Summary of the 15th
International Symposium on Plant Virus Epidemiology
Madrid, Spain, 5-8 June, 2022

The 15th International Symposium on Plant Virus Epidemiology was held in Madrid, Spain at the CSIC campus, and was hosted by Dr. Alberto Fereres, past chair of International Committee for Plant Virus Epidemiology. The symposium was attended by 152 participants from 24 countries on five continents, and included 7 keynote speeches, 61 oral presentations, and 77 poster presentations. The lectures and presentations provided valuable information regarding recent advances in plant virus epidemiology research from throughout the world. The International Committee on Plant Virus Epidemiology and meeting organizers are grateful to CSIC for hosting the symposium and to the many sponsors.

Sections 1 & 2: General Epidemiology and Diagnostics, Surveillance, and Modeling

Michael J. Jeger. **Emerging themes and approaches in plant virus epidemiology.** Highlighted challenges faced in the study of plant virus epidemiology, including the complexity of interactions, scaling of experimental approaches, the application of models, and factors that should be considered in experimental design.

Chrysoula Orfanidou. **Cucurbit cytorhabdovirus 1: a novel whitefly transmitted cytorhabdovirus infecting zucchini crops in Greece.** Described a new cytorhabdovirus from zucchini including distribution in Greece, particle morphology via transmission electron microscopy, genome organization and transmission by whitefly (*Bemisia tabaci* MED).

Pedro Gómez. **Epidemiology and genetic diversity of cucurbit aphid-borne yellows virus and watermelon mosaic virus in cucurbit crops.** Monitored the incidence of six aphid-borne viruses in cucurbit crops over a ten-year period in Spain. A key observation was the frequent co-infection of the polerovirus, cucurbit aphid-borne yellows virus, with the potyvirus, watermelon mosaic virus, and it was suspected this may be biologically relevant. High-throughput sequencing revealed a complex population structure for CABYV and indicated the possible influence of agricultural practices on virus population diversity.

Nataša Mehle. **Tomato brown rugose fruit virus in aqueous environments – survival and significance of water-mediated transmission.** Wastewater was confirmed as the source of greenhouse infections of Tomato brown rugose fruit virus when grown through both soil and hydroponics.

João Lopes. **Prevalence and vector transmission of new maize viruses in São Paulo State, Brazil.** Maize yellow mosaic virus (*Polerovirus*; Solemoviridae), transmitted by the corn leaf aphid, *Rhopalosiphum maidis* and maize striate mosaic virus (*Mastrevirus*, Geminiviridae), transmitted by the corn leafhopper, *Dalbulus maidis* were found infecting maize in São Paulo State at rates of 59 and 79 percent, respectively.

Jan Kreuze. **Developing elements for global plant virus management: diagnostics, surveillance, and modelling.** Using potato and sweet potato as examples, described how high throughput sequencing based surveillance approaches can provide information to better understand the impact of plant viruses on crops, support development of more targeted field and lab based diagnostic tools for use in virus management, and how modeling approaches can be used to support surveillance and preparedness of emerging viruses in the face of climate change.

Aimee R. Fowkes. **Applying high throughput sequencing in a generic surveillance workflow: a case study using UK peas.** Described the advantages and limitations of using high-throughput sequencing (HTS) in virus surveys, and demonstrated the value of HTS through the identification of unexpected viruses in the United Kingdom.

Marleen Botermans. **Tomato brown rugose fruit virus in the Netherlands: The rise of a novel clade.** The use of high-throughput sequencing revealed demonstrated that multiple introductions of Tomato brown rugose fruit virus had occurred in The Netherlands. Eradication was effective in many cases, but some recurrence of the same genotype indicated this was not always successful. In 2021 ad new infestation occurred with a new genotype.

Stephan Winter. **Evaluating the threat of introducing non-European virus isolates of tomato leaf curl New Delhi virus into Europe.** Isolates of tomato leaf curl New Delhi virus (ToLCNDV) from Europe and India were compared for efficiency of spread by Bemisia tabaci. ToLCNDV and Tomato yellow leaf curl virus (TYLCV) were found to have stable mixed infections. Tomatoes with the Ty-1 gene for TYLCV resistance are not resistant to ToLCNDV although infection of Ty-1 tomatoes is delayed compared with fully susceptible tomatoes.

Alex Giménez-Romero. **Global risk predictions for Pierce's disease of grapevines.** A climate-driven ecological model was developed and found to predict Pierce's Disease in the United States with 90% accuracy. The model was used in a global simulation that differences in performance among wine grape producing regions with regard to Pierce's Disease risk levels. Results highlighted the importance of considering climae variability and an invasive criterion to improve performance of risk maps.

Section 3: Virus Ecology and Evolution

Fernando García-Arenal. **Virus host ranges and transmission dynamics in heterogeneous environments.** Deep sequencing was used to compare virus infection dynamics among four habitat types. Results indicated that environmental heterogeneity can lead to non-random plant-virus associations, and facilitates identification of reservoir plant communities and prevalence of host infection, and associations were largely independent of virus adaptation to a host plant.

Alberto Cobos. **Plant virus mixed infections modulate vertical transmission.** Evaluated the impact of mixed virus infections on seed-transmission of *Turnip mosaic virus* (TuMV) and *Cucumber mosaic virus* (CMV) seed transmission in six *Arabidopsis thaliana* genotypes in which both viruses differ in their efficiency of vertical transmission. Results indicated synergistic effects for TuMV and antagonistic effects for CMV seed transmission rate as compared with single infection. Changes in the efficiency of seed transmission were related to modifications in virus multiplication but not in virulence.

Mark P. S. Rivarez. **Global diversity of solanum nigrum ilarvirus 1 among diverse plant hosts and associated metagenomes and its biological characterization.** Evaluated the diversity of the recently described Solanum nigrum ilarvirus 1 (SnIV1) from locations around the world from both plants and non-plant sources, including endophytic fungi, demonstrating its global occurrence and low sequence divergence.

Denis Kutnjak. **A cross-environment viromics study of tomatoes, weeds and water reveals many new plant virus species and links between sample types.** The viromes of tomato, associated weed species, and irrigation and surface water samples were evaluated over two years from several locations in Slovenia, and identified 37 known and 56 new viruses. This comprehensive virome study represents a baseline for understanding the epidemiological links between plants and environmental waters and will help us detecting and better understanding possible future emergences of viral diseases in tomato and other crops.

Judith K. Brown. **Phylogenetic and population analyses of cotton leafroll dwarf virus reveals extensive genomic variability and global sub-populations.** Genomic variability of cotton leafroll dwarf virus among isolates from the United States and South America were compared. The results provisionally suggest multiple independent

introductions over time, and or of selective spread of certain isolates over others that originated from one or a few infection foci in the United States.

Sections 4 & 5: Virus-Vector Interactions and Other Vector-Borne Diseases.

Veronique Brault. **When plants and aphids are under the control of viruses.** Discussed how viruses may affect plant traits in ways that facilitate their transmission by vectors, focusing on polerovirus/aphid/plant pathosystems. involving transcriptomic, metabolomic, genetic and behavioral approaches indicated that infected plants must be attractive to aphids and aphids need to settle on the plant long enough to reach the phloem and ingest sap for effective transmission.

Sharella Schop. **Yellowing viruses promoting their own spread by reducing Mature Plant Resistance to aphids in sugar beet.** Demonstrated negative effects of mature plant resistance to aphids and plant yellowing on aphid behavior, survival and fecundity, including the impact of polyphenol oxidases from the chloroplast that contribute to stomach deposits within aphids and lead to aphid mortality.

Patricia Sanches. **Aphid symbionts influence the transmission of a plant virus.** The effects of five different aphid endosymbionts on the transmission of pea enation mosaic virus (PEMV) to fava beans by pea aphids (*Acyrthosiphon pisum*) were investigated, as well as how aphid behavioral preferences and performance were influenced. Results demonstrated that endosymbionts can influence the aphid behavior and performance in ways that effect virus transmission, and suggest this has implications for the evolution of viral pathosystems, as well as potentially important implications for epidemiology.

Alana L. Jacobson. **How do you make a mixed infection: effect of acquisition sequence on propagation of TYLCV and ToMoV by *Bemisia tabaci.*** Investigated how the acquisition of each of two begomoviruses, by Bemisia tabaci MEAM1 in tomato influenced the probability of virus acquisition, virus titers accumulated in vectors after acquisition, probability of virus transmission, titers of transmitted virus, probability of infection in inoculated host plants, and accumulation of viruses in infected host plants. Results revealed a complex interplay among virus-virus-vector-plant interactions as viruses are acquired, circulate through their vectors, and are inoculated into host plant tissue.

Cecilia Tamborindeguy. **How does '*Candidatus* Liberibacter solanacearum' manipulate plant and insect immunity?** Studies were conducted to identify over 100 putative effector proteins and use this to study interactions between '*Candidatus* Liberibacter solanacearum' (Lso), host plants, and the potato psyllid vector. This approach is yielding new knowledge about the mechanisms used by Lso to manipulate plant and insect immunity.

Domenico Bosco. **Vector biology, abundance, dispersal and temporal transmission dynamics shape *Xylella fastidiosa* epidemiology in Apulia.** Studies evaluated the acquisition of *X. fastidiosa* by its spittlebug vector, vector population dynamics and dispersal and the impact of factors such as insect abundance, survival, and seasonal host-plant shifting.

Daniele Cornara. **Elucidating the inoculation mechanism of *Xylella fastidiosa.*** EPG-assisted transmission trials were carried out with both the blue-green sharpshooter and the meadow spittlebug, leading to establishment of a theoretical framework on how the fastidious bacterium is inoculated into its host plant.

Section 6: Disease Management

Hanu R. Pappu. **Disease management in the omics era: Status and future prospects.** Approaches utilizing genomics and other 'omics approaches for improving management of viral diseases was presented, including topical application of dsRNA for induction of RNA interference, the application of CRISPR-based genome editing for resistance to viruses as well as technologies such as high throughput sequencing and associated bioinformatics resources.

Cécile Desbiez. **Specificity of resistance and tolerance to cucumber vein yellowing virus in melon accessions and evidence for resistance-breaking associated with a single mutation in VPg.** Complete resistance to cucumber vein yellowing virus (CVYV) was identified in a melon accession, whereas another accession exhibited tolerance. The resistance wais controlled by a dominant allele, and the tolerance by a recessive allele. However, the resistance was found to be strain specific. Further studies suggested a fitness cost for a resistance-breaking strain of CVYV.

John A. Walsh. **Integrated control of a polerovirus.** A three-year study to evaluate integrated control of turnip yellows virus (TuYV) in brassicas was conducted, and included reduced and informed insecticide treatments, partial plant resistance and planting date. Potential new sources of resistance to TuYV were also evaluated.

Enrique Moriones. **Use of glandular trichomes to control whitefly-transmitted viruses in tomato: modulation by natural enemies.** A trichome-based resistance based on antixenosis and antibiosis was introgressed into cultivated tomato from the wild tomato *S. pimpinellifolium* was shown to be effective to control *Bemisia tabaci* and *Trialeurodes vaporariorum* whiteflies. The resistance against whiteflies was effective to limit spread of the persistently transmitted begomovirus, tomato yellow leaf curl virus (TYLCV) and the semi-persistently transmitted crinivirus tomato chlorosis virus (ToCV). Early induction of methyl jasmonate increased resistance against whiteflies.

Section 7: Climate Change

Tomás Canto**. Anthropogenic climate change and its impact on interactions between viruses and plants.** The impact of anthropogenic climate change on plants, viruses, and virus vectors, as well as humans and their crops was discussed. Studies are investigating the effects of individual abiotic parameters, or of complex ambient changes, on those biological systems.

Anders Kvarnheden. **Milder autumns may increase risk for infection of crops with turnip yellows virus.** Results of a survey of rapeseed in Sweden demonstrated an abundance of turnip yellows virus in rapeseed. TuYV, a virus normally associated with brassica species, was found coinfecting sugar beet along with beet mild yellowing virus and beet chlorosis virus.

Álvaro Gutiérrez-Sánchez. **Modelling the effects of climate change on plant virus vertical transmission and prevalence.** The effect of climate change conditions (elevated CO2 concentration, light intensity and temperature) on cucumber mosaic virus (CMV) and turnip mosaic virus (TuMV) seed transmission and seed survival was evaluated in *Arabidopsis thaliana*. Results showed that infection by both viruses favored long-term seed survival of CMV-infected seeds, but not of TuMV-infected seeds. Simulations indicated that climate change conditions impacted virus prevalence only when both seed transmission and survival are simultaneously enhanced.

Awards for student oral and poster presentations:

Best Oral Presentation Award: Ornela Chase

Best Poster Awards: Oumaima Moubset and Marcelle Johnson

Selection of the site for the 16th ISPVE:

Three sites presented excellent proposals to host the next ISPVE meeting during the business meeting on 8 June. Following the presentations, Sao Paulo Brazil was selected as the site for the next ISPVE, which will be held in 2025. We look forward to seeing you all in Brazil!