REPORT ON THE 7TH INTERNATIONAL PLANT VIRUS EPIDEMIOLOGY SYMPOSIUM, ALMERIA, SPAIN. APRIL 11-16, 1999

The seventh International Symposium on Plant Virus Epidemiology was held in the Hotel Playadulce at Aguadulce, Almeria on the south east mediterranean coast of Spain from April 11-16, 1999. The Almeria district was chosen as the location because it is the centre of Spain's lucrative intensive plastic plant house based vegetable industry, and this 'out-of-season' industry is threatened by virus diseases particularly those transmitted by whiteflies. The chief conference organiser was Alberto Fereres of the Consejo Superior de Investigaciones Scientificas in Madrid. The symposium was attended by 280 participants from 28 different countries, and covered a wide range of topics related to its epidemiology theme. Participants included a diverse array of researchers and other interested parties.

On the evening of our arrival (Sunday) a welcome reception was held at Hotel Playadulce. On Monday, in the opening keynote presentation Mike Thresh (UK) summarised the past 100 years of plant virus epidemiology. Mike traced the build up in the knowledge base on the subject, from the discovery of viruses to the current position at the end of the present century. Among other things, he stressed the diverse modes of persistence and spread that viruses exhibit, autonomous versus vector transmission, differences due to climatic and geographical zone, factors influencing virus inoculum dispersal, local versus distant spread, roles of wild plants as virus reservoirs, and contrasting scenarios where rapid spread or slow virus spread are typical. He also contrasted currently neglected areas of activity, e.g. beetle and mealybug transmitted viruses, with the intense activity now associated with whitefly and thrips borne viruses. Mike emphasised how the ecological tradition in plant virology has recently recovered despite having reached a low ebb not too long ago. He welcomed the increasing application of new techniques and innovations to help solve epidemiological problems and emphasised the continuing role of epidemiology in addressing the viral challenges we face as we move towards the next millennium. Mike also traced the history of the Plant Virus Epidemiology Committee since its foundation in 1978 through the series of international meetings it has organised at roughly 3 year intervals in different continents culminating in the seventh meeting in Almeria. The main aim of the group is to bring together researchers from all over the world working on epidemiology and control of plant virus diseases (and other interested parties) to discuss current research interests. It has been very successful in doing this. A well deserved tribute to Mike was given in the conference dinner at the close of the symposium for the way he has so effectively 'fathered' the epidemiology group as its founding chairman over 21 years through to the present.

The first oral session dealt with 'plant virus transmission mechanisms' and began with Alberto Fereres who discussed electrical monitoring of insect probing and feeding behaviour during non-persistent virus transmission by aphids. A negative correlation exists between the time elapsed from the last intracellular puncture to the end of the acquisition probe and the ability to transmit potato virus Y. Thus virus inoculability starts decreasing immediately after acquisition begins, possibly as a result of salivation. Differences in vector efficiency between aphid species seem related to the duration of probing. Tom Pirone (USA), Benny Raccah (Israel) and Stephane Blanc (France) described virion-helper component-stylet interactions in non-persistent aphid transmission and methods of purifying helper component. Differential retention of helper component may be another

cause of differences in vector efficiency between aphid species. Henryk Czosnek (Israel) described increased transmission of tomato yellow leaf curl virus through sexual contact between whiteflies, with more transmission occurring from male to female than female to male. Multiplication of the virus within individual whiteflies decreased their fitness and life expectancy. There were two presentations from the John Innes Institute (UK) on molecular aspects of the mechanisms involved in transmission of geminiviruses. Finally, Dick Peters (the Netherlands) reported infection of transmitting and non transmitting western flower and onion thrips by tomato spotted wilt virus. When first instar larvae acquire the virus midgut cells become infected and then the virus moves to the salivary glands. In non-transmitting thrips no virus enters the salivary glands. In transmitters the amount of virus replicating in the mid gut determines the amount of transmission.

