https://shop.bdspublishing.com/checkout/Store/bds/Detail/WorkGroup/3-190-52948

› Courses and meetings

The following are non-ISHS events. Make sure to check out the Calendar of ISHS Events for an extensive listing of all ISHS meetings. For updated information log on to www.ishs.org/calendar

1st COST Action CA15223 Conference 'Modifying plants to produce interfering RNA' – Iplanta, 15-17 February 2017, Rome, Italy. Info: Prof. Dr. Bruno Mezzetti, CA15223 IPlanta Coordinator, E-mail: b.mezzetti@staff.univpm.it, Web: http://iplanta.univpm.it/node/26

HORTI ASIA – International Tradeshow for Horticultural & Floricultural Production and Processing Technology, 15-17 March 2017, Bangkok, Thailand. Info: Chinakit Viphavakit, Project Manager, Phone: +662 670 0900 ext. 105, E-mail: chinakit.vip@vnuexhibitionsap.com, Web: http://horti-asia.com/

Plant Genomics and Gene Editing Congress, 16-17 March 2017, Amsterdam, The Netherlands. Info: http://www.global-engage.com/event/plant-genomics/

1st Berry School, 21-24 March 2017, Málaga, Spain. Info: Dr. Sonia Osorio, Universidad de Málaga, Dept. Biología Molecular y Bioquímica, Facultad de Ciencias, Campus de Teatinos, 29071 Málaga, Spain, Phone: +34 952 134 271, E-mail: sosorio@uma.es, Web: www.goodberry-eu.eu/news-events/1st-berry-school-in-malaga

Course on Lighting in Greenhouses and Vertical Farms, 3-5 April 2017, Wageningen, The Netherlands. Info: Prof. Dr. Ir. Leo F.M. Marcelis, Head of chair group Horticulture and Product Physiology, Wageningen University, P.O. Box 16, 6700 AA Wageningen, The Netherlands, Phone: +31 317 485675, E-mail: Leo.Marcelis@wur.nl, Web: http://www.wur.nl/en/activity/Lighting-in-greenhouses-and-vertical-farms-2017

Plant Genomics and Gene Editing Congress, 10-11 April 2017, Hong Kong. Info: http://www.global-engage.com/event/plant-genomics-asia/

Symposium/Festival on Plants, Ecology and Colours, 15-21 May 2017, Antananarivo, Madagascar. Info: Dr. Dominique Cardon, Emerita Senior Researcher CNRS, CIHAM/UMR 5648, Lyon, France, E-mail: ardon.dominique@wanadoo.fr, Web: www.ridanet.org

III International Symposium on Woody Ornamentals of the Temperate Zone

Section Ornamental Plants #ishs_seop
Commission Landscape and Urban Horticulture #ishs_cmuh

› ISHS representative Dr. Johan Van Huylenbroeck (right) presenting the ISHS medal to Symposium Convener Dr. Stan C. Hokanson (left).

› Participants of the symposium.

The III International Symposium on Woody Ornamentals of the Temperate Zone was convened in Minneapolis, Minnesota, USA by Dr. Stan C. Hokanson, from August 2nd to 5th, 2016. The technical portion of the symposium comprised seven oral presentation sessions, a poster session, and a small group break-out discussion session. Topic areas for the seven oral sessions included two sessions dedicated to Plant Breeding and Genetics, and sessions on Pests and Diseases; Plant Production, Propagation and Physiology; Nursery Production, Substrates, and Nutrition; Water Management; and Genetic Resources and Conservation. Forty-eight individuals participated in the four-day event.

Although there were no grand departures from the main topic areas defining the previous two symposia, the relative increase in the number of presentations pertaining to water use efficiency, drought tolerance, and nutrient fate certainly reflected the increased societal and landscape nursery industry focus on these issues. This was also evident in the four keynote presentations. A presentation by Dr. Dewayne Ingram, University of Kentucky, USA, regarding the carbon footprint and ecosystem services rendered during the life-cycle of landscape plants revealed a net positive contribution when considering carbon sequestered and energy cost savings provided by woody trees and shrubs. Dr. Taryn Bauerle, Cornell University, USA, suggested, in her presentation on new approaches to the study of plant roots, that we are on the verge of making key advancements in our understanding of what occurs in the zone beneath the mulch. Dr. Valeria Bianciotto, Institute for Sustainable Plant Protection (IPSP), Italy, expanded the perspective on the root zone with a presentation on the current and potential role for arbuscular mycorrhizal fungi to serve as natural fertilizers, and the possibility of limiting the use of applied fertilizers. Dr. Johan Van Huylenbroeck, Institute for Agricultural and Fisheries Research (ILVO), Belgium, detailed the importance and complexity of breeding woody plants with durable resistance to biotic and abiotic stresses and the role of genetically resistant plants in reducing the use of chemicals in the landscape.

The program included a small group break-out discussion session titled "Woody Ornamental Paradigms and Pitfalls: Is There an Easier Way?" The intent of the session was to document, at this point in time, challenges and potential solutions to intransient problems faced by the community of woody landscape plant producers and researchers. The breakout groups topic areas were: plant physiology; sustainable plant production and landscapes; pests and diseases; and breeding and genetics.

- One of the pivotal questions entertained by the plant physiology group was "What is plant physiology in 2016?" Plant physiology has moved from the study of whole plants to the study of molecular biology. While this should certainly be celebrated as an advancement, it leaves many fundamental and seemingly simplistic questions outside the realm of current funding priorities.
- Regarding the area of sustainable plant production and landscapes, a key problem noted was the lack of awareness of the critical role landscape plants play in our mental, physical, and economic well-being. Increased efforts are needed to educate the populace that food plants are not the only kind of plants critically impacting human welfare.
- The discussion on woody plant pests and diseases noted that the increase in global trade and travel has led to an increase in the frequency and number of exotic dis-

› Tour of the University of Minnesota Horticultural Research Center.

› ISHS student award winners: Alexander Susko (left) for the best student oral presentation and Erin Pfarr (right) for the best student poster presentation.

ease and pest introductions seen around the world. There is a critical need to find ways to proactively identify these diseases and pests before they become entrenched. The group noted there is currently not enough funding devoted to pre-emptive detection and new diagnostic tools. The National Clean Plant Network was noted as an exemplary example of such an approach. The group felt this effort should be expanded to include many additional taxa. However, the sheer diversity of woody ornamentals on the market renders this a daunting task.

- Participants in the breeding and genetics group noted the continued importance of breeding new and demonstrably improved woody plant cultivars. Specifically noted were the need for sterile, non-invasive plants, plants with multi-season and/or multi-use (food and ornamental qualities) and plants with biotic and abiotic stress tolerance. It was noted that there is a critical need for thorough testing/evaluation of selections and cultivars. Such testing/evaluation needs to be completed in multiple locations over multiple years in order to determine the durability and worthiness of the germplasm. The group contemplated the role for public breeding programs in the future of cultivar development, noting that it will largely fall in the realms of germplasm enhancement and trait characterization, these being processes the private sector is not ideally suited to carrying out. However, such work is expensive, time-consuming and has no ready source of funding.
- The funding problem was noted by all groups and ascribed in large part to the fragmented nature of the industry. The woody ornamental group of plants is comprised of so many different plant taxa, many with unique needs, that it makes it extremely difficult to develop focused, comprehensive, large-scale grant proposals which are necessary to fund the needed research. The private sector will need to play an increasing role in providing such funding and bringing pressure to bare on governments for such support.

Awards were made for the outstanding student poster and oral presentations at the symposium. Alexander Susko, University of Minnesota, USA, received the award for the best oral presentation, "Development of spatially balanced collection schemes to better detect adaptive genetic variation in woody species". Erin Pfarr, Morton Arboretum, USA, received the award for the best poster presentation, "Genome sizing and ploidy estimations of *Weigela* species and cultivars".

The symposium included tours of the Minnesota Landscape Arboretum and the University of Minnesota Horticultural Research Center, and a tour of Bailey Nurseries. The symposium concluded with a proposal from colleagues at the University of Turin to host the IV International Symposium on Woody Ornamentals of the Temperate Zone, to be convened in Torino, Italy in 2020. This proposal was enthusiastically received by the attendees.

Stan C. Hokanson

› Contact

Dr. Stan C. Hokanson, University of Minnesota, Department of Horticulture, Breeding & Genetics, Woody Landscape Plants, 258 Alderman Hall, 1970 Folwell Ave., St. Paul, MN 55108, USA, e-mail: hokan017@umn.edu

› XI International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems

Section Pome and Stone Fruits #ishs_sefr

› Participants of the symposium.

The XI International Symposium on Integrating Canopy, Rootstock and Environmental Physiology in Orchard Systems was convened by Prof. Luca Corelli Grappadelli, and was held on 28 August to 2 September, 2016, in Bologna, Italy. The symposium brought together the Orchard and Plantation Systems, the Rootstock Breeding and Evaluation, and the Environmental Physiology and Developmental Biology ISHS Working Groups (WGs). The 5-day program featured oral and poster contributions, a day-long field excursion and a celebratory session honouring the achievements of Prof. Silviero Sansavini, Professor Emeritus at the University of Bologna, ISHS Fellow and ISHS President from 1994 to 1998. About 130 delegates from all over the world travelled to Bologna to participate in the activities. The program featured not only contributions relative to temperate crops, but also subtropical and tropical crops, a welcome expansion that has fostered very interesting interactions.

The increasing world population challenges horticulture to find methods and techniques for increasing quality and yield of fruit crops. Symposium participants from around the world debated many issues related to fruit production, ranging from classical studies of physiology to computer programs describing tree growth and yield potential based, for example, on climate variables. In the session "Training and Architecture", evidence was presented that modulating tree growth can be an essential component for a more efficient orchard. Progress was presented on the development of simulators to predict final tree shape, carbohydrate assimilation and fruit size distribution. The goal of novel planting systems is to double production. Tree light interception is paramount, and pruning strategies play an essential role in determining production. Some researchers are focusing on sunburn in those environments where it is a threat. To control vigour, the manipulation of xylem, not to mention the removal of buds, can be valuable solutions. In the session "Light Management and Pruning", the contributions on automation of pruning outnumbered those on manual pruning, demonstrating continuing innovations in this area.

The "Rootstocks" session included the highest number of presentations and posters, a testament to the amount of work and progress that is going on in this field. The majority focused on dwarfing, particularly for temperate crops. Different rootstocks, in different environments and soil management, affect crop performance. Some can modify hormone concentration and that can be influenced by the type of graft. Some rootstocks possess or impart disease resistance. Interestingly, some rootstocks do not vary their behaviour in different environments, showing both positive and negative aspects. Marker-assisted methods are employed to speed up genotype selection. In mango, vigorous growth has to be controlled to increase yield and research is attempting to identify the most suitable rootstocks. The same is happening for walnut. The use of new waterlogging tolerant rootstocks may be important in adverse environments as a tool to survive anoxia, especially in those areas where there is a shift to more tropical climate conditions.

Two one-day fieldtrip options were arranged, one focusing on pome and the other on stone fruit, which took the participants to the Ferrara and Faenza-Forlì areas, respectively. The focus in both cases was training systems and orchard design (bi-baum for pome and Slender Fusetto for stone fruits). Orchard protection systems (Alt-Carpò in different solutions) were also demonstrated in commercial orchards.

In the "Environmental Physiology" session, the dynamics of non-structural carbohydrates were elucidated under variable environmental conditions and a view was given of how dormancy is affected, particularly accounting for future climate change. The "Tree Productivity" session focused on flowering and fruit set, two aspects that are receiving novel input from microscopy studies coupled with DNA quantitation and ploidy levels. In the "Sink/Source Relations" session, examples were

› Prof. Ted DeJong (left), Chair of the ISHS Section Pome and Stone Fruits, presenting the ISHS medal award to Symposium Convener Prof. Luca Corelli Grappadelli (right).

› Dr. John W. Palmer (left) and Dr. Jill Stanley (center) congratulate Prof. S. Sansavini (right) during the session to honour his achievements.

› Prof. Ted DeJong (left) and Prof. Luca Corelli Grappadelli (right) presenting the ISHS student awards to A) Alexandra Boini for the best student oral presentation and B) Brian Makaredza for the best student poster presentation.

given on how high density systems, crop load management and cultivation area influence yield. A strong link was established between these factors. In the final session on "Fruit Quality" non-destructive techniques were presented to assess final yield quality traits, from ripening indicators, to molecular analysis, to portable kits that inform the grower about the thinning rate.

The session on "Flowering, Fruit Set and Plant Growth Regulators" featured presentations on chemical thinning and plant growth regulators on pear and apple, whilst papers on ecophysiology and yield production of subtropical and tropical crops were also presented. Closing the symposium, the "Water Relations and Soil Management" session challenged participants to consider how sustainable and targeted irrigation and soil fertilization can help in conditions of water scarcity and difficult soils. Making horticulture as sustainable as possible is today's main objective, but resources show negative outlooks: irrigation volumes are predicted to decrease, along with available soil. How will research deal with both?

The symposium featured three keynote speakers, whose job was, on different days, to address topics relevant to each of the three ISHS Working Groups that contributed to the program. Stuart Tustin from New Zealand presented a talk on "The planar cordon – new planting systems concepts to improve light utilisation and physiological function to increase apple orchard yield potential"; Gregory Lang from USA spoke on "Integrating canopy architectures and rootstock traits to optimize fruit production in different environments"; and Maciej Zwieniecki from USA focused on "Management of nonstructural carbohydrate pools in trees preparing for the challenges imposed by a warmer world". All three presentations were well received and generated interesting discussions.

Several students presented papers from their work, and were entered into the competition for the ISHS student awards. The recipients of the awards were Alexandra Boini (Italy) and Brian Makaredza (South Africa), for the best oral and poster presentation, respectively. Their work focused on light management in apple orchards (Boini) and canopy factors influencing sunburn and fruit quality of Japanese plums (Makaredza).

The business meeting's major decisions were: Stefano Musacchi (Washington State University) was elected new Chair of the ISHS Working Group Orchard and Plantation Systems; Gennaro Fazio (ARS-USDA) was confirmed as Chair of the ISHS Working Group Rootstock Breeding and Evaluation; Luca Corelli Grappadelli (University of Bologna) was elected Chair of the ISHS Working Group Environmental Physiology and Developmental Biology. The next symposium in the series will be convened by Stefano Musacchi in Wenatchee (Washington, USA) in 2020.

› Participants of the pome fruit technical excursion view orchards at Consorzio Italiano Vivaisti (CIV) Nurseries.

Alexandra Boini

› Contact

Alexandra Boini, Viale Fanin 44, 40127, Bologna, Italy, e-mail:alexandra.boini@unibo.it

VI International Symposium on Tropical and Subtropical Fruits

Section Tropical and Subtropical Fruits #ishs_sets

› Opening ceremony.

› Participants of the symposium.

The VI International Symposium on Tropical and Subtropical Fruits was successfully held on 26-28 September, 2016, in Kafr El-Sheikh, Egypt. The symposium was organized by the Horticulture Department, Faculty of Agriculture, Kafr El-Sheikh University, under the auspices of the ISHS.

The symposium attracted participants from 10 countries (Brazil, China, Egypt, Hungary, India, Italy, Libya, Sudan, Thailand and USA), who shared their knowledge and experience on a wide range of topics related to tropical and subtropical fruits.

The symposium was opened by Dr. Ali R. El-Shereif, Symposium Convener, Prof. Dr. Hassan Younis, Dean of the Faculty of Agriculture, Prof. Dr. Magdy Khalafalla, Head of the Horticulture Department, and Prof. Dr. Maged El-Kemary, President of Kafr El-Sheikh

› Symposium Convener Dr. Ali R. El-Shereif (left) receiving the ISHS medal award from Prof. Dr. Sisir Mitra (right), ISHS representative.

› Dr. Ali R. El-Shereif and Prof. Sisir Mitra presenting the ISHS student awards to A) Ms. Lien Phuong Le Nguyen from Hungary for the best student oral presentation, B) Mr. Mahmoud A.M. Bakir from Egypt for the best student poster presentation.

› Participants during a field trip to Pico company in El-Tahrer area, Behera governorate, Egypt.

University. This was followed by a welcome address by Prof. Dr. Sisir Mitra, ISHS representative and Chair of Section Tropical and Subtropical Fruits.
Keynote presentations were delivered by Prof. Dr. Sisir Mitra and Prof. Dr. Maria A. Germanà, who shared their knowledge on "Climate change: impact, and mitigation strategies for tropical and subtropical fruits" and "The haploidy technology for citrus and other subtropical fruit crop breeding", respectively.
The key symposium themes were climate change and production, breeding, biotechnology and genetic resources, physiology and ecology of fruit trees and postharvest handling and storage.
At the end of the second day, a business meeting was arranged during which ISHS student award certificates were presented to Ms. Lien Phuong Le Nguyen from Szent István University, Hungary, for the best student oral presentation entitled "Effect of ethylene absorber on banana during storage" and to Mr. Mahmoud A.M. Bakir from Horticulture Research Institute, Agricultural Research Center, Egypt, for the best student poster presentation entitled "Rooting of date palm offshoots by using growth regulators injection".
The social program of the symposium included an excursion to Burullus lake protectorate and a cultural show. On the third day, the delegates were taken on a field trip to one of the private sector agricultural companies, giving them the opportunity to see modern farming of tropical and subtropical fruits in Egypt.
At the end of the symposium the Convener expressed his appreciation to all participants, sponsors and members of the organizing committee for their contributions and efforts.

Ali R. El-Shereif

› Contact

Dr. Ali R. El-Shereif, Horticulture Department, Faculty of Agriculture, Kafrelsheikh University, Egypt, e-mail: aelshereif@agr.kfs.edu.eg

› X International Symposium on Grapevine Physiology and Biotechnology

Section Vine and Berry Fruits #ishs_sevi
Commission Molecular Biology and In Vitro Culture #ishs_cmmv

The X International Symposium on Grapevine Physiology and Biotechnology (GPB) was held under the auspices of ISHS in Verona (Italy) from June 13th to 18th, 2016, and convened by Prof. Mario Pezzotti. It was held in the spectacular venue of the "Palazzo della Gran Guardia" located in front of the famous Roman Arena. The event attracted over 250 delegates and received many contributions from all over the world, including 64 oral presentations and 228 posters, covering the most recent developments in international grapevine research.

