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Inventory

An annotated list of plant viruses described in Paraguay (1920–2023)

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Abstract: Despite an economy based mostly on agriculture, literature on viral diseases of plants is scarce in Paraguay. Only recently, researches on plant viruses took an impulse resulting in a precise identification of many of them affecting plants either cultivated or not. To provide reliable information regarding plant viruses present in Paraguay, an annotated list of them was prepared, covering descriptions from 1920 to present day. There have been some important outbreaks with severe yield losses in crops as cucurbits, citrus, sesame, bean, maize, peanuts and tomato. Many of older descriptions are included for their historical significance, but most identifications made require confirmation. On the other hand, recent descriptions have been completed, based on several assays, especially molecular characterization. This list is organized alphabetically following scientific names of the plant species found naturally infected by viruses, with comments about symptoms, geographical distribution, incidence, identification procedures, and other information, with due literature references. It is based on a compilation of publications made on plant virus diseases in Paraguay. Described virus species, in a total of 38 recognized by ICTV, belonging to 17 different genera (*Alphaendornavirus, Ampelovirus, Begomovirus, Benyvirus, Carlavirus, Cilevirus, Closterovirus, Comovirus, Cucumovirus, Dichorhavirus, Fabavirus, Luteovirus, Ophiovirus, Orthotospovirus, Potexvirus, Potyvirus* and *Tobamovirus*), besides two unclassified, and four unidentified. There is also a case of viroid described in *Citrus* spp. Infections caused by potyviruses are the most numerous. These viruses were described in more than 40 plant species, belonging to 18 botanical families. Because of crop diversity and richness in native flora, many more viruses must be present in Paraguay, which future works will certainly reveal, especially with the increase in manpower involving researches, especially cooperative with foreign centers, on plant viruses, which has been very limited until now. Also, knowledge on existing viruses may have relevance in understanding their epidemiology and provide the basis for their control strategies and quarantine measures, to avoid new variants of existing viruses or new viruses being introduced.
Keywords: *Plant virus identification; plant species; virus species.*

Una lista comentada de virus de plantas descritos en Paraguay (1920–2023)

Resumen: A pesar de una economía basada principalmente en la agricultura, la literatura sobre enfermedades virales de las plantas es escasa en Paraguay. Sólo recientemente se han impulsado las investigaciones sobre los virus de plantas, lo que ha permitido identificar con precisión muchos de ellos que afectan a plantas cultivadas o no. Para brindar información confiable sobre los virus de plantas presentes en el Paraguay, se elaboró una lista comentada de los mismos, abarcando descripciones desde 1920 hasta la actualidad. Se han producido algunos focos importantes con severas pérdidas de rendimiento en cultivos de cucurbitáceas, cítricos, sésamo, frijol, maíz, maní y tomate. Muchas de las descripciones más antiguas se incluyen por su importancia histórica, pero la mayoría de las identificaciones realizadas requieren confirmación. Por otro lado, las descripciones recientes han sido completadas, basadas en varios ensayos, especialmente de caracterización molecular. Esta lista está organizada alfabéticamente siguiendo los nombres científicos de las especies de plantas que se encontraron naturalmente infectadas por virus, con comentarios sobre síntomas, distribución geográfica, incidencia, procedimientos de identificación y otras informaciones, con las debidas referencias bibliográficas. Se basa en una recopilación de publicaciones realizadas sobre enfermedades virales de plantas en Paraguay. Especies de virus descritas, en un total de 38 reconocidas por el ICTV, pertenecientes a 17 géneros diferentes (*Alphaendornavirus, Ampelovirus, Begomovirus, Benyvirus, Carlavirus, Cilevirus, Closterovirus, Comovirus, Cucumovirus, Dichorhavirus, Fabavirus, Luteovirus, Ophiovirus, Orthotospovirus, Potexvirus, Potyvirus y Tobamovirus*), además de dos sin clasificar y cuatro sin identificar. También existe un caso de un viroide descrito en *Citrus* spp. Las infecciones causadas por potyvirus son las más numerosas. Estos virus fueron descritos en más de 40 especies de plantas, pertenecientes a 18 familias botánicas. Debido a la diversidad de cultivos y la riqueza de la flora nativa, muchos más virus deben estar presentes en Paraguay, lo que seguramente revelarán trabajos futuros, especialmente con el aumento de la mano de obra involucrada en investigaciones, en cooperación con centros extranjeros, sobre virus de plantas, que ha sido muy limitada hasta el momento. Además, el conocimiento sobre los virus existentes puede ser relevante para comprender su epidemiología y proporcionar una base para sus estrategias de control y medidas de cuarentena, para evitar la introducción de nuevas variantes de virus existentes o nuevos virus.

Palavras-chave: *Identificación de virus vegetales; especies de plantas; especies de virus.*

Introduction

1. Agriculture in Paraguay

The territorial area of Paraguay is roughly 406,000 km2, with an estimated population of 7.2 million (Hanratty & Meditz, 1988). The main agricultural products are soybean (planted area 3.4 million Ha), maize (800,000 Ha) and wheat (400,000 Ha), followed by crops as sugarcane, cassava, rice, citrus, sorghum, mate herb, and in smaller scale, tobacco, pineapple, oily seeds, sesame, etc. Agricultural inputs represent a market of approximately US$ 2 billion, with agrochemicals accounting for about 1/3 of this value (CAPECO, 2023).

The Paraguayan economy has been very favorable in the last decade, with an average gross domestic product (GDP) growth of approximately 5%, higher than the average for the continent. Export growth and favorable international prices for primary products led to this result (Brozón, G. R., & Nakayama, H. D., 2023). Paraguay's main export product is soybean, and its production directly influences the national GDP (Morínigo et al., 2018). In 2020, Paraguay was the fourth largest producer of soybeans in the world. In 2022, incomes of 2.8 Million dollars came from export of soybeans and derivatives (CAPECO, 2023). Soybean frontier expansion continues principally in the Paraguayan Chaco, where approximately 700.000 ha of land are considered suitable for soybean production (Henderson et al., 2021).

Crop production in 2021 in Paraguay was 10.5 million tons of soybean, 4.0 million tons of maize, 7.2 million tons of sugarcane, 3.3 million tons of cassava, 1.1 million tons of rice, 900 thousand tons of wheat, 116 thousand tons of mate herb and 29.8 thousand tons of cotton (MAG, 2023).

Concerning livestock, beef exports went from 82 million kilos in 2004 to 232 million kilos in 2013 according to the United Nations Comtrade Database - (UN Comtrade 2014). According to the Central Bank of Paraguay, the export of these agricultural commodities is currently representing almost 40% of the GDP. Interestingly, the logistics of these exports are mostly based on very efficient river transportation, with many portuary terminals installed along the rivers Paraguay and Paraná (BCP, 2017).

2. Current situation of the agricultural research in Paraguay

Historically, agricultural research in Paraguay started with Moisés Santiago Bertoni, a Swiss researcher, in his private research station in Yaraguarazapá in 1887, and produced more than 300 publications on Eastern Paraguayan agricultural themes until 1927 (Wilcox, 2020). Despite some modest governmental efforts, agricultural research has not made much progress in subsequent years. Most of agricultural expansion and increase in productivity was based on the import of foreign technology. Though in small scale, formal agricultural and livestock researches started in 1943, when the Inter-American Technical Service for Agricultural Cooperation (STICA), a US agency, organized the National Agronomic Institute (IAN) in Caacupé and the Experiment Station Barrerito (EEB) in Caapucú. IAN focused their efforts on crops like wheat, soybean, bean, corn, sorghum, citrus, cotton, tobacco, and pasture, while EEB operated an animal farm for cattle. STICA was restructured in 1966 by the Ministry of Agriculture and Livestock (MAG), being transferred to the newly created Agricultural Research and Rural Extension Directorate (DIAER), and ten experimental fields were organized in most important agroecological zones. Four emblematic programs on cotton, wheat, soybeans, and corn were established based on a multidisciplinary team with capable human resources trained at undergraduate and graduate levels abroad. These efforts led to the release of crop products that were adapted to Paraguay's agroclimatic conditions. In 1990, the MAG structure was simplified. The DIAER became the Directorate of Agricultural Research (DIA) and the Directorate of Agrarian Extension (DEAg), under the Subsecretary of Agriculture. The Subsecretariat for livestock became responsible for Animal Research and Production Directorate (DIPA) (Beintema et al., 2000). However, since then, there has been a progressive decrease in the efficiency of these structures due to budget decreases, resulting in lower salaries for researchers and technicians. To mend the situation, a new organization, the Paraguayan Institute of Agrarian Technology (IPTA) was created by the law (Ley de la Nación nº 3788, May 21st, 2010), fusing DIA and DIPA.

The Japanese community in Paraguay also played an important role in the development of agricultural research. Research and technical assistance centers were created in Pirapó, Yguazú and La Paz, which formed the so-called Agricultural Technology Center in Paraguay (CETAPAR), funded by the Japan International Cooperation Agency (JICA). With the help of Japanese specialists, soybean crop was introduced in these regions as well as the adaptation of vegetable crops and the creation of new varieties as the melon 'Luna Yguazú' and tomato 'Súper Cetapar'. More recently, the so-called National Institute of Biotechnology (INBIO), which is a non-profit civil association, has been funding research to promote the development of national biotechnology research (Beintema et al., 2000; IPTA, 2022).

Presently, the National Council for Science and Technology (CONACYT), created in 1997, became more active in recent years with increased budget, funding a large number of research projects and providing scholarships, including to agricultural sciences. (Ekboir et al., 2003).

The Agricultural College of the National University of Asuncion (UNA) in San Lorenzo was founded in mid-1950s to offer undergraduate courses in agronomy and veterinary science. Two decades later, these courses served as the basis of the Faculty of Agronomy and Veterinary Sciences. Research at UNA was limited due to limited budget. Although the Research Projects Directorate (DIPRI) has funded research for full-time faculties, it has been on a limited scale. In September 1974, the Superior University Council separated the Faculty of Agronomy and Veterinary Sciences into two independent faculties, and retained the Faculty of Agronomic Engineering. Finally, in 1994, the name of the Faculty of Agronomic Engineering was changed and it became the Faculty of Agrarian Sciences (FCA) (Ekboir et al., 2003).

3. *A brief history of plant virology in Paraguay*

The first mention of a plant viral disease in Paraguay goes back to 1920, when Spegazzini published a paper on citrus diseases. On inspections made in Paraguay in 1919, he described lesions on stems and trunk, but not on fruits, and designated the disease as 'lepra explosiva', attributing wrongly the causal agent as *Amylirosa aurantiorum*. Bitancourt (1955) commented that the symptoms observed by Spegazzini were caused by citrus psoriasis. Fawcett & Bitancourt (1940) toured several South American countries from April 17th to 22nd, 1937 to examine citrus diseases. Visits were made in the region of Asunción, Trinidad and San Lorenzo, where they found leprosis symptoms on sweet oranges, calling attention to differences in symptoms between leprosis symptoms in Florida and South America. In that same decade, Howard Porter, served with the Food supply division of the Institute of Inter-American Affair (U.S.) and worked with IAN from July 1946 to August 1947, and described what appears to be the first documented geminivirus symptoms in tomato crops in the country (Porter, 1947).

The study of plant viruses in Paraguay has begun with the collaborations of Japanese experts. During the period 1986 to 1988, Toshihiko Katusbe from the Japan International Research Center for Agricultural Sciences (JIRCAS) established the first partnerships. In surveys of 14 major crops, more than 50 kinds of diseases were identified, five of them, in strawberries, citrus, sugarcane and soybean, were attributed to a virus (Katusbe & Romero, 1991).

Starting July 1991, for three years, Dr. Kenichiro Shohara, a Japanese consultant at JICA, conducted a comprehensive survey on plant viral diseases in Paraguay. In FCA/UNA, he worked with local staff members from the Department of Agronomy and Phytopathology. The regions that were surveyed included Asunción and surrounding regions that produce agricultural products in the triangle of Asunción, Ciudad de Este, and Encarnación. A large number of viruses were found, and most of them were recognized using transmission assays, serology, and electron microscopy, while some were only recognized based on symptoms. These results were published in Spanish and Japanese (Shohara, 1995; Shohara et al., 1994).

From April 1997 to March 2002, the framework of the "Project for the Improvement of Vegetable Production Technology for Small-Scale Farmers in Paraguay", six JICA experts worked with IAN and DEAG to develop technology improvement activities, led by Dr. Takashi Ishijima (Ishijima & Okwara, 2002). Among those six experts, Dr. Yutaka Kimura investigated the chemical management of tospovirus and geminivirus vectors in tomato crops and the density of vector insect populations. In the same JICA Project, Dr. Tamito Sakurai (Department of Biology and Environmental Sciences, National Agricultural Research Center for Tohoku Region, Japan) studied the transmission of tospovirus by adults of *Frankliniella schultzei* collected in tomato fields in Paraguay in February of 2000, in collaboration with Dr. Yutaka Kimura and Dr. Takashi Ishijima (Sakurai, 2004).

Regarding local scientists, González-Segnana, from the Biology Department at FCA/UNA, was the first full-time plant virologist in Paraguay starting in September 1989. He earned his master's degree at the Universidade Federal de Viçosa and characterized an isolate of Orchid Ringspot Tobamovirus (ORSV) from Paraguay (González-Segnana, 1989). He also received additional training, especially on citrus viruses, at the Citrus Research and Educational Center (CREC) of the University of Florida, in Lake Alfred, and he devoted his initial works on surveying Citrus tristeza virus (CTV) in Paraguay.

Starting in 2005, a close cooperation program was developed between González-Segnana's group and the Departamento de Fitopatologia e Nematologia (LFN) from Escola Superior de Agricultura Luiz de Queiroz (ESALQ), Universidade de São Paulo (USP), Piracicaba campus. The beginning of cooperation occurred when E.W. Kitajima, a plant virologist from ESALQ, arrived in Paraguay to investigate citrus leprosis and first met González-Segnana. In the years that followed, Kitajima visited Paraguay several times, and along with González-Segnana and his team, visited several agricultural production areas in Paraguay. One important problem on sesame grown in San Pedro was identified as viral nature, caused by Cowpea aphid-borne mosaic virus (CABMV) (González-Segnana et al., 2011), and subsequent studies resulted in an efficient control. This cooperation extended also with Argentinian research groups of National Institute of Agricultural Technology (INTA) from Bella Vista and Concórdia, on citrus viruses (Cáceres et al., 2013). Because of this cooperation program, starting 2014, Esquivel-Fariña, a student of González-Segnana, did his graduate studies (MS 2014/2016; Ph.D 2017/2020), working with Tomato chlorosis virus (ToCV), supervised by J.A.M. Rezende, at the LFN/ESALQ (Esquivel-Fariña, 2016; 2019). He also received additional training as a visiting PhD student at the U.S. Agricultural Research Station in Salinas (CA) under the supervision of Dr. Willian Wintermantel. After returning to Paraguay, Esquivel-Fariña served successively as a researcher for the Ministry of Agriculture and a private company, surveying plant viruses in Paraguay, and recently joined the FCA/UNA.

Material and Methods

The present list was inspired on by a similar one, prepared for plant viruses and viroids described in Brazil (Kitajima, 2020), and it is based on a list of publications about plant viruses described in Paraguay beginning with the seminal paper by Spegazzini on citrus leprosis in 1920 to recent works in 2023. Such list was prepared by the authors, compiling publications made on plant viruses found in Paraguay, by local specialists or foreign visitors, and also of the viruses detected in samples collected in Paraguay and analyzed elsewhere. Following the model used by former listings (Sastry et al., 2019; Kitajima, 2020), this list was prepared by the scientific name of hosts, in alphabetical order, and within each species, viruses found naturally infecting them, with details about site of occurrence, incidence, symptoms and procedures for their identification, and the pertinent reference. In addition, a complementary, reverse list, by viruses and host plants they found infecting was prepared, relaying on the most recent listing organized by ICTV-ICTV_Master_Species_List_2021_v2.xlsx (ICTV, 2022). In older papers, identification of viruses was made by symptoms, serology and in a few cases, by electron microscopy. Only in recent descriptions, more reliable molecular detection and identification were used.

Results and Discussion

The literature search resulted in finding a total of 38 virus species, belonging to 17 genera, presently recognized by ICTV, besides two still unclassified and two, unidentified, and one classified viroid species. The pathogens were infecting more than 40 plant species, belonging to 18 botanical families. *Potyvirus* was, by far, the genus with the most representatives described in Paraguay, comprising 16 species and two unidentified members, followed by *Potexvirus*, with four species, and *Begomovirus, Tobamovirus* and *Orthotospovirus*, with two species each. On the host side, The *Fabaceae* family had the highest number of virus-infected species, with eight, followed by *Solanaceae*, with seven. Cucumber mosaic virus and Cowpea aphid-borne virus were viruses found infecting more plant species, each with seven [see list of plant species and the reverse list of viruses (Table 1) below].

Since the territory of Paraguay faces strongly agricultures regions of Brazil (states of Paraná and Mato Grosso do Sul) and Argentina (provinces of Formosa, Corrientes and Misiones), it is likely that many viruses, present in these areas may already occur in Paraguay. Indeed, recently epidemy of "huanglongbing" (HLB), caused by the phloem bacterium *Candidatus* Liberibacter, and transmitted by the psyllid *Diaphorina citri*, a serious problem for citrus crops in Brazil, reached Paraguay in 2013 (Mora-Aguilera et al., 2013), seven years after first detection in the state of São Paulo, Brazil (Sanches et al., 2018).

Recent impulse in scientific research in Paraguay, including in agricultural sciences, with a new generation of specialists, it is expected that an exponential increase in knowledge on viral diseases will occur, with an ever growing number of plant viruses being discovered in Paraguay.

Table 1. List of plant viruses and viroids described in Paraguay, with the plant species found infected by them, in the nature.

Realm: ***Monodnavira***	
Kingdom: *Shotokuvirae*	
Phylum: *Cressdnaviricota*	
Class: *Repensiviricetes*	
Order: *Geplafuvirales*	
Family: *Geminiviridae*	
Genus: *Begomovirus*	
Species: *Sweet potato leaf curl virus*	*Ipomea batatas*
Tomato yellowspot virus	*Leonurus sibiricus*
Realm: ***Ribovira***	
Kingdom: *Orthornavirae*	
Phylum: *Kitrinoviricota*	
Class: *Alsuviricetes*	
Order: *Hepelivirales*	
Family: *Benyviridae*	
Genus: *Benyvirus*	
Species (unc.): Wheat stripe mosaic virus	*Triticum aestivum*
Order: *Martellivirales*	
Family: *Bomoviridae*	
Genus: *Cucumovirus*	
Species: *Cucumber mosaic virus*	*Brassica rapa*
	Citrullus lanatus
	Cucumis melo
	Cucumis sativus
	Cucurbita maxima
	Nicotiana tabacum
	Zea mays
Family: *Closteroviridae*	
Genus: *Ampelovirus*	
Species: *Pineapple mealybug wilt-associated virus***	*Ananas comosus*
Genus: *Closterovirus*	
Species: *Citrus tristeza virus*	*Citrus spp*

Continue...

Continuation

Family: *Endornaviridae*	
Genus: *Alphaendornavirus*	
Unclass. species: *Capsicum frutescens* endornavirus	*Capsicum baccatum* var. pendulum
Family: *Kitaviridae*	
Genus: *Cilevirus*	
Species: Citrus leprosis virus C	*Citrus spp*
Unidentified	*Hibiscus rosa-sinensis*
Family: *Virgaviridae*	
Genus: *Tobamovirus*	
Species: *Odontoglossum ringspot virus*	Several orchid genera
Species: *Tobacco mosaic virus*	*Nicotiana tabacum*
	Solanum lycopersicum
Order; *Tymovirales*	
Family: *Alphaflexiviridae*	
Genus: *Potexvirus*	
Species: *Cassava common mosaic virus*	*Manihot esculenta*
Cymbidium mosaic virus	Several orchid genera
*Potato virus X***	*Solanum tuberosum*
Strawberry mild yellow edge virus	*Fragaria x ananassa*
Family: *Betaflexividae*	
Subfamily: *Quinvirinae*	
Genus: *Carlavirus*	
Species: *Chrysantem virus B***	*Chrysanthemum sp*
Unidentified	*Solanum tuberosum*
Class: *Tolucaviricetes*	
Order: *Tolivirales*	
Family: *Tombusviridae*	
Genus: *Luteovirus*	
Species: *Barley yellow dwarf virus*	*Triticum aestivum*
Phylum: *Negarnaviricota*	
Subphyum: *Haploviricotina*	
Class: *Mineviricetes*	
Order: *Serpentovirales*	
Family: *Aspivirale*	
Genus: *Ophiovirus* (1)	
Species: *Ophiovirus citri***	*Citrus spp.*
Class: *Monjiviricetes*	
Order: *Mononegavirales*	
Family: *Rhabdoviridae*	
Subfamily: *Betarhabdovirinae*	
Genus: *Dichorhavirus*	
Species: Orchid *fleck virus*	Several orchid genera
Subphylum: *Polyploviricotina*	
Class: *Elliotviricetes*	
Order: *Bunavirales*	
Family: *Tospoviridae*	
Genus: *Orthotospovirus*	
Species: *Groundnut ringspot orthotospsovirus*	*Arachis hypogaea*
	Petunia x hybrida
	Solanum lycopersicum
Tomato spotted wilt orthotospovirus	*Acanthospermum hispidum*
	Nicotiana longiflora
	Physalis sp.
	Solanum lycopersicum

Continue...

Continuation

Phylum: *Pisuviricota*	
Class: *Pisoniviricetes*	
Order: *Picornavirales*	
Family: *Secoviridae*	
Subfamily: *Comovirinae*	
Genus: *Comovirus*	
Species: *Cowpea severe mosaic virus*	*Vigna unguiculata*
Genus: *Fabavirus*	
Species: *Broad bean wilt virus***	*Pisum sativum*
Class: *Stelpaviricetes*	
Order: *Patatavirales*	
Family: *Potyviridae*	
Genus*: Potyvirus*	
Species: *Bean common mosaic virus***	*Phaseolus vugaris*
*Bean common mosaic necrosis virus***	*Phaseolus vugaris*
*Bean yellow mosaic virus***	*Phaseolus vugaris*
Cowpea aphid-borne mosaic virus	*Amaranthus hybridus*
	Arachis hypogaea
	Crotalaria incana
	C. juncea
	C. spectabilis
	Sesamum indicum
	Vigna unguiculata
*Dasheen mosaic vírus***	*Colocasia sp.*
Papaya ringspot virus	*Carica papaya*
	Cucurbita maxima
*Peanut mottle vírus***	*Arachis hypogaea*
Potato virus Y	*Nicotiana tabacum*
Sorghum mosaic virus	*Saccharum officinarum*
*Soybean mosaic vírus***	*Glycine max*
Sugarcane mosaic virus	*Saccharum officinarum*
	Sorghum bicolor
	Zea mays
Sweet potato feathery mottle virus	*Ipomea batatas*
Sweet potato virus G	*Ipomea batatas*
*Turnip mosaic virus***	*Brassica rapa*
*Watermelon mosaic vírus***	*Cucurbita maxima*
Zucchini yellow mosaic virus	*Citrullus lanatus*
	Cucumis sativus
	Cucurbita maxima
Unidentified	*Allium schoenoprasum*
	Manihot esculenta
Family: *Pospiviroidae*	
Genus: *Pospiviroid*	
Species: *Citrus exocortis viroid***	*Citrus* spp.
Other viruslike cases:	
Isometric particles, unidentified	*Manihot esculenta*
	Stevia sp.

*Based on ICTV Master Species List 2021 v.2.

**Pending confirmation by serological or molecular detection.

List of plant species infected by viruses and viroids, described in Paraguay (1920–2023)

A

***Acanthospermum hispidum* DC (Bristlly starbur) Asteraceae**
Orthotospovirus
***Tomato spotted wilt orthotospovirus* (TSWV)**

A. hispidium, locally known as Toro-rati, is a common wild plant with antifungal activity with potential use in medicine (1). ELISA made on samples of bristly starbur plants with leafroll and yellows symptoms showed a positive reaction against TSWV antibodies (2).
Ref.: (1) Portillo et al. Journal of Ethnopharmacology 76(1): 93. 2001; (2) Shohara, K. Shokubutsu boeki 49(2): 32. 1995.

***Allium schoenoprasum* L. (Chives) Amaryllidaceae**
Potyvirus
Potyvirus unidentified

A still unidentified presumed potyvirus causing mosaic symptoms on chives was observed by electron microscopy analysis, as deduced by the detection of elongated particles ca. 760 nm long in leaf extracts of symptomatic onion plants (1).
Ref.: (1) Shohara K Shokubutsu boeki 49(2): 32. 1995.

***Amaranthus hybridus* L. (Amaranth) Amaranthaceae**
Potyvirus
***Cowpea aphid-borne mosaic virus* (CABMV)**

Amaranth plants displaying chlorotic spots and mosaic were found in Choré, San Pedro, next to a bean plantation with high incidence of virus-like symptoms. Mechanical inoculation in indicator plants, serology and molecular (RT-PCR) assays confirmed CABMV infection in plants of *A. hybridus*. (1).
Ref.: (1) González-Segnana, L. R. et al., Tropical Plant Pathology 38(6): 539. 2013.

***Ananas comosus* (L.) Merr. (Pineapple) Bromeliaceae**
Closterovirus
***Pineapple mealybug wilt-associated virus* (PMWaV)**

Plant samples collected from Paraguay and maintained at the USDA-A RS National Clonal Germplasm Repository in Hilo, Hawaii, were tested positive for PMWaV by ELISA test (1). The natural infection has not been confirmed since then, and its actual presence in the country is unknown.
Ref.: (1) Hu, J. S. et al. Plant Pathology 45(5): 829. 1996.

***Arachis hypogaea* L. (Groundnut, peanut) Fabaceae**
Potyvirus
***Peanut mottle virus* (PMoV)**

Natural infections of peanut plants showing mosaic and mottle symptoms were reported in the Central Department. The presence of 740 nm viral particles was confirmed by electron microscopy analysis of infected tissue. Mechanical inoculation produced local lesions in *Chenopodium quinoa.* The causal virus was tentatively identified as Peanut mottle virus (PMoV), but it needs to be confirmed.
Ref.: (1) Shohara, K. Shokubutsu boeki 49(1): 32. 1995.

***Cowpea aphid-borne mosaic virus* (CABMV)**

CABMV was found infecting peanut plants causing mosaic symptoms in the Deptarment of San Pedro during a survey made in the period of 2010 to 2012. Serological (ELISA) and molecular (RT-PCR) assays confirmed CABMV-infections in peanut plants surrounding CABMV-infected sesame plantations. Thus, peanut plants are suggested as part of the epidemiology of dispersion of CABMV in sesame culture (1).
Ref.: (1) González-Segnana, L. R. et al., Tropical Plant Pathology 38(6): 539. 2013.

Orthotospovirus
***Groundnut ringspot orthotospovirus* (GRSV)**
Peanut plants displaying symptoms of tospovirus, including ringspots, mosaic, yellowing, and reduced leaf size, were found in an experimental area at FCA/UNA. Serology confirmed the infection of these peanut plants with GRSV.
Ref.: (1) Macchi-Leite, G., et al. Res. V Congreso Nacional de Ciencias Agrarias. 2021.

B

***Brassica rapa* (Turnip) Brassicaceae**
Cucumovirus
***Cucumber mosaic virus* (CMV)**
Potyvirus
***Turnip mosaic virus* (TuMV)**

Transmission assays and serology were used to detect CMV in turnip samples with mosaic symptoms found in Colonia Iguazú. On the other hand, flexuous and elongated particles ca. 750 nm long were found in leaf extracts of the same sample, by electron microscopy, suggesting potyvirus infection, possibly by TuMV, indicating a case of double infection (1). TuMV infection has not been confirmed by serological or molecular assays since then, and its actual presence in the country is unknown.
Ref.: (1) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995.

C

***Capsicum baccatum* L. var. *pendulum* (Chili pepper) Solanaceae**
Endornavirus unclassified
***Capsicum frutescens endornavirus* 1 (CFEV1)**

During a study on the evolution of endornaviruses in pepper and related species, CFEV1 was detected in *C. bacatum* seeds collected in Paraguay, by molecular means (1).
Ref.: (1) Safari, M. & Roossinck, M. J. Molecular Plant-Microbe Interactions 31(7): 766. 2018.

***Carica papaya* L. (Papaya) Caricaceae**
Potyvirus
***Papaya ringspot virus-P* (PRSV-P)**

Leaf extracts of papaya plants showing mosaic symptoms revealed the presence of elongated, ca. 740 nm particles by electron microscopy. Cucumber was able to be infected mechanically. The causal virus was tentatively identified as PRSV-P (1). In November 2020, papaya trees showing symptoms of leaf size reduction, yellow and severe mosaic, and

ringspots on the fruits were found in the Asunción Central department. PRSV-P infection was confirmed by RT-PCR and serologic assays.
Ref.: (1) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995; (2) Esquivel-Fariña, A. et al., Journal of Plant Pathology 104(1), 451. 2022.

***Chrysanthemum sp.* Asteraceae**
Carlavirus
***Chrysantemum virus B* (CVB)**
Elongated particles, ca. 670 nm long, possibly a carlavirus, were detected by electron microscopy, in leaf extracts of asymptomatic chrysanthemum plants, and tentatively identified as CVB, pending confirmation (1).
Ref.: (1) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995.

***Citrullus lanatus* Thumb. Matsui & Nakai (Watermelon) Cucurbitaceae**
Cucumovirus
***Cucumber mosaic virus* (CMV)**
CMV was detected using electron microscopy, transmission assays, and serology in mosaic-bearing watermelon plants (1).
Ref.: (1) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995

Potyvirus
***Zucchini yellow mosaic virus* (ZYMV)**
The presence of 750 nm particles in extracts of watermelon leaves with mosaic symptoms was detected by electron microscopy analysis. Based on mechanical transmission tests and serology this potyvirus was identified as ZYMV (1).
Ref.: (1) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995.

***Citrus spp*. Rutaceae**
Closterovirus
***Citrus tristeza virus* (CTV)**
Surveys conducted between 1986 and 1988 on major crops in Paraguay revealed several viral diseases on citrus crops, including CTV (1). Shohara in 1991-1993 also identified CTV in citrus plant samples showing leaf curling symptoms based on the presence of 1800 nm particles in leaf extracts by electron microscopy, and confirmed by serology (2). Using a technique combining serology and electron microscopy (MEIAD), CTV was detected in samples from Paraguay (3). By the end of the nineties, CTV had infected 96% of the citrus trees in the eastern regions of Paraguay. Interestingly, no CTV was detected in citrus plants grown in the Dept. Boquerón. The initial plants were imported into Texas by German colonizers in 1930. It is likely that the hot and dry conditions of the region do not favor the aphid vectors, thus avoiding incoming of CTV, since no citrus plants were introduced from other regions (4). In 2007, CTV was detected in selected grapefruit clones through a biological test using subtle lemon (*C. aurantifolia*) as an indicator plant, in the Depts. of San Pedro and Concepción (5).
Ref.: (1) Katusbe, T., & Romero, M. I. JARQ-japan agricultural research quarterly, 25(3), 172. 1991; (2) Shohara, K. Shokubutsu boeki 49 (1): 32. 1995; (3) Vega, J. et al. Fitopatologia Brasileira 16: XXVI. 1991; (4) González-Segnana, L.R. et al., Proceedings Florida State Horticultural Society 110: 43. 1997. (5) Perez, J. A., & González-Segnana, L.R. Investigación Agraria 9(2): 5. 2013.

Ophiovirus
***Ophiovirus citri* [*Citrus psorosis virus* (CPsV)]**
During the limited inspection made in 1937, Fawcett & Bitancourt observed mild cases of psorosis, based on symptoms, in citrus plants nearby Asunción (1). The presence of CPSV in Paraguay was confirmed during surveys conducted between 1986 and 1988 on major crops. More recently, the presence of CPsV in symptomatic citrus trees was reported in the city of Carlos A. López at Itapúa department (3).
Ref.: (1) Fawcett, C.H. & Bitancourt, A.A. O Biológico 6: 289. 1940; (2) Katusbe, T., & Romero, M. I. JARQ-Japan agricultural research quarterly 25(3): 172. 1991. (3) Godoy, G. M. et al. Investigación Agraria 6 (1): 15. 2013.

Cilevirus
***Citrus leprosis virus C* (CiLV-C)**
Just a few years after the disease was described in Florida, citrus leprosis was reported in Paraguay, in Asunción and named as “lepra explosiva” in 1920, by Spegazzini. At the time, he wrongly attributed the causal agent as a fungus *Amylirosa aurantiorum* (1). In 1937 Fawcett & Bitancourt visited Asunción and surroundings (Trinidad, San Lorenzo) as part of a long journey throughout several South American countries observing citrus diseases, and confirmed the presence of leprosis based on symptoms (2, 3). Further inspections revealed that citrus leprosis is widespread on orange and/or mandarin orchards in Paraguay (Boquerón, Concepción, San Pedro, Cordillera, Alto Paraná and Itapúa departments), the identification confirmed by electron microscopy and molecular assays (4). An extensive molecular survey on samples collected from several sites on the American continent, confirmed that Citrus leprosis virus C (CiLV-C) is the prevalent virus causing the citrus leprosis syndrome in Southern South America, including Paraguay (5). CiLV-C vector in Paraguay, as elsewhere, is identified as *Brevipalpus yothersi* (6).
Ref.: (1) Spegazzini, C. Annales de la Sociedad Científica 90:155. 1922. (2) Fawcett, H.S. & Bitancourt, A.A. O Biológico 6: 209. 1940; (3) Bitancourt, A.A. Arquivos do Instituto Biológico 22: 161. 1955; (4) Cáceres, S. et al. Tropical Plant Pathology 38(4): 282. 2013; (5) Chabi-Jesus, C. et al. Frontiers in Microbiology 12: 641. 2021; (6) Tassi, A.D. Tese Doutorado, ESALQ/USP. 2018.

Pospiviroid
Citrus exocortis viroid (CEVd)
The possible presence of CEVd in Paraguay, affecting citrus plants, was suggested based on symptoms observed in surveys during 1986 to 1988. The identification is still pending confirmation (1).
Ref.: (1) Katusbe, T., & Romero, M. I. JARQ-J agricultural research quarterly 25(3): 172. 1991.

***Colocasia sp.* (Yam) Araceae**
Potyvirus
***Dasheen mosaic virus* (DsMV)**
Electron microscopic analysis detected 750 nm particles in leaf extracts of yam plants showing mosaic symptoms, which were tentatively identified as being of DsMV (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Crotalaria incana* L. Fabaceae**
***Crotalaria juncea* L. Fabacea**
***Crotalaria spectabilis* L. Fabaceae**
Potyvirus
***Cowpea aphid-borne mosaic virus* (CABMV)**

Sesame crops have been found commonly infected by CABMV, occasionally resulting in significant losses. As part of studies to understand the epidemiology of this virus, surveys have been conducted to assess its presence in cultivated or spontaneous plants nearby sesame fields. Assays to detect CABMV included mechanical transmission to certain indicators (*Chenopodium quinoa, Vigna unguