X INTERNATIONAL PEACH SYMPOSIUM

Take home messages of the ISHS Webinar
"Current trends and challenges of peach fruit production"

ISHS International Society for Horticultural Science

CUT FRUIT SCIENCES GROUP

Maria Jose Aranzana, IRTA-CRAG
The impact of somatic mutations in peach breeding

- Somatic mutants (sports) have awaken the interest of horticulturists, growers, breeders and scientists for centuries.
- Most of somatic mutations affect only one cell layer or a fraction of the meristem, forming chimeras. Chimerism needs to be taken into consideration for propagation as well as for genomic studies.
- Only those mutations in cells of layer L2 will pass to the progeny through the gametes. Mutations in the other layers will only be maintained by vegetative propagation.
- Despite that great interest, little is known about the causes and mechanisms of somatic variability. Genomic studies, involving layer-specific whole genome sequencing, will help to quantify and understand such mechanisms.

Ksenija Gasic, Clemson University
Advances in cultivar and rootstock breeding: A case study in peach

- Rosaceae family and in particular Prunus genus, synteny and collinearity provides opportunities to translate horticultural and disease trait information across species into modern breeding pipelines.
- The advancement of genomic technologies coupled with the drastic reduction in sequencing costs have provided unprecedented opportunities to rapidly understand the linkage between genetics, environment and the phenotypes for these crops.
- Peach reference genome assembly provided the foundation for quantum leaps in understanding and mapping traits loci in peach, Prunus and other closely related Rosaceous species.
- Conventional breeding of peach cultivars and rootstocks is supplemented by DNA information for many traits of interest in both parent and seedling selection.
- Application of DNA information in breeding allows for increase in breeding efficiency as individuals with desirable trait profile can be selected in early stages and field evaluations are focused on those that have the desired combination of traits.

Davide Neri, University of Ancona

Current trends in training systems

- Pruning and training peach trees is a traditional practice. How it can be improved nowadays? And why we should make it different from what it was done for a long time by the farmers? The pruning renews the fruiting parts of the peach trees creating every year a productive equilibrium which allows to have enough fruits for the farmers and enough vegetation for the trees. If the fruits are in excess the tree stops to feed the roots, the fruit quality (size, sugar content) is poor, the tree vigor declines and the resilience to abiotic and biotic stress collapse, the ageing advances rapidly up to the senescence.
- In new orchards which use novel very productive varieties suitable for international markets, but also for local communities, it is important to reduce the cost of labor. How to deal with this change improving training and pruning of fruit trees? The first step is to properly manage the shoot to root ratio. Moving from vigorous rootstocks in low density "3D" orchards to medium vigor ones in high density "2D" orchards improve air and light distribution in the canopy but it requires more attention to water supply and fertilization. The transition from traditional orchards to more intense ones with smaller trees requires to improve the physiological control of the tree and the systemic functioning of the orchards to face the climatic change and make more efficient and stable the production. To make sustainable orchards it is also important to preserve a certain amount of soil biodiversity through different cover crops and living mulches which allow a better root functioning and humification. Limiting soil sickness and allelopathic problems brings to less root dystrophy and longer peach productions with less replant problems.
- The second step is to better manage the shoot and fruit ratio. Each fruit needs to have an appropriate number of leaves to get enough photosynthetic produces, and be partially shadowed to avoid sunburn. On the same time the branches need to be organized in a conic shape which maintains the growing equilibrium and high quality of the fruit production. The orchards need appropriate tree shape and regularity to improve the mechanization and make easier the pruning and the harvest. Minimal winter and green pruning in intensive orchards with simple training systems seems to be the possible "golden rule" for improving the protected fruit production. Green pruning boosts the control of shoot growth and leaf area while photo-selective nets can improve the environmental control against hailstorms, heavy rain and insects for sustainable high density 2D orchards.

Ioannis Minas, Colorado State University

Revealing the true impact of preharvest factors on peach fruit quality development and metabolism

- Peach per capita consumption is in constant decline over the last decades in USA.
- Poor consumer satisfaction from the quality of peaches is the main reason that drives consumers away from peaches.