› Group photo outside the 400-year-old venue.

› Technical visits to the varied wine regions of Verona.

The selection of speakers was not easy. Our policy was to give priority to those who have not had the opportunity to present their work at recent GPB symposia, and especially young scientists, to transmit to them a sense of belonging in the growing grapevine scientific community.

During the opening ceremony we had the pleasure of hosting the Honourable Member of Parliament, Massimo Fiorio, as a representative of the Italian Ministry of Agriculture. He expressed appreciation for the international research effort on grapevine biotechnology and reported the recent encouraging opening of Italian and European policy towards new breeding technologies.

The symposium was structured into seven sessions covering the following topics: 1) plant and fruit development; 2) yield, berry ripening, grape and wine quality; 3) environmental interactions and climate change; 4) soil, water relations and nutrition; 5) grapevine-pathogen interactions and disease resistance; 6) advances in phenotyping, -omic technologies, large data management and future biotechnological tools; and 7) postharvest physiology.

We selected a top-quality list of 12 invited speakers, who were chosen with the aim of providing "cross-contamination" among different areas of scientific expertise. They included:

- Jim Giovannoni (USA) – "Molecular and genetic regulation of fruit ripening in tomato a model for discovery and application to other fruit systems."
- Paul Boss (Australia) – "Developmental changes in grape composition and the implications for the wine volatile profiles."
- Mondher Bouzayen (France) – "Convergence between hormone signaling and epigenetic regulation is central to driving the fruit set process in tomato."
- Stefano Poni (Italy) – "Affecting yield components and grape composition through manipulations of the source-sink balance."
- Hans Schultz (Germany) – "Environmental interaction and climate change – some open questions with respect to grapevine physiology."
- Nathalie Ollat (France) – "Grapevine roots: the dark side."
- Samuel Ortega Farias (Chile) – "Remote sensing tools for monitoring vineyard water requirements and vine water status."
- Pere Mestre (France) – "Molecular analysis of the interaction between grapevine and its pathogens for the creation of disease resistant varieties."
- Fabio Fiorani (Germany) – "Phenotyping – gaining quantitative information about plant-environment interactions: novel developments integrating to mechanistic, high-throughput and field approaches."
- Doreen Ware (USA) – "Translating plant genomes: opportunities and challenges with big data."
- Giovanni Battista Tornielli (Italy) – "The secret postharvest life of a grape berry."

In particular, we took advantage of many new approaches and ideas recently emerging in plant science, especially in the field of genomics and genome editing, plant phenotyping, physiology and biotechnology. Given the pivotal role of research and scientific innovation in facing most urgent challenges, such as climate change and the need for more sustainable viticulture, we believe that these new fields of research have provided all of us with exciting avenues of inspiration for the near future.

The scientific program was also integrated with a technical visit on Wednesday 15th to experience first-hand all aspects of local grapevine growing and winemaking. The tour included Soave, Valpolicella, Bardolino, Custoza and Lugana wine regions and allowed participants to enjoy the history and breathtaking beauty of the Verona area. They also had the opportunity to taste and purchase wines and enjoy local food. Many gave very positive feedback about the chance to see different cultural practices that are peculiar to the Veneto region.

Awards for outstanding poster contributions were given to the following students:

- Erica D'Incà (Italy) – "Vegetative-to-mature organ transition in grapevine: the key roles of four NAC transcription factors."
- Natasha Walbaum (Canada, studying in Israel) – "Berry, it's hot outside – manipulating cluster microclimate to improve yield homogeneity."
- Yvette Wohlfahrt (Germany) – "Influence of elevated CO2 on vigor and yield of *Vitis vinifera* 'Riesling' and 'Cabernet Sauvignon'."
- Zelmari Coetzee (Australia) – "Modifying soil potassium content and decreasing plant net carbon assimilation alter the sugar-potassium relationship in the grape berry."

› A) Erica D'Incà, B) Zelmari Coetzee, C) Yvette Wohlfahrt and D) Pietro Delfino receiving their poster awards.

- Pietro Delfino (Italy) – "Meta-QTL analysis and candidate prioritization for grapevine phenology traits."
- Zachary Harris (USA) – "Long non-coding RNAs in grapevine."

The symposium logistics were assisted by an App that allowed delegates to find all major information, updates, announcements or changes to the program, directly on their phone or tablet. The App also provided an excellent tool for networking with fellow delegates.

In conclusion, we believe that the networking and collaboration opportunities developed during the meeting will positively impact on the quality of grapevine research in all countries, reinforcing the link between precious traditional values and innovative future approaches.

Mario Pezzotti

› Contact

Prof. Mario Pezzotti, Convener, Dipartimento di Biotecnologie, Università degli Studi di Verona, Italy, e-mail: mario.pezzotti@univr.it

› VIII International Strawberry Symposium

Section Vine and Berry Fruits #ishs_sevi
Commission Organic Horticulture #ishs_cmor
Commission Plant Genetic Resources #ishs_cmgr

From August 13 to 17, 2016, research scientists, industry representatives and professionals involved in the field of strawberry research met in Québec City, Canada for the VIII International Strawberry Symposium (ISS2016), also known as the "Strawberry Olympics", held every 4 years to coincide with the real Olympics. This symposium was organized by the Horticulture Research Center of Université Laval under the auspices of the International Society for Horticultural Sciences (ISHS). Drs. Yves Desjardins and André Gosselin convened the symposium.

This symposium is the largest forum for the strawberry industry, gathering to discuss the most recent science on the crop. The ISS2016 was attended by 419 participants representing 30 countries from 5 continents. Over 260 presentations were made, including 13 plenary, 79 regular oral and 172 poster presentations. As the Conveners used the new ISHS ROSA online submission system, 141 manuscripts were swiftly reviewed by an active board of 85 dedicated reviewers. They were then revised by the authors, accepted, and were ready for technical editing the day of the symposium. In addition, another 213 growers and industry people participated in a side event called the "Strawberry TechTransfer". This event was organized jointly by the Conveners and the Quebec Strawberry Growers Association to allow the local and national strawberry industry to benefit from the unique critical mass of scientists gathered in Québec City. The Conveners acknowledge the support of the staff from the Horticultural Research Center, the local organizing committee and Conférium, the PCO, who ran the event very professionally, as well as the many sponsors without whom this symposium would not have been possible. Special thanks are addressed to the Ministry of Agriculture and Food of Québec (MAPAQ) and the Quebec Tourist Office for their financial support.

Figure 1. Overview of the welcome cocktail with its spectacular food including strawberry.

In his opening remarks to the symposium, Dr. Desjardins presented a historical overview of the past ISS symposia and outlined the evolution of strawberry research over the last 30 years. He also stressed the importance of the City of Québec in the history of strawberry as we know it now. He presented historical data relating to the export of the first plants of *Fragaria virginiana* from Québec to the "Jardins des Plantes" in France, where natural hybridization with *F. chiloensis* took place, giving rise to the strawberry we know now (*F.* X *ananassa* Duch.). After official presentations by the Ministries, and growers' representatives, Dr. Bernadine Strik, Chair of the ISHS Section Vine and Berry Fruits, addressed the delegates with a few words of welcome. All attendees were then invited to a welcome cocktail where strawberries were at the forefront (Figure 1).

Strawberry genetics and selection, the key to success

The first plenary lecture was presented by Dr. Rick Harrison from Driscoll's company, USA, who presented a broad overview of the general trends for the production of strawberry

Figure 2. Dr. André Gosselin (left), Dr. Bernadine Strik (second from right) and Dr. Yves Desjardins (right) presenting the ISHS student awards to A) Mr. Henning Wagner (second from left) for the best student oral presentation, B) Mrs. Karla Garcia (second from left) for the best student poster.

Figure 3. The Conveners Drs. André Gosselin (center) and Yves Desjardins (right) receiving the ISHS award from Dr. B. Strik (left), Chair ISHS Section Vine and Berry Fruits.

Figure 4. The visit to Ile d'Orléans and the Onésime Pouliot Farm and Gosselin Farm was very interesting in a magic surrounding.

and outlined the importance of breeding and selection in the advancement of the strawberry industry. He was followed by Dr. Vance Whitaker, USA, who presented an informative talk on the use of molecular biology tools for the selection of new traits related to quality of strawberry and recent advancements at the University of Florida breeding program. Dr. Beatrice Denoyes from INRA, France, presented a comprehensive talk on the genomic tools available to unravel the mechanisms underlying the agronomical traits of strawberry. Following this, Dr. Nahla Bassil from USDA, USA, discussed the importance of the new RosBreed in the advancement of strawberry breeding. This was followed by a detailed presentation by Dr. Jiajung Lei, China, on the impressive and unique *Fragaria* genetic resources of China and their utilization within international breeding programs.

Strawberry quality and health

One key aspect explaining the impressive growth of the strawberry industry worldwide is consumer appreciation of their good taste coupled with the health effects that have recently been scientifically described. In this context, Dr. Maurizio Battino, from Marche Polytechnic University in Italy, presented an overview of the beneficial effects of strawberry on health and the molecules that are most likely responsible for the beneficial effect. Two other keynote lectures dealt with selection for quality traits in strawberry. The first one was presented by Dr. Kevin Folta from the University of Florida, who presented evidence of the beneficial use of biotechnological tools and metabolic engineering to improve the flavour and taste of strawberry. The second was presented by Dr. Klaus Olbricht from Germany, who discussed how to breed back-flavours into strawberry, using the well characterized old European genetic resources and the development of volatile metabolomic signatures to identify specific quality traits.

Greenhouse and organic production trends

Now-a-days, strawberries are available all year long and can be produced even in winter under protected cultivation. One of the limiting steps to economically produce fruit during winter is poor light availability. Dr. Tom Van Delm from Hoogstraten in Belgium presented a comprehensive talk on the different technologies available for artificial lighting of greenhouse strawberry and their effect on the physiology of the plants. In a similar manner, Dr. Martine Dorais, Chair of the ISHS Commission Organic Horticulture, presented an enlightening talk on the organic production of strawberry. The demand is very strong worldwide and growers will have to develop approaches to supply this demanding market.

Figure 5. Overview of some of the participants to ISS2016.

Strawberry is prone to entomological and pathological attacks

Strawberry is a tender fruit that is susceptible to many diseases and insect problems. One particular recent problem has been the world outbreak of the two spotted wings drosophila affecting many berry crops and particularly strawberry. Dr. Vaughn Walton from Oregon State University presented a very interesting talk on the life cycle of the pest and the IPM strategies that are under development to reduce and control the insect. Dr. Richard Bélanger also gave a fascinating presentation on the use of silicon to prophylactically reduce the incidence of many strawberry diseases and particularly to control powdery mildew. He described in detail the basic physiology of the nutrient and its mode of action in the strawberry plant.

Lots of fun during social activities

One of the foremost reasons to attend an ISHS meeting is to exchange recent results and developments and to share ideas. After intense workdays, it is, however, nice to relax and share other experiences. The attendees thus participated in a memorable BBQ at the Envirotron of the Horticulture Research Center and in the Roger Van den Hende botanical garden. The weather was exceptionally good and entertainment by the group Tous Azimuts (http://www.tous-azimuts.ca), the leader of which is Yves Desjardins' son, completed an excellent evening.

The last social activity to take place was an official closing banquet attended by 250 people at the newly opened Québec Musée National des Beaux Arts. During the evening, Dr. Strik took the podium to announce the winners of the best ISHS student oral and poster awards, namely Henning Wagner from the Techniche Universitat Dresden, Germany, for his talk entitled "Investigations on the chemical composition of cuticular waxes in twelve *Fragaria* genotypes" (Figure 2A) and Karla Garcia from the University of Arizona, USA, for her poster entitled "Flowering responses of American short day strawberry cultivars" (Figure 2B).

Figure 6. The Hoogstraten group were of great help in the organization of the ISS2016 and we are thankful for their participation.

The Conveners thank Drs. Retamales (Chile), Lesermann (Germany) and Strik (USA) for undertaking the hard task of evaluating the many presentations and posters. Dr. Strik also presented the ISHS medals and certificates to the Conveners, Drs. André Gosselin and Yves Desjardins (Figure 3).

Technical tours

The symposium finished on a good note with three technical tours organized in different regions of the province of Québec. The first tour visited the Orleans Island where a large concentration of strawberry production takes place. Participants were able to see extensive out-of-soil tunnel production and new approaches to irrigation and pest control in the field (Figure 4). The second tour went to the south shore of the St-Laurence River to see large scale day-neutral strawberry farms. The last tour went to visit Lareault Nurseries and see extensive production under plastic, north of Montreal.

Business meeting

The last activity of the symposium was the traditional ISHS business meeting, which was professionally conducted by Dr. Bernadine Strik. The ISHS members attending the meeting elected Dr. Curt Rom to become the next Chair of the ISHS Working Group Strawberry Culture and Management. The bid to hold the next ISS2020 was between Antwerpen (Belgium), presented by Tom van Delm representing the Belgian Hoogstraten group, and Remini (Italy), presented by Bruno Mezzetti from Ancona. After two outstanding presentations, the decision for the next symposium venue went to Italy who will organize ISS2020 in March.

Final words

The Conveners would like to thank all the participants for attending this symposium. The spirit was fantastic (Figure 5). We are especially indebted to the Hoogstraten group for organizing the program of the Strawberry TechTransfer and for participating so actively in the organization of ISS2016 (Figure 6). Their support was invaluable to the success of the event. They even postponed their triennial event to avoid clashing with ISS2016. We encourage all to participate next year in the III International Strawberry Congress in Belgium.

Yves Desjardins and André Gosselin

› Contact

Drs. Yves Desjardins and André Gosselin, Conveners ISS2016, Institute of Nutraceuticals and Functional Foods, Horticultural Research Center, Faculty of Agriculture, Laval University, Quebec, QC G1K 7P4, Canada, phone: (1)418-656-2131x2359, e-mail: yves.desjardins@FSAA.ulaval.ca, Andre.gosselin@fsaa.ulaval.ca

› III International Conference on Agricultural and Food Engineering

Commission Irrigation and Plant Water Relations #ishs_cmir
Commission Horticultural Engineering #ishs_cmen
Section Tropical and Subtropical Fruits #ishs_sets

› Attendees in the main conference hall. Photo by Md. Nasir Hussin.

The Department of Biological and Agricultural Engineering, in partnership with the Department of Process and Food Engineering, Universiti Putra Malaysia, hosted the International Conference on Agricultural and Food Engineering (CAFEi2016) for the third time. It was held in Kuala Lumpur, Malaysia, on August 23-25, 2016 and was convened by Dr. Samsuzana Abd Aziz.

The opening ceremony on 23 August was followed by a keynote address given by Professor Dr. Mary L. Wolfe (President of the American Society of Agricultural and Biological Engineers) focussing on global partnerships and the role of agricultural, food, and biological engineers in ensuring global food security. Professor Dr. Lei Tien (Head of Illinois Laboratory for Agricultural Remote Sensing, USA) was the second keynote speaker and discussed in detail the application of near-real-time sensing systems for precision agriculture. The third keynote speaker was Professor Dr. Mikio Umeda (Secretary General of International Commission of Agricultural and Biosystems Engineering), who presented his view on the development of mechanization and automation in Asia, focussing on Malaysia. Finally, the last keynote speaker, Professor Dr. Ir. Lilik Soetiarso (Dean of Faculty of Agricultural Technology, Universitas Gadjah Mada, Indonesia), presented an overview of applied research on intelligent systems in bioproduction engineering for a small-scale bio-industrial system.

A total of 141 papers were presented and divided into seven categories, namely agricultural mechanization and automation, soil and water engineering, bio-information systems, bioprocess and environment, food processing, postharvest engineering, and others. The conference was attended by more than 150 participants from 21 countries and from diverse national and international institutions, such as local and foreign universities, national and international research institutes, as well as government agencies.

The presentations addressed a wide spectrum of topics in recent agricultural and food engineering disciplines. Several papers on remote sensing and spectroscopy techniques for fruit and plant assessments were presented, mostly focussing on oil palm. Irrigation studies on crops like olive, barley, tomato, canola, rice, banana and maize were presented in the soil and water engineering category. There were very interesting presentations on mechanization and automation efforts for cost and production efficiency in oil palm, potato, sugar cane, rice, cassava and water melon. Some studies on bioprocessing and environmental control for tomato, black pepper and strawberry cultivation were discussed. The postharvest engineering category focused mainly on processing and handling of grains like maize and rice, vegetables like shallot and carrot, and tropical fruits like banana and mango.

Among the papers, some of the more notable were:

- Quantification of macropores and N and P transport through macropores under no-till and chisel plow tillage systems: simulated rainfall experiments;
- Emissivity determination of oil palm fresh fruit ripeness using a thermal imaging technique;

› Group photo of all participants on the third day of the conference. Photo by Md. Nasir Hussin.

› Prof. Manuela Zude-Sasse (left), Chair of ISHS Commission Irrigation and Plant Water Relations, presenting the ISHS medal award to Dr. Samsuzana Abd Aziz (right), Symposium Convener.

› Dr. Samsuzana Abd Aziz (left) and Prof. Manuela Zude-Sasse (right), presenting the ISHS student award to Okon Johnson Esua from Nigeria (second from left) for the best student oral presentation and to Ho Thanh Huong from Thailand (second from right) for the best student poster presentation.

- Effect of low temperature storage on the postharvest quality of minimally processed shallot (*Allium ascalonicum* L.);
- Controlling weevil in stored maize by means of physical disturbance;
- Current status and future trends of the use of hyperspectral remote sensing systems in precision agriculture.

Two best student presentation awards were given to Okon Johnson Esua from Nigeria for the best student oral presentation entitled 'Postharvest spoilage of tomato (*Solanum lycopersicum*) and associated effects on some antioxidant bioactive compounds' and to Ho Thanh Huong from Thailand for the best student poster presentation entitled 'Non-destructive prediction of moisture content of lime (*Citrus aurantifolia* Swingle 'Paan') by multiple regression analysis of its electrical and physical properties'.

During the field tour on the last day of the conference, participants were taken to Putrajaya's agricultural heritage park, where they learnt about a wide variety of commercial crops in Malaysia, including tropical fruit trees, herbs and spices, rubber, palm oil, tea, and coffee. They were able to taste fresh tropical fruits like mango, rambutan, durian, mangosteen and jackfruit. Activities such as rubber tapping, latex collection, crop maintenance, and fruit preservation were observed.

The conference was a platform for open dialogue and intense discussion between researchers, academics, engineers and growers. The next edition of this conference will take place in 2018 and more information about the conference can be accessed at the symposium website available at http://www.ishs.org/symposium/564 .

Samsuzana Abd Aziz

› Participants trying local fruits during the technical tour.

› Contact

Dr. Samsuzana Abd Aziz, Department of Biological and Agricultural Engineering, Faculty of Engineering, Universiti Putra Malaysia, 43400 UPM, Selangor, e-mail: samsuzana@upm.edu.my

› VI International Conference on Landscape and Urban Horticulture

Commission Landscape and Urban Horticulture #ishs_cmuh
Commission Protected Cultivation #ishs_cmpc

The VI International Conference on Landscape and Urban Horticulture was held at the Royal Olympic Hotel in Athens, Greece, from June 20 to 25, 2016. It was organized by the Laboratory of Floriculture & Landscape Architecture (LFLA) of the Agricultural University of Athens (AUA), under the auspices of the International Society for Horticultural Science (ISHS). The conference was convened by Maria Papafotiou, Professor/Head of the LFLA/Head of the Department of Crop Science of AUA, Panayiotis A. Nektarios, Professor at

› The Conveners, Prof. Dr. M. Papafotiou, Prof. Dr. P.A. Nektarios and Dr. A. Paraskevopoulou, at the opening session.

› Participants of the conference.

LFLA, and Angeliki Paraskevopoulou, Assist. Professor at LFLA.

The theme of the conference, "Landscape and urban horticulture in pursuit of social, environmental and economic wellness", emphasised the need to reflect on our contemporary way of life in relation to landscape design and urban horticulture. Increased building density and urban sprawl have tipped the balance between nature and humans, leading to unsustainable urban development characterised by social, environmental and economic problems. Urban horticulture plays an integral role in contributing to human health and wellbeing. Thus, the VI International Conference on Landscape and Urban Horticulture focused on identifying contemporary urban aesthetic, environmental and social problems and sought to intensify the impact of possible solutions through interdisciplinary scientific collaboration to disperse knowledge, expertise and technology.

The conference was very successful in bringing together 126 delegates from 24 countries spread over four continents. Overall, four keynote speeches, 42 oral, 48 short oral and 62 poster presentations were given in three days, in a single auditorium, which allowed delegates to get to know one another, to socialize and disseminate information more effectively amongst them. A technical tour took place on the fourth day, and a welcome reception and a Gala dinner provided additional opportunities for the delegates to get together and experience the Greek lifestyle.

On the first day, about 50 of the delegates took a tour of the campus of the Agricultural University of Athens and participated in the welcome reception.

In the opening session on the second day, the tone of the conference was set and delegates were welcomed by Dr. M. Papafotiou, Symposium Convener and Professor of LFLA at AUA, by Dr. G. Scarakis, Professor of Plant Breeding and Dean of the School of Agriculture, Engineering and Environmental Sciences of AUA, by Dr. K. Moore, Professor of Landscape Architecture at Birmingham City University and President of the International Federation of Landscape Architects (IFLA), by Dr. K. Goltsiou, Landscape Architect and President of the Panhellenic Association of Landscape Architects, and finally, by Dr. G. Prosdocimi Gianquinto, Professor of Horticulture at the University of Bologna and Chair of the ISHS Commission Landscape and Urban Horticulture, who presented the current activities of ISHS. The conference was opened by Dr. G.Th. Papadoulis, Professor of Agricultural Entomology and Acarology at AUA and Rector of AUA.

Two plenary lectures followed as an introduction to the two sessions: "Design and management of public green spaces & historical sites" (Session 1) and "Sustainability of urban landscape and horticulture/landscape restoration" (Session 2).

The first plenary lecture, entitled "The plant community; a model for horticultural thought and practice in the C21st?", was given by Dr. James Hitchmough, Professor of Horticultural Ecology and Head of the Department of Landscape Architecture, University of Sheffield, UK. The scientific understanding of how designed communities of horticultural plants can be assembled to maximize stability and to function most usefully was explored, both ecologically and in terms of their aesthetic attractiveness to human beings.

The second plenary lecture, entitled "A new look at landscape: infrastructure and education", was given by Dr. Kathryn Moore, Professor of Landscape Architecture, Birmingham City University, UK, and President of IFLA. This talk examined the challenges of providing a more expansive, interdisciplinary approach in both design and landscape education and pointed out that, whatever the discipline,

› Technical tour. A. The director of the Botanical Garden of Julia & Alexander N. Diomedes, Dr. I. Vallianatou, showing the participants the plan of the garden; B. At the garden of the Presidential Mansion.

› Symposium Conveners presenting the ISHS student awards to
A) Vladimir Ionut Boc for the best student oral presentation,
B) Lamprini Tassoula for the best student poster presentation.

what is absolutely critical is the manner in which we practice – not simply the materials we use. Further, it was emphasised that pedagogy and research should move into the more ambiguous realm of ideas and expertise.

A third plenary lecture, entitled "Plant selection and diversity make a difference for green roof ecosystem functioning", was given on the following day by Dr. Jeremy T. Lundholm, Professor and Head of the Ecology of Plants in Communities laboratory, Saint Mary's University, Canada. The key research question, whether increasing species or life form diversity on a green roof can improve the provision of ecosystem services, was addressed and a testable hypothesis that different ecosystem services should be maximized by mixed plantings at different spatial scales was proposed. The sessions on the second day addressed "Green technologies and bioclimatic planning" (Session 3) and "Botanical gardens/healing gardens/landscape ecology" (Session 4). Also, two poster sessions were held, and in the evening the Gala dinner in the Glyfada coastal district was attended by about 45 of the delegates.

The fourth plenary lecture, entitled "Root zone colonization space for urban trees as a foundation to meet design and longevity goals", was given on the last day of presentations by Dr. Jason Grabosky, Professor of Ecology, Evolution and Natural Resources, Rutgers University, USA. Results on integrating pavement support with root zone requirements in soil design were presented and discussed as a way to influence the carrying capacity without losing other aspects of urban infrastructure to provide a more livable and ecologically fit environment. The topics of sessions on the final day were, "Urban horticulture" (Session 5), "Urban biodiversity" (Session 6) and "Water management for urban green spaces" (Session 7). After the last session of the day, the business meeting of the Commission Landscape and Urban Horticulture was held.

The conference covered a variety of topics. These included sustainable design and management, sustainable use of water and water management, and the use of native plants for conservation of resources and for biodiversity reasons. There seemed to be an increase in topics related to landscape design, such as the design and management of historical places and botanical or historical gardens, compared to conferences held in previous years. In contrast, topics related to urban agriculture were not strongly covered. The need for collaboration between designers, ecologists and horticulturists was identified, to ensure urban green and urban horticulture issues would be approached successfully.

In recognition of the outstanding work of graduate students, two ISHS student awards were given. The best graduate student oral presentation was awarded to Vladimir Ionut Boc from the University of Agronomic Sciences and Veterinary Medicine, Romania, for his presentation entitled "Introducing the bioclimatic security concept in green infrastructure planning and design". The best graduate student poster presentation was awarded to Lamprini Tassoula from the Agricultural University of Athens, Greece, for her presentation entitled "Growth of the Mediterranean xerophyte *Scabiosa cretica* L. on an extensive green roof under different substrate types and irrigation regimes".

Technical tour

On the fourth day of the conference about 50 delegates attended the technical tour, which brought together the past and the present of landscape design. The tour started early in the morning with a guided tour of the Botanical Garden of Julia & Alexander N. Diomedes (area 154.000 m^2) designed in 1897. The garden, based on the plans of the landscape architect Herta Hammerbacher, is integrated within the natural Mediterranean landscape in a suburb of Athens. Next the participants were taken to the National Garden (area 154.000 m^2), originally designed as part of the gardens surrounding the former palace which is today's Parliament Building, and which became the first ornamental park of Modern Athens (1927). Garden works were overseen by the French garden designer Francois Louis Barauld and his assistant since 1846, agronomist Friedtrch Schmidt. The garden style is "picturesque", enriched in places with "classical" elements and adapted to Greek environmental conditions. Following this, the participants were taken to the Presidential Mansion, the former Crown Prince's Palace, designed in 1897 by the German architect Ernst Moritz Theodor Ziller. Here they visited gardens (25.000 m^2) from the eclecticist period. After lunch at a Greek tavern where a wide range of Greek food was sampled, participants were taken to the newly constructed Stavros Niarchos Park (area 170.000 m^2), which constitutes the grounds of the Stavros Niarchos Foundation Cultural Center (SNFCC), and includes new facilities for the National Library of Greece and the Greek National Opera designed by Renzo Piano Building Workshop Architects. The Stavros Niarchos Park, planted with Mediterranean plant species, covers 85% of the SNFCC site and constitutes one of the largest green roofs in Europe. The tour for most of the participants ended at 19:00 pm, but some chose to stay at Stavros Niarchos Park to participate in the events of the day that were open to the public and included a talk by Renzo Piano on the design principals of the SNFCC.

Social events

Welcome reception

About 50 of the delegates took a tour of the campus of the Agricultural University of Athens, where they were guided through the Botanical garden and the experimental fields, greenhouses and experimental green roofs of the Laboratory of Floriculture and Landscape Architecture. They visited Plato's 2,300-years-old olive tree, the collection of mineral rocks at the Laboratory of Mineralogy and Geology, and the Agricultural Museum of the University. A welcome reception with Greek food and wine was held in the evening in the garden of the Agricultural Museum.

Gala dinner

The Gala dinner, attended by about 45 delegates, was set at a pavilion-restaurant by the sea on the beach of Glyfada. International cuisine, Greek wine, music, a lot of dance, and a beautiful sunset followed by the almost full moon, combined to produce a memorable night for us all.

Maria Papafotiou

› Contact

Prof. Dr. Maria Papafotiou, Dept. Crop Science, Lab. Floriculture & Landscape Architecture, Agricultural University of Athens, 75, Iera Odos, 118 55 Athens, Greece, e-mail: mpapaf@aua.gr

› II International Symposium on Germplasm of Ornamentals

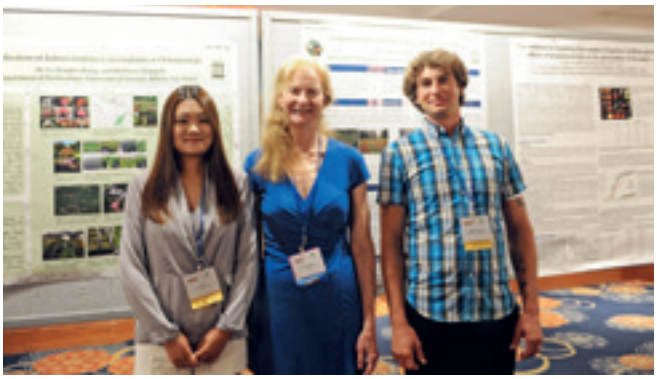
Commission Plant Genetic Resources #ishs_cmgr
Section Ornamental Plants #ishs_seop
Commission Molecular Biology and In Vitro Culture #ishs_seop

› Participants of the symposium.

The II International Symposium on Germplasm of Ornamentals was held from 8 to 12 August 2016, in Atlanta, Georgia, USA. The motto of the symposium was "Better Ornamental Plants for the Better World!" This symposium was endorsed by Commission Plant Genetic Resources and supported by Section Ornamental Plants of the International Society for Horticultural Science (ISHS). This scientific forum provided the opportunity to establish and maintain close contacts between scientists, producers, and growers interested in the area of ornamental horticultural research. The venue was arranged in conjunction with the 113th annual conference of the American Society for Horticultural Science in Atlanta, Georgia. This provided a wide opportunity for the symposium participants to join ASHS concurrent meetings and activities. The event was particularly well attended by Chinese, American, and South Korean participants with a total attendance of 68.

The meetings were convened by Prof. Dr. Donglin Zhang, Professor of the Michael Dirr Endowed Chair in the Department of Horticulture, University of Georgia, USA, with Co-Conveners Prof. Dr. Qixiang Zhang from Beijing Forestry University, China, and Prof. Dr. Byoung Ryong Jeong from Gyeongsang National University, South Korea. The staff of the University of Georgia, Department of Horticulture and of the Beijing Forestry University organized the meetings and tours. The meetings were well supported by 10 private

› (Right to left) Dr. Kim Hummer, ISHS Representative, handing out the ISHS medal awards to Convener Prof. Dr. Donglin Zhang, Atlanta, Georgia, USA, and Co-Conveners Prof. Dr. Qixiang Zhang, Beijing, China, and Prof. Dr. Byoung Ryong Jeong, Sacheon, South Korea.



› Dr. Kim Hummer, ISHS Representative (center), with the winners of the ISHS student awards: Mr. Nathan Maren, North Dakota State University, for the best student oral presentation (right), and Ms. He Li, University of Georgia, for the best student poster presentation (left).

› Hibiscus hybrid in the trials of Dr. John Ruter, University of Georgia, Athens, Georgia, USA. Photo by K. Hummer.

› Demonstration of herbaceous ornamental plantings at the University of Georgia, during a symposium tour.

ornamental industry companies in addition to the ISHS and the University of Georgia Foundation. Great appreciation is given particularly to Transcend Nursery, the Georgia Seed Development Commission, and Spring Meadows Nursery for their generous financial support of the meetings.

Dr. Margaret Pooler, Research Leader of the US Department of Agriculture, National Arboretum, Washington, D.C., USA, gave the keynote opening address on "Good genes – germplasm and breeding work together to create new plants at the US National Arboretum". She described the history of ornamental research at the arboretum leading up to today's latest releases. Forty-two oral and 22 poster presentations were made during the symposium. The scientific presentations were divided into five sections: New Ornamentals, Selection and Breeding, Germplasm Resources, Application of Modern Technology, and Conservation and Sustainability.

Oral and poster graduate student competitions were held. Mr. Nathan A. Maren, graduate student of Dr. Todd P. West, North Dakota State University, USA, won the ISHS student award for the best oral presentation entitled "Hybrid analysis of somatic fused lilac (*Syringa* spp.)." Ms. He Li, graduate student of Dr. Matthew Chappell, Department of Horticulture, University of Georgia, USA, won the ISHS student award for the best poster presentation entitled "Utilization of *Kalmia latifolia* L. germplasm as ornamentals."

On Wednesday 10 August 2016, participants were treated to an afternoon tour of Pike's Nursery Garden Center on Camellia Lane, Atlanta, Georgia. They traveled on to the Atlantic Botanical Garden at Gainesville, Georgia, for a catered dinner. At the Botanical Garden, Mr. Robert 'Buddy' Lee, from Plant Development and Services, Inc., spoke on "Ornamental plant breeding and encore azalea". After dinner, Mr. Scott McMahon, Plant Explorer for the Atlanta Botanical Gardens, gave a presentation of exciting events during recent expeditions in China and Vietnam entitled "Ornamental plant exploration around the world."

On Friday 12 August 2016, the group traveled to Angel Creek Nursery and Southeastern Growers, Inc. farms. Dr. Matthew Chappell introduced the locations and Ms. Carol Seadale, Manager, described the propagation and production protocols for the many ornamental woody trees produced on these two farms. The group then traveled to the University of Georgia Horticultural Farm in Athens, Georgia. After a southern homestyle barbeque lunch, the group set out to see *Hibiscus* and other ornamental trials, described by Dr. John Ruter. Dr. Donglin Zhang hosted a tour of the wonderful woody ornamental landscape arboretum at the farm. The group then traveled to the trial herbaceous ornamental gardens on the campus at the University of Georgia, Athens. Dr. Ruter guided the group through the magnificent multi-colored trials including petunias, caladiums, geraniums, begonias, and canna lilies, to name a few flowers in the garden.

At the business meeting, the group accepted the bid from Prof. Dr. Byoung Ryong Jeong, Gyeongsang National University, Sacheon, South Korea, to be the next convener and he agreed. The upcoming symposium is planned to occur in Jinju, South Korea, in April or May, 2020.

Kim E. Hummer and Donglin Zhang

› Contact

Dr. Kim E. Hummer, ISHS Science Editor and ISHS representative at the II International Symposium on Germplasm of Ornamentals, USDA ARS NCGR, 33447 Peoria Road, Corvallis, OR 97333-2521, USA, e-mail: kim.hummer@ars.usda.gov

Prof. Dr. Donglin Zhang, Symposium Convener, University of Georgia, Dept. of Horticulture, 1111 Plant Science Building, Athens, GA 30602-7273, USA, e-mail: donglin@uga.edu

From the Secretariat

› New ISHS members

ISHS is pleased to welcome the following new members:

New Individual Members

Albania: Dr. Majlinda Cakalli Kullaj; **Algeria:** Ms. Hafida Merzouk; **Argentina:** Fernando Munzi, Claudio Rodgers, Ms. María Clara Sanchez, Dr. Pedro Sansberro, Luis Taquini; **Australia:** Dr. Angela Atkionson, Stephen Beckwith, Ridley Bell, Mr. Dan Berrigan, David Chandlee, Derek Fisher, John Jessett, Robert King, Greg Murtha, Tyler Scofield, Mr. Ian Smith; **Belgium:** Mr. Jonas Decorte, Katrijn Van Laere, Ms. Sofie Van Laethem, Dr. Danny Vereecke; **Brazil:** Ms. Renato Farinacio, Mr. Renato Fernandes Galdiano Junior, Dr. Maria Luisa Mendes Rodrigues, Prof. Dr. Edson Mizobutsi, Ms. Rodrigo Moraes, Prof. Dr. Fernanda Nery, Caroline Oliveira Timoteo, Ms. Joyce Pereira Alvarenga, Ms. Carolina S. Schuchovski Augusto, Prof. Dr. Marlucia Santana, Prof. Dr. Paulo Santos, Mr. Raphael Silva, Mr. Lucas Souza, Ms. Rafaela Souza, Assoc. Prof. Marciel Stadnik; **Canada:** Joel Abbey, Lora Harris, Mr. Rob MAhaffey, Benjamin Martin, Chris McKee, Mr. Simon Terrault; **Chile:** Mr. Juan Cristobal Arroyo, Juan Cares Serrano, Denise Donnay, Dr. Oriana Flores, Prof. Dr. Rolando Garcia-Gonzáles, Assoc. Prof. Jose Luis Henriquez, Juan Pablo Hube, Alfredo Lira, Ariel Luengo, Jorge Nanjari, Raul Olivares, Melisa Osorio, María José Palma, Roberto Pereira, Julia Pinto, Ms. Jessica Saavedra Bruna, Carolina Salgado, Dr. Paula Salinas, Daniel Santana Geraldo, Fernando Andrés Villagrán Muñoz; **China:** Fang Ding, Jinlong Du, Jianhua Gao, Prof. Wubin Gao, Shoukun Han, Dr. Yu-Jin Hao, Guohui Huang, Prof. Lili Huang, Hongzhou Jiang, Assoc. Prof. Feng Lin, Guangzhe Qu, Rongdong Qu, Prof. Liying Sun, Peng Xie, Ding Yuan, hai zhang, Assist. Prof. Jingjin Zhang, Min Zhang; **Chinese Taipei:** Ms. Jasmine Chen; **Colombia:** Manuel Cuellar, Camilo Herrera, Veronica Herrera; **Cyprus:** Dr. Antonios Chrysargyris; **Denmark:** Dr. Justyna Wieczynska; **Egypt:** Prof. Dr. Saneya EL Neshawy; **Finland:** Mr. Juho Hautsalo; **France:** Carole Becel, Mr. Cyriaque Le Gouguec, Dr. Toni Talab, Gilles Vercambre; **Germany:** Ms. Nicole Brandes, Mr. Dirk Jäger, Dr. Benye Liu; **Greece:** Konstantinos Megalidis; **India:** Mr. Prateek Dixit, Mr. Rajender Kumar; **Indonesia:** Mr. Djoko Prijono; **Iran:** Assist. Prof. Sasan Aliniaeifard, Sirus Ekhtiari, Alireza Etminan, Ezatollah Farshadfar, Mohammad Ali Kargar, Ali Mehras Mehrabi, Mahdi Safavi, Lia Shoshtari, Assist. Prof. Vahid Tavallali; **Ireland:** Ms. Catherine Donovan; **Italy:** Valeria Bianciotto, Mr. Vito Buono, Dr. Giampaolo Buriani, Marco Rosario Butera, Callum Kay, Luca Lovatti, Prof. Michele Scotton; **Japan:** Eri Hayashi, Assist. Prof. Kazuo Ikeda, Mr. Hayato Morimoto; **Jordan:** Dr. Sobhia Saifan; **Korea (Republic of):** O Hyeon Kwon, Dr. Yang Sook Lim; **Lebanon:** Dr. Safaa Baydoun; **Madagascar:** Dr. Denis Randriamampionona; **Malaysia:** Fatimah Kayat, Kek Kiong Ng; **Malta:** Mr. Davide Sardella; **Mauritius:** Mr. Teeluckdharry Baldawoo; **Mexico:** Argenis Diaz Meza, Ivette Flores, Arturo Garcia, Carlos Guzman, Sorin Lomeli, Rafael Mariscal, Andres Martinez-Vera, Jesús Morales-Huerta, Juan Pacheco, Guillermo Romo, Belem Santiago, Eduardo Tirado; **Morocco:** Dr. Mustapha Aitchitt; **Netherlands:** Godfried Douven, Ronnie Kersten, Ramon Melon, Pablo Segovia, Rob van Mullem; **New Zealand:** Dr. Cyril Brendolise, Dr. Kerry Everett, Mr. Nick Hoskins, Mr. Shane Olsson, Ms. Jacqueline Oseko, Ms. Yongyan Peng, Steven Saunders, George Taiaroa, Mr. Kerry Templeton, Joy Tyson, Ms. Vonda Windley; **Nigeria:** Mr. Emmanuel Olajide; **Oman:** Ms. Latifa Al Kharusi; **Peru:** Daniel Moreira, Luis Rodríguez; **Poland:** Stanislaw Krzyzak, Magdalena Pancerz, Mr. Jacek Sulek; **South Africa:** Ms. Karla-Mart Beyers, Assoc. Prof. Kim Clarke, Ms. Alicia Pretorius, Petrus Steinberg, Ms. Willien Strutz; **Spain:** Wil Lemmer, Peña Limon, Manuel Romero Velázquez, Philipp Schulze, Mr. Adán Valero, Dinis Vicente Grussner; **Sri Lanka:** Ms. Bodiyabaduge Sewwandi G. Chandrasekera, Dr. Darshani Weerahewa; **Thailand:** Dr. Volker Kleinhenz; **Turkey:** Assoc. Prof. Elman Bahar, Prof. Dr. Turgut Cabaroglu; **United Kingdom:** Phillippa Dodds, Rupert Hargreaves, Dr. Catherine Horwood, Mr. Athanasios Mandis, Dr. Susan McCallum, Nic Walton; **United States of America:** Dr. Achour Amiri, Deanna Bayo, Paul Birchall, Kendra Blaker, Sara Bratsch, Ms. Milica Brogan, Mary Calkins, Nolan Callahan, John Davis, Emily Ellingson, Juan Franco Coronado, James French, Geoff Furniss, Greg Furniss, Christopher Gottschalk, Jason Griffin, Mr. Johannes Grove-Nielsen, Paul Halladin, Jorden Hinrichsen, Massimo Iorizzo, Hamish Kay, David Lawson, Joaquin Lopez, Prof. Amy Love, Megan Mathey, Steve Mcnamara, Dan Meier, Peter Moe, Mr. Martin Mora, Clay Owens, Jonathan Pedersen, Bryan Peterson, Erin Pfarr, Doug Phillips, Renata Pincelli-Souza, Robert Reid, Thomas Richardson, Hilda Patricia Rodriguez-Armenta, Assoc. Prof. Laban Rutto, Sambhav Sambhav, Scott Seddon, Alan Smith, Rolston St Hilaire, John Ullman, Brooke VanLooy, Oscar Vargas, Maria Velez-Climent, Todd West, Bob Williams, Sarah Wool, Ashley Yow, David Zlesak, Kathryn Zuzek; **Vietnam:** Dr. Thi Thu Hoai Tran

› Index to Volume 56 of *Chronica Horticulturae*

Subject index

Book Reviews

History

Horticultural Science Focus

Horticultural Science News

Issues

News & Views from the Board

Spotlight on Honoured ISHS Members

Symposia and Workshops

The World of Horticulture

Author index

› Available issues of *Acta Horticulturae*

Available numbers of *Acta Horticulturae* (in print). These as well as all other titles are also available in *ActaHort CD-rom* format. For detailed information on price and availability, including tables of content, or to download an *Acta Horticulturae* order form, please check out the 'publications' page at www.ishs.org or go to www.actahort.org

Acta Number	Acta Title	Price (EUR)
1149	II International Workshop on Bacterial Diseases of Stone Fruits and Nuts	40
1148	II World Congress on the Use of Biostimulants in Agriculture	56
1147	IX International Symposium on Artichoke, Cardoon and Their Wild Relatives	102
1146	III International Symposium on Organic Matter Management and Compost Use in Horticulture	75
1145	International Symposium on Biotechnology and Other Omics in Vegetable Science	58
1144	III International Symposium on Postharvest Pathology: Using Science to Increase Food Availability	112
1143	VII International Symposium on Edible Alliaceae	87
1142	VI Balkan Symposium on Vegetables and Potatoes	108
1141	III International Conference on Fresh-Cut Produce: Maintaining Quality and Safety	91
1140	Proceedings of the 2015 Annual Meeting of the International Plant Propagators' Society	100
1139	III Balkan Symposium on Fruit Growing	166
1138	EUFRIN Thinning Working Group Symposia	46
1137	International Symposium on Innovation in Integrated and Organic Horticulture (INNOHORT)	88
1136	I International Symposium on Grapevine Roots	77
1135	III International Symposium on Citrus Biotechnology	56
1133	XI International Rubus and Ribes Symposium	118
1132	XVIII International Symposium on Horticultural Economics and Management	60
1131	III International Conference on Quality Management in Supply Chains of Ornamentals	52
1130	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposia on the Physiology of Perennial Fruit Crops and Production Systems and Mechanisation, Precision Horticulture and Robotics	146
1129	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposium on Impact of Asia-Pacific Horticulture - Resources, Technology and Social Welfare	58
1128	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposium on Horticulture in Developing Countries and World Food Production	83
1127	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): International Symposium on Plant Breeding in Horticulture	117
1126	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): Plenary Sessions of IHC2014 and VII International Symposium on Education, Research Training and Consultancy	75
1125	XXIX International Horticultural Congress on Horticulture: Sustaining Lives, Livelihoods and Landscapes (IHC2014): V World Congress on Medicinal and Aromatic Plants and International Symposium on Plants, as Factories of Natural Substances, Edible and Essential Oils	99

For an updated list of all titles (in print or ActaHort CD-rom format) logon to www.actahort.org

› Calendar of ISHS events

For updates and extra information go to www.ishs.org and check out the calendar of events. Alternatively use the "science" option from the website navigation menu for a comprehensive list of meetings for each Section, Commission or Working Group. 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 2017

- March 7-10, 2017, Napier (New Zealand): **IV International Symposium on Molecular Markers in Horticulture.** 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 E-mail symposium: Yvonne.McDiarmid@plantandfood.co.nz Web: http://www.molecularmarkers.co.nz
- NEW March 26-30, 2017, Coquimbo (Chile): **IX International Congress on Cactus Pear and Cochineal: CAM Crops for a Hotter and Drier World.** Info: Nicolás Franck Berger, Universidad de Chile, Casilla 129, Coquimbo, Chile. E-mail: nfranck@uchile.cl or Prof. Carmen Saenz, Universidad de Chile, Casilla 1004, Santiago, Chile. Phone: 56 2 29785731, E-mail: csaenz@uchile.cl E-mail symposium: cactuscongress2017@gmail.com Web: http://www.cactuscongress2017.uchile.cl/
- March 28-30, 2017, Santiago (Chile): **III International Symposium on Bacterial Canker of Kiwifruit (Psa).** Info: Paulina Sepulveda, INIA-LA Platina Chile, Zurich 221 Depto 101, Santiago, Chile. Phone: (56)225779147, E-mail: pssr2009@gmail.com E-mail symposium: symposium.psa2017@gmail.com Web: http://www.psa2017.cl
- April 6-8, 2017, Kandy (Sri Lanka): **IV International Conference on Postharvest and Quality Management of Horticultural Products of Interest for Tropical Regions.** Info: Dr. Chalinda Beneragama, Department of Crop Science, Faculty of Agriculture, University of Peradeniya, 20400 Sri Lanka Peradeniya, Sri Lanka. Phone: (94)812-395127), E-mail: chalindab@gmail.com E-mail symposium: pqmhp2017@gmail.com Web: http://pqmhp2017.org/
- April 24-28, 2017, Lavras, Minas Gerais (Brazil): **VII International Symposium on Production and Establishment of Micropropagated Plants.** Info: Prof. Dr. Renato Paiva, Alameda dos Flamboyants 103, Condominio Jardim das Palmeiras, 372000-000 Lavras-Minas Gerais, Brazil. Phone: (55)3538291359, Fax: (55)3538291100, E-mail: renpaiva@dbi.ufla.br or Dr. Diogo Pedrosa Corrêa da Silva, Rua América de Moura Maia, 57, apto 02, Lavras, Brazil. E-mail: pedrosacorrea@yahoo.com.br or Dr. Michele Reis, R. Misseno de Padua, 296 apt. 202, Centro, 37200--00 Lavras-Minas Gerais, Brazil. Phone: (55)035 38291619, E-mail: mvreis@yahoo.com.br Web: http://www.pempbrazil.com
- May 1-4, 2017, Ramsar (Iran): **International Symposium on Wild Flowers and Native Ornamental Plants.** Info: Dr. Pejman Azadi, National Institute of Ornamental Plants, PO Box 37815-137, Mahallat, Iran. E-mail: azadip22@gmail.com E-mail symposium: info@wildflowers2017.com Web: http://wildflowers2017.com/
- May 8-11, 2017, Antalya (Turkey): **International Symposium on Carob: a Neglected Species with Genetic Resources for Multifunctional Uses.** Info: Prof. Dr. Hamide Gubbuk, Akdeniz University, Faculty of Agriculture, Department of Horticulture, 07058 Antalya, Turkey. Phone: (90)2423102422), Fax: (90)2422274564, E-mail: gubbuk@akdeniz.edu.tr Web: http://www.carob2016.org
- NEW May 22-26, 2017, Fullerton, CA (United States of America): **X International Workshop on Sap Flow.** Info: Prof. Dr. H. Jochen Schenk, Department of Biological Science, California State University Fullerton, PO Box 6850, Fullerton, CA 92834-6850, United States of America. Phone: (1)6572783678, E-mail: jschenk@fullerton.edu E-mail symposium: info@rivertothesky.org Web: http://www.rivertothesky.org/
- NEW May 22-26, 2017, Cayo Guillermo, Ciego de Ávila (Cuba): **III International Symposium on Plant Cryopreservation.** Info: Dr. Marcos Edel Martinez-Montero, Bioplantas Center, Plant Breeding Lab., University of Ciego de Avila, Car. a Moron km 9, CP 69450 Ciego de Avila, Cuba. Phone: (53) 33 22 5768, Fax: (53) 33 26 6365, E-mail: marcosem@bioplantas.cu E-mail symposium: cryo.ishs2017@gmail.com Web: http://bioveg.bioplantas.cu/CryoSymp2017
- May 23-26, 2017, Pontevedra (Spain): **VII International Symposium on Brassicas.** Info: Elena Cartea, CSIC, PO BOX 28, 36080 Pontevedra, Spain. Phone: (34)986854800, E-mail: ecartea@mbg.csic.es or Pablo Velasco, Misión Biológica de Galicia (CSIC), Apartado 28, 36080 Pontevedra, Spain. Phone: (34)986854800, E-mail: pvelasco@mbg.csic.es or Pilar Soengas, Misión Biológica de Galicia (CSIC), Apartado 28, 36080 Pontevedra, Spain. Phone: (34)986854800, E-mail: psoengas@mbg.csic.es or Dr. Victor Rodriguez, Mision Biologica de Galicia, Palacio de Salcedo, Carballeira, 8 (Salcedo), 36143 Pontevedra, Spain. Phone: (34)986854800, E-mail: vmrodriguez@mbg.csic.es E-mail symposium: brassica2017@csic.es Web: http://brassica2017.com
- NEW May 28 - June 3, 2017, Skukuza (South Africa): **IV International Symposium on Postharvest Pathology.** Info: Prof. Lise Korsten, University of Pretoria, School of Plant and Crop Science, Pretoria 0002, South Africa. Phone: (27)124203295, Fax: (27)124204588, E-mail: lise.korsten@up.ac.za Web: http://www.postharvest2017.co.za/
- June 5-9, 2017, Yamagata (Japan): **VIII International Cherry Symposium.** Info: 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 or Prof. Dr. Ryutaro Tao, Lab. Pomology, Fac. Agric., Kyoto University, Kitashirakawa Oiwake-cho, Sakyo-ku Kyoto 606-8502, Japan. Phone: (81)757536053, Fax: (81)757536497, E-mail: rtao@kais.kyoto-u.ac.jp or Hideki Murayama, Faculty of Agriculture, Yamagata University, 1-23 Wakabamachi Tsuruoka, Yamagata 997-8555, Japan. Phone: (81)235282887, Fax: (81)235282812, E-mail: mhideki@tds1.tr.yamagata-u.ac.jp Web: http://cherry2017.jshs.jp
- June 18-22, 2017, Warsaw (Poland): **XII International Controlled and Modified Atmosphere Research Conference - CaMa2017.** Info: Dr. Krzysztof Rutkowski, Research Institute of Horticulture, Konstytucji 3 Maja 1/3, 96-100 Skierniewice, Poland. Phone: (48) 468345363, E-mail: krzysztof.rutkowski@inhort.pl or Prof. Dr. Franciszek Adamicki, Research Institute of Horticulture, Konstytucji 3 Maja 13 Str., 96-100 Skierniewice, Poland. Phone: (48)46 833 34 34, Fax: (48)46 833 31 86, E-mail: franciszek.adamicki@inhort.pl
- June 19-23, 2017, Palermo (Italy): **International Symposium on Flowering, Fruit Set and Alternate Bearing.** Info: Prof. Francesco Marra, Department of Agricultural & Forest Science, Viale delle Scienze, Edificio 4 ingresso H, 90128 Palermo, Italy. Phone: (39)09123861236, Fax: (39)09123861211, E-mail: francescopaolo.marra@unipa.it or Prof. Dr. Tiziano Caruso, Department of Agricultural & Forest Science, University of Palermo, Viale delle Scienze, Edificio 4 ingresso H, 90128 Palermo, Italy. Phone: (39) 09123861207, E-mail: tiziano.caruso@unipa.it or Prof. Dr. Sisir Kumar Mitra, B-12/48, Kalyani, Nadia, West Bengal 741235, India. Phone: (91)9432174249, Fax: (91)3325828460, E-mail: sisirm55@gmail.com E-mail symposium: info@fsab2017.it Web: http://www.fsab2017.it

For updates logon to www.ishs.org/symposia