The second oral session was entitled 'current approaches to plant virus epidemiology'. Olga Esteban (Spain) described a 'squash capture PCR' for direct detection of non-persistently transmitted viruses in single aphids. By selection of appropriate primers, nested PCR can be used to differentiate transmissible and non transmissible strains of the same virus within an aphid. Chuck Nibblet (USA) reported differentiation of citrus tristeza virus strains in citrus samples based on minor sequence variations in their capsid proteins detected by RT-PCR. Peter Markham (UK) used PCR and dot-blot hybridisation to study the geographical distribution of cotton leaf curl disease in Pakistan and the requirement for an additional nanovirus-like component for expression of typical leaf curl symptoms in cotton plants. Ossmat Azzam (IRRI) used RT-PCR to show that a single field site can contain isolates of rice tungro spherical virus with different evolutionary histories. Fernando Garcia-Arenal (Spain) and Donato Gallitelli (Italy) used RNA sequence information to study biodiversity and population changes in isolates of cucumber mosaic virus. Virus populations changed over time. Loss of the satellite RNA responsible for severe necrotic symptoms in tomato occurred due to the impact of necrosis in diminishing the rate of virus spread from plant to plant. Daniele Bourdin (France) and Trefor Woodford (UK) discussed the taxonomic status of the *Myzus persicae* vector group including *M. persicae*, *M. antirrhinii* and *M. nicotianae,* and the relative efficiencies of clones of each as potato leaf roll virus vectors. A novel rDNA fingerprinting technique using micro-satellites was used to distinguish aphid clones. Some clones of all three were efficient vectors. Studies on relative transmission efficiencies should ideally involve several distinct clones per species.

On Tuesday, the third and longest oral session concerned 'whitefly-associated problems of vegetable crops'. Emilio Rodriguez-Cerezo (Spain) traced the history of whitefly transmitted virus problems afflicting the plastic house cucurbit industry in Almeria. In the early days, beet pseudo yellows virus transmitted by the glasshouse whitefly was the main concern but in 1990 *Bemisia tabaci* arrived and displaced the glasshouse whitefly bringing with it serious problems with cucurbit yellow stunting disorder. Both viruses cause identical yellowing symptoms. Two *B. tabaci* biotypes (B and Q) are present in Spain and both transmit the virus readily. Very frequent application of insecticides is usually needed to keep the yellowing symptoms the virus causes at bay. Avoidance of overlapping host crops and good weed removal are key control measures to decrease the virus source. Rodrigo Valverde (USA) discussed three viruses commonly found together in the field in sweet potatoes in Louisiana, sweet potato feathery mottle, sweet potato chlorotic stunt and sweet potato leafcurl. Both of the later are readily transmitted by *B. tabaci* biotype B. Mixed infections with more than one virus cause yield

decreases but single infections do not. Gail Wisler (USA) discussed the spread of three tomato-infecting viruses transmitted by whiteflies into new areas, tomato infectious chlorosis, tomato chlorosis and an unnamed virus. Confusion of their symptoms with those of nutritional problems leads to underestimation of their occurrence. Movement of infected breeding material, international trade and the increase in protected cropping are all contributing to expansion in the natural range of whitefly borne viruses in the USA. Enrique Moriones (Spain) reported two different types of tomato yellow leaf curl in Spain, the Sr and Is types. The virus arrived in Spain in 1992 and was represented by the Sr biotype. Starting in 1996, the more severe Is type, which is more readily transmitted by *B. tabaci* type B, displaced the Sr type. Philip Stansly (USA) described management practices for geminivirus epidemics in field grown tomatoes in Florida and neighbouring states. The B biotype and continuous cropping are the main driving forces behind epidemics which predominantly involve tomato yellow leaf curl and tomato mottle viruses. A crop free period to break the cycle of virus and vector, and widespread use of soil applied imidacloprid insecticide against whiteflies proved the most effective control measures, with virus resistant cultivars also included as an additional measure in the Dominican republic. John Colvin (UK) described the spread and management of tomato leaf curl virus in tomato in southern India where insecticides are sprayed as often as every second day to control its whitefly vectors. The vector does not reproduce on tomato and potential management strategies include breeding for virus resistance, use of nylon nets to exclude whiteflies from nursery beds and removal of weed reservoirs. Henryk Czosnek (Israel) discussed breeding tomato for resistance to tomato yellow leaf curl using resistance from *Lycopersicum hirsutum*. This resistance is broad spectrum as it is also effective against certain other geminiviruses. Moshe Lapidot (Israel) reported breeding for tolerance to tomato yellow leaf curl virus from tomato breeding lines TY172 and TY197.