- Fruit quality is only improved at the preharvest/orchard stage, and it can only be maintained during postharvest handling.
- To improve peach fruit quality the influence of preharvest factors on fruit quality development and metabolism must be clearly understood and accurately quantified.
- Peach quality is improving with the advancement of maturation and preharvest factors can affect fruit maturation process.
- Traditional fruit quality and maturity assessment methods are destructive, labor intensive and are not friendly for field use and large-scale data acquisition.
- The development of novel non-destructive techniques using visual-near infrared radiation (Vis-NIR) to accurately estimate tree-fruit quality on-tree (dry matter contend (DMC), soluble solids concentration (SSC)), can support growers and researchers on decisions regarding the proper harvest time, on the evaluation of cultural techniques, new cultivars, and rootstocks towards increasing orchard quality potential
- NIRS accurately sensed DMC, SSC differences in peach at 729-935 nm, however, adaptation from growers is still behind as it requires calibration and high accuracy to overcome the cost of initial investment.
- Index of absorbance difference (I_{AD}, DA-meter) does not correlate with flesh firmness (FF, standard industry index of maturity), but describes better fruit physiological maturity status and can be used a non-destructive measure of maturation in studies requiring maturity control for fair comparisons among treatments.
- A concept device (patent pending) for simultaneous maturity/quality assessment can allow the characterization of the true influence of preharvest factors (training, pruning, crop load, canopy position, rootstock etc.) on fruit internal quality and metabolism by comparing fruit at equal maturity.
- Among preharvest factors crop load severely affects peach internal fruit quality and maturity at harvest.
- Peach primary metabolism shifts according to development process and is not changing in response to preharvest factors even in extreme carbon supply/competition conditions and this is mainly obvious in comparisons among treatments at equal maturity.
- Early-stage fruit metabolite responses to distinct carbon supply (distinct fruit crop loads) prime peach fruit quality development.
- Early peach fruit/flower thinning secures sufficient carbon supply and allows for 'luxury' metabolic investments on secondary metabolites (e.g., catechin) that are priming fruit quality potential.
- Excessive tree vigor (cultivar/rootstock) and fruit position in the canopy affects light availability, fruit quality and maturity.
- Significant differences in internal fruit quality after controlling for maturity were found across canopy positions only in high vigor conditions where light availability was non-uniform.
- Mesocarp is less affected by the light environment, due to protection from exocarp and is heavily regulated by development (i.e., maturation).

- Exocarp metabolite profiles were more distinct in high vigor conditions, due to less uniform light conditions.
- Use of summer pruning and/or rootstocks to facilitate uniform canopies for optimized light availability and fruit quality as well as uniform maturation.
- Sorbitol, sucrose and catechin are indicative metabolites of superior fruit quality in peach.
- Amino acids (Asp, Asn, Gly & Thr), citric acid and monosaccharides (sorbose & fructose) are indicative of inferior quality in peach.

María Fabiana Drincovich, University of Rosario

The metabolic diversity of peach fruit and its usage as phytochemicals resources with roles in human nutrition and health

- The fruit is one of the most metabolite-rich organs of plants and contains a wide range of chemical complements involved in taste and flavor; with nutraceutical properties; and with defense properties against biotic and abiotic stress.
- The overall fruit quality is closely related to its metabolic composition. The metabolomic content of peach fruit determines many of the important features related to its QUALITY.
- The chemical composition of peach fruit is highly diverse: the different peach varieties display differential metabolomic content, which is further highly modulated by post and preharvest management and development. The different parts of the peach fruit display also differential metabolic composition.
- To improve peach fruit QUALITY we need a deep knowledge of the pathways and the regulatory systems that control the level of metabolites involved in taste, flavour and with healthy & nutraceutical properties.
- To get chance to identify regulatory networks controlling metabolite levels related to quality, we need to integrate metabolomic information with transcriptomic & proteomic data across the different sources of metabolic diversity and reconfiguration of peach fruits, in order to get chance to match the level of key metabolites to gene clusters.
- As metabolite & transcript databases become larger, we will have more chances to identify markers for peach quality improvement. Programs for quality improvement are necessary to increase peach consumption for healthy diets around the world.
- We should advance in the integration of knowledge from different groups involved in peach research, combining datasets collected by different groups and establishing standards for data collection and formatting. These data should be loaded in an open-shared platform.

Juan Carlos Melgar, Clemson University

Leading the peach industry to sustainable orchard fertilization

- There is a need for reconciling the high yield and high-quality peach production with reducing the impact of overfertilization on our natural resources.
- Artificial intelligence and precision agriculture technologies are currently available for assessing tree nutritional status and implementing optimized fertilization.

- Early season peach trees are capable or accumulating and mobilizing more nutrients back to reserves than late season cultivars. Thus, early season cultivars can take advantage of postharvest applications whereas fertilization for late season cultivars are more efficient at taking up nutrients applied to the soil at or after bloom.
- Nutrients translocation to permanent structures during leaf senescence increase with tree age.
- Environmental conditions leading to delayed senescence (warm temperatures in fall) and reduced soil moisture increase nutrient resorption and accumulation in storage organs.
- Thus, fertilization rates should consider not only tree nutritional status the previous year and yield, but also variables such as tree age, ripening season, environmental conditions and climatic patterns, pruning intensity, and soil health and management at each orchard.

Bo Zhang, Zhejiang University

Regulation of peach fruit flavor-related volatiles

- There is a conserved molecular mechanism in which transcription factor *NAC* activates ripening-related *AAT* expression, which in turn catalyzes volatile ester formation in multiple fruit species
- Transcription factor *PpbHLH1* regulates linalool synthesis during peach fruit ripening and in response to UV-B irradiation
- Epigenetic modifications such as DNA methylation and H3K27me3 are associated with volatile production in peach fruit

Ignasi Iglesias, Agromillora

Towards enhanced peach fruit quality and reduction of production cost: a proposal of efficient training systems for future orchards

- Agronomical models in peach and particular training trees is a traditional practice that can be improved in order to adapt it to changing requirements of fruit industry and consumers, in particular, the increase of production costs and the demand for high quality product. It should be produced in a sustainable manner for both, the environment and the growers in terms of profit. Is possible reduce the cost of production increasing fruit quality?
- Reducing the cost of production is a need in all the producing countries because it is increasing cost and scarcity, but also the increasing difficulty to get the desired prices for growers. In peach the inputs represent around 70% of total cost of production and, among then the labour is the most important (45-50%). The logical way to reduce the cost it's developing training systems with a better accessibility to the canopy of labour and machines increasing consequently their efficiency. Moving from vigorous rootstocks in low density "3D" orchards to medium vigor ones and more efficient in terms of yield, will improve also light distribution in the canopy, increasing fruit quality, reducing the pesticides use and increasing its efficiency in high density "2D" orchards.
- The main aspects to be considered in this approach towards efficient and sustainable agronomical models for the peach are:
  - Planar canopies are the key (not only) of efficiency in future orchards.

- Planar canopies + vigour controlling rootstocks plus intensification = early and increased yield and fruit quality, reducing cost of production.
- Intensification is essential to reduce the cost of training during the first years in 2D or planar canopies.
- Increasing restrictions or not availability of crop regulators makes necessary the use of size controlling rootstocks as in other fruit species.
- Early yields and efficiency in the use of inputs (labour, pesticides, fertilizers, water) is a contribution to environmental sustainability and profitable production value for growers.
- Future peach production need to be developed under the concept of "sustainable intensification", then genetics (variety/rootstock) plus technology of production will be the key for success.

Benedicte Quilot-Turion, INRA

Recent advances on peach-brown rot interactions: searching solutions to fight in a sustainable manner

- The crucial importance to choose the right protocols to assess brown rot (*Monilinia spp*.) susceptibility of fruit
- the most promising resistance factors to brown rot may rely on fruit skin
- there is a large diversity of cuticular compounds (phenolic esters of triterpenoids) and variability in contents among collections which is promising for breeding
- the correlations between phenolic and triterpenoid compounds and infection traits observed along fruit development and within peach populations at maturity suggest some compounds may play a role in brown rot infection
- the *in vitro* tests performed showed that some compounds may have opposite effects on the different components of growth and pathogenicity of the fungus; their use would not be straightforward
- the infection by *M. laxa* is limited by compounds synthesized by the fruit following injury; 11 volatile compounds were associated with wounded fruits and RNAseq analyses highlighted pathways activated after injury
- breeding programs for brown-rot resistance will have to combine complementary factors to achieve sufficient tolerance

Jordi Giné-Bordonaba, IRTA

Ethylene and ROS-scavengers in peach: are these key players determining the fruit resistance to biotic stress?

- Studying changes at the physiological and biochemical level in parallel to brown rot susceptibility along peach fruit growth is a suitable approach to identify compounds or key metabolic pathways involved in brown rot tolerance.
- Changes in the concentration of specific primary (citrate) and secondary metabolites (or up-regulation of specific ROS-scavenging related genes) together with the fruit ethylene

biosynthetic or signalling pathway seem to determine, to different extent, the peach fruit tolerance to *Monilinia* spp. infection at various fruit phenological stages.

- *Monilinia* infection not only among different strains but also at each fruit developmental stage is achieved by different mechanisms with ethylene being a key factor determining the fruit susceptibility to brown rot.
- In flowers or early fruit developmental stages, a way for *Monilinia* to infect the fruit seems to inhibit the ethylene biosynthetic pathway thereby aiming to suppress the ethylene-induced fruit defences.
- In contrast, in fruit of an advanced maturity stage, *Monilinia* seem to promote ethylene biosynthesis via activation of ACS and leading to softening hence favoring the fruit colonization.
- Changes at the ethylene biosynthetic or signalling pathway during the Monilinia-stone fruit interaction seem to be coordinated by ROS. Indeed, some of the identified ROS-related scavenging compounds were capable to alter the colony morphology *in vitro and so* showing promising results for the development of new products capable to tackle Brown rot in stone fruit in a more sustainable manner.

Carla Casals, IRTA

Brown rot on stone fruits: from epidemiology studies to the development of effective control strategies

- The epidemiology of *Monilinia* spp. in the field, in Catalonia, has been deeply studied. The main sources of primary inoculum were the overwintered mummies while rotten fruit in the field from 15 days before harvest are the main sources of secondary inoculum.
- One of the main outcomings from the field epidemiology data was the development of a prediction model for *Monilinia* spp. risk infection. This model was validated under semi-commercial conditions and the implementation of the model allowed to significantly reduce the number of fungicide treatments in the field.
- Regarding the epidemiology at postharvest, a wide range of fungi was found as a source of inoculum in packinghouses. However, the presence of *Monilinia* spp. was practically zero. Moreover, under postharvest storage conditions the risk of fruit contamination and infection by *Monilinia* spp., or the disease development were extremely low.
- A wide range of environmental-friendly and effective alternative strategies to synthetic fungicides to control *Monilinia* spp. were developed, mainly focusing on heat treatments, including hot water, curing, radiofrequency and microwaves.
- The combination of different strategies is necessary to improve the control of postharvest diseases. The combination of hot water treatment plus the use of a biological control agent (*Bacillus amyloliquefaciens* CPA-8) improved the level of efficacy in comparison with their individual application.

Guido Schnabel, Clemson University

Biology, epidemiology and management of diseases of peach driving the spray program in the southeastern United States

- Brown rot, bacterial spot, and peach scab drive the spray program for peach disease management in the southeastern United States
- Emphasis should not only be put on fungicide efficacy but also on resistance management
- For the last 15 years, the strategic use of multisite and singe-site fungicides has provided excellent brown rot management with no noticeable resistance selection in the causal agent *Monilinia fructicola* despite high disease pressure
- Bacterial spot remains challenging to control due to lack of effective spray material and consumer demand for susceptible varieties
- Tolerance to copper in *Xanthomonas arboricola*, the causal agent of bacterial spot, may pose additional challenges for growers in the future

Laura Rossini, University of Milan

Design and realization of the multi-site *PeachRefPop* collection: an international research and breeding tool for fruit trees

- Germplasm collections represent the cultural heritage of generations of farmers/breeders and rich reservoirs of genetic diversity that we can mine for traits and genes of interest for future breeding
- Long-term maintenance of collections remains particularly challenging due to intrinsic vulnerabilities and costs for in vivo maintenance through vegetative propagation. Constraints in material exchange also pose major risks of loss of unique materials, other than of transmission of harmful pathogens, particularly critical for vegetatively propagated trees. Finally, the lack of standardized management practices and phenotyping protocols hampers comparison/integration of information collected by different institutions.
- Multi-site collections have several merits to address some of the above challenges. In the short-term they provide a safety net for the preservation of rare materials and opportunities for testing performance of different varieties under a range of environmental and management conditions. In the longer term, multi-site collections allow to overcome usual limitations of most breeding programs where the breeder works in a certain geographical area and selection is focused on adaptation to those specific conditions.
- The PeachRefPop is the first attempt to coordinate transnational scientific research in peach to work interactions between genotypes, environment and management practices. This unique resource captures in just 400 accessions the genetic diversity of peach germplasms represented in European collections and was planted in 5 different locations representative of major growing areas in the Mediterranean basin (In Italy, Spain and Greece).
- In order to improve resilience and sustainability of fruit production, an important priority for future research is the development or implementation of reliable approaches for phenotyping a large number of trees for traits related to biotic and abiotic stresses.

Nikos Papadopoulos, University of Thessaly

Invasive pest threatens the sustainable peach production

- Facilitated by global warming and changes in land use and copping practices (e.g. planting of early maturing cultivars), and intensified by global trading of fresh fruit and propagation plant materials and human mobility, biological invasions of plant pest constitute one of the main concerns of plant protection for the peach production worldwide.
- Out of the long list of major invasive pests for the peach production that includes beetles (e.g *Aromia bungii*), bugs (e.g. *Halyomorpha halys*) and moths (e.g. *Thaumatotibia leucotreta*) true fruit flies (Diptera: Tephritidae) stand out.
- Because infested fruits are hard to be intercepted (eggs and larvae are burrowed into fruit flesh), fruit flies arrive to novel areas without being noticed. During the early steps of the invasion process established populations may also escape detection. In addition, eradication and containment efforts may become extremely expensive and often not effective.
- Management of invasive fruit flies in peach producing areas should prioritize preventive measure and should address all invasion steps in a sound and cohesive approach.
- The EU supported Horizon 2020 project FF-IPM (In-silico boosted, pest prevention and off-season focused IPM against new and emerging fruit flies, https://fruitflies-ipm.eu) is tackling fruit fly invasion in pome and stone fruit production areas of Europe (focusing on peaches) by generating new biological knowledge and developing novel interception and detection tools and strategies.

Thomas M. Gradziel, University of California at Davis

Breeding peaches for processing: challenges and opportunities

- The relatively lower value of peaches for processing necessitates greater production efficiencies including higher productivity over a longer productive life for the orchard, and lower costs, particularly for labor.
- The bulk handling, including mechanical harvest, transport and processing make cultivar development and testing more similar to nut crops such as almond.
- Cultivated almond and its wild relatives also offer novel and useful genetic solutions to current and emerging processing peach needs.
- Useful traits may not be readily apparent until introgressed into a peach background.
- An expanded breeding germplasm may provides the best strategy to solve unanticipated calamities such as the accidental introduction of destructive diseases and pests or climate changes beyond traditionally acceptable environmental thresholds.

Guglielmo Costa, University of Bologna

Peach chemical fruit thinning: where we are, where we can go

- The European peach industry to became again competitive must look for different productive models that allow higher production and a reduction of production cost
- In peach, fruit thinning guarantee high quality fruit, but actually the fruit thinning is mainly performed by "hand", requires a high number of skilled labor in a short period of time and is extremely costly.
- In recent times the mechanical thinning was an alternative to the hand thinning although it has proven to require modification of the training system to be adapted to the "mechanical thinning machine" and simultaneously an adaptation of the machines to the training system to obtain an appropriate result.
- The chemical thinning option should be the best and most cost-effective solution.
- Until now the lack of reliable chemicals thinners did not allow to transfer into practice the peach fruit chemical thinning.
- However, the possibility to control the fruit load in different moments of the annual life cycle of the peach (flower differentiation, dormancy, bloom and fruitlet stage) might offer the possibility to perform an efficient "strategy" for reach the desired result through a manipulation of fruit load.
- This will be made possible considering that new molecules have been released to affect flower differentiation and to control the amount of flowers the following year or to act as chemical fruitlet thinners (such as the formulate Accede, that will be release this year).
- However, it has to be kept in mind that fruit abscission is a complicate physiological process influenced by a series of internal and external factors that complicate the scenario and recently the climate changes are further increasing this complexity.
- Different working groups ("EUFRIN WG on Fruit thinning", "North-East Plant Growth Regulator" and "ISHS Plant Growth Regulators WG" are committed for improving thinning performance and thus require more intensive and dynamic efforts that need to be coordinated within an international R&D platform to exchange information on the new molecules and the new cultivars in order to set up timely strategies in the different cultivation areas. To improve the efficiency of these "Working Groups" and to speed up solutions, this activity should be supported by constant structural fund policy from both institutional agency and the whole productive chain.