After the coffee break, James Legg (IITA), Peter Markham and John Colvin (UK) described different facets of the current pandemic of cassava mosaic viruses in East Africa. The severe form of the disease found mainly in Uganda is caused by a hybrid between east African cassava mosaic and African cassava mosaic. The whitefly vector *B. tabaci* favours cassava as a host and multiplies better on infected than healthy cassava, especially in susceptible and sensitive cultivars, and increase in whitefly numbers is one of the main factors driving the pandemic. Intensive rouging of symptom-affected cassava plants is advocated to prevent whitefly build up on infected plants. Marcia Roye (Jamaica) described genetic diversity among geminiviruses infecting crops and weeds in Jamaica. Fransisco Morales (CIAT) reviewed the current position with whitefly transmitted viruses in Latin America. At least 40 such viruses are known and the advent of the B biotype of *B. tabaci* in Latin America has greatly exacerbated the situation. The position is so bad in some areas that daily spraying of insecticides is practiced against whitefly vectors. Risk areas can be predicted from latitude, altitude and rainfall with low altitude and warm, dry conditions favouring epidemics. GIS is helpful in identifying high risk areas. Thomas Henneberry (USA) described management strategies for dealing with *Bemisia.* Avoidance of whitefly susceptible cultivars is important along with good irrigation and fertilisation, as stressed plants favour their build up and promoting healthy growth to avoid stress decreases their numbers. Because they develop resistance to normal insecticides but not to the chloronicotinyl group, applying immidacloprid is very useful as a control measure. Early harvest and destruction of crop residues were other key measures as they prevent whitefly flights to new crops.

After the poster session on Tuesday, there was an introduction to the technical field trip and details of how the local plastic house vegetable industry at Almeria operates was provided along with information on the agronomic practices employed, virological and insect vector issues and a discussion of integrated disease management strategies. The Almeria region produces 35% of Spain's horticultural export earnings with 50% of its production exported. It has 27,000 hectares of plastic houses. This was followed by a meeting on the activities of the Plant Virus Epidemiology Committee of the International Society of plant Pathology. This and later discussions resulted in a new committee being chosen with representatives from each continent.

On Wednesday, the symposium technical field trip involved visits to plastic houses where tomatoes, capsicums and various cucurbitaceous crops were being grown. Among the virus diseases commonly found in the plastic houses are tomato yellow leaf curl and cucurbit yellow stunting disorder (whitefly-borne), tomato spotted wilt (thrips-borne), cucumber mosaic, watermelon mosaic and squash mosaic (aphid-borne), and melon necrotic spot (*Olpidium* vectored). Several of these were seen on the field trip generating considerable interest. Multiple spraying with insecticides was being used to keep whitefly under control in these crops and infected plants were being rouged out by hand. Integrated disease management strategies have been developed for each individual crop and are being gradually adopted. These greatly decrease the requirement for multiple insecticide sprays. There were also visits 1) to a vegetable packing plant where a diverse array of vegetable produce was seen and an auction of produce for export was underway, and 2) to a local horticultural research station where experiments involving vegetable crops in plastic houses and fruit trees of a range of types were demonstrated. Afterwards participants were treated to a traditional Andalucian lunch with multi-courses washed down with local wines. Following this they could opt for a visit to sites of historical interest going back more than 2,000 years in Almeria or for a trip to the nearby 'cabo de gata-nijar' nature reserve.

On Thursday, the fourth oral session concerned 'modelling plant virus epidemics'. Larry Madden (USA) set the ball rolling with a theoretical assessment of the impacts of different virus – vector transmission mechanisms on plant virus disease epidemics. The influences of rate of virus acquisition, rate of inoculation and length of latent period on virus disease dynamics and effects of control measures were explored using the linked-differential-equation model of host and vector populations. This was not an easy talk for the less mathematically minded! Johnson Holt (UK) described a new general model of plant virus disease spread that incorporates vector aggregation. With cassava mosaic virus spatial aggregation of vectors on cassava plants is an inevitable consequence of infection which promotes their reproduction. Vector aggregation decreases the effective contact rate and therefore the predicted abundance of infected hosts. His model takes this into account. Eventually overcrowding leads to emigration of vectors and dispersal of inoculum to other fields. In contrast, Mike Jeger (the Netherlands) discussed modelling virus source effects in tree nurseries rather than vector populations. Sarah Pethybridge (Australia) described using spatial analyses of spread patterns of three viruses in hop plantations to hypothesise on the means of spread. Plants infected with prunus necrotic ringspot virus were significantly aggregated down rows suggesting contact spread during mowing of the understory of young hop growth rather than sread than via pollen transmission. In contrast, the random distribution of the hop carlavirus suggested spread by alate aphid vectors. Merrit Nelson (USA) then gave a 'big picture' account of analysis of regional virus epidemics and vector incidence using GIS and geostatics to guide management decisions.

Recurring patterns of incidence and risk of virus disease develop on a regional scale because of the cumulative effect of local landscape elements. GIS and geostatics help in understanding and communicating these site-specific patterns. Pamela Anderson (CIAT) described the ongoing development of a mathematical model as an analytical tool to prioritise integrated virus disease management research on whitefly transmitted viruses in Latin America. This was another 'big picture' talk covering the situation, particularly in tomatoes, in Latin America and the Caribbean. Using sensitivity analysis, her model provides recommendations on the future epidemiological research needed and the most epidemiologically cost effective IPM tactics to employ. Forest Nutter (USA) reported on temporal and spatial analysis of data on spread of two phytoplasma diseases infecting papaya plantations in the Northern Territory of Australia. Debbie Thackray (Australia) described a simulation model forecasting aphid outbreaks and cucumber mosaic virus epidemics in lupin crops in the mediterranean type climate of Western Australia. Her model is based primarily upon rainfall during late summer and early autumn. This determines the availability of herbaceous host plants (mainly weeds) on which aphids build up before moving into crops sown in late autumn or early winter. The model successfully predicted the time of arrival and build up of aphids, spread of CMV, yield loss and virus transmission to harvested seed.

The fifth oral session was entitled 'epidemiology of arthropod-borne viruses'. Anna Maria Pereira (Portugal) reported on the occurrence of tospoviruses since Western Flower Thrips was first found in 1989 in Portugal. Tomato spotted wilt virus was first found in the following year and impatiens necrotic spot virus in 1994. The former is now widespread. Mariano Cambra (Spain) reported on citrus tristeza virus in Valencia. Models of spatial and temporal spread have been established in different areas. Dick Peters (the Netherlands) described different patterns of spread of rice yellow mottle virus in irrigated rice in Africa and concluded that most were consistent with contact rather than beetle transmission. Pablo Vercruysse (Belgium) reported on facets of the epidemiology of the carrot motley dwarf complex in parsley. Mats Lindblad (Sweden) descibed the epidemiology and control of the leafhopper-borne wheat dwarf virus in winter wheat. Leafhoppers brought in the virus to wheat crops in autumn and spraying with pyrethroids in spring halved the final numbers of infected plants. Abdullah Gera (Israel) described transmission of iris yellow spot tospovirus by *Thrips tabaci*. The virus and vector were widespread in onion growing areas. Angeles Achon (Spain) reported on the occurrence of maize dwarf mosaic and sugar cane mosaic viruses infecting maize. The former was by far the most abundant in Spain where *Sorghum halepense* was the key reservoir host.

The sixth and final oral session dealt with 'management and control strategies'. Fernando Ponz (Spain) described a way of classifying isolates of potato virus Y from pepper distinguishing four groups based on their reactions to pepper virus resistance alleles. Peter Thomas (USA) gave a paper on pathogen derived transgenic resistance. The resistance of 512 transformed lines of potato containing replicase constructs of potato leaf roll virus were tested against 66 isolates of the virus in the field. Some lines were identified with a 'high level of resistance' but still in these the eyes of occasional tubers were infected at harvest and by the end of storage it had spread widely within them. Spread of the virus to transgenic plants in the field was much less common than to non-transgenic potato plants. Michel Ravelonandro (France) reported on the performance of a transgenic plum line (C5) transformed with a coat protein construct of plum pox virus. It withstood field exposure under high inoculum pressure in Poland without becoming infected with the

virus. Amit Gal-On (Israel) described production of a full length infectious clone (AG1) of attenuated zuchini yellow mosaic virus that harbours a point mutation which abolishes aphid transmission. Field experiments in squash and watermelon demonstrated a protective effect of the clone when used for cross protection. Tefion Jones (UK) reported that, in assessments made over 5 years in the field, blackcurrant gene *Ce* conferred effective resistance to blackcurrant reversion disease and to its gall mite vector. A second gene *P* conferred only partial resistance to both. Yeheskel Antignus (Israel) provided an update on the use of UV-absorbing polythene in plastic houses to protect against infestation with *B. tabaci* type B and western flower thrips vectors. Dramatic reductions in insect vector numbers were recorded where UV light is removed by making plant houses of this plastic. This results in greatly decreased virus spread, eg with tomato yellow leaf curl in tomato. UV absorbing screens of 50 mesh size, but not larger, were also effective. There was little effect on the growth of vegetables but ornamentals sometimes developed unwanted flower pigments. The final two papers dealt with integrated disease management strategies for virus disease control, the first from a virologists perspective and the second from and entomologists standpoint. Roger Jones (Australia) described the development of effective integrated disease management strategies that have been widely adopted for control of cucumber mosaic and bean yellow mosaic viruses in lupins. Inoculum introduced with the lupin seed constitutes the primary source with the former while the latter invades the lupin crop from adjacent annual clover pastures. Differences in the measures adopted between the two viruses reflect this source difference. Management involves sowing lupin seed with minimal virus infection (cucumber mosaic), perimeter non-host crop barriers (bean yellow mosaic), promoting early canopy cover, retaining stubble groundcover, improved weed control and isolation (both viruses). Mike Irwin (USA) stressed the problems of using traditional IPM approaches for controlling insect feeding damage when dealing with insect vectors and attempts to minimise spread of the viruses they transmit. He also emphasised the additive effect in terms of the amount of control obtained when different types of control measures are combined and the importance of considering interactions.

The symposium was very intensive with many contributions packed into each oral session. There was also a very extensive set of poster presentations complementing the oral sessions, but covering a much broader range of issues, often with very up-to-date information. The book of abstracts can be referred to for details of these. The conference dinner on the last day was most enjoyable complete with delicious Spanish food, a fine array of local wines and “flamenco” dancing.

In conclusion, the symposium was well organised, productive and informative. There was a lot of stimulating discussion both in the formal sessions and, especially, outside them. The hotel where the meeting was held and its location were well chosen. I have returned home in an enthused frame of mind with a lot of new information and contacts useful not only to me but also to the rest of the group I work with. The organisers of the the symposium, Alberto Fereres and his helpers from Madrid and Almeria, should be heartily congratulated on a job well done. I thank the BSPP for the travel award that enabled me to attend, participate in and present research at this important and memorable meeting.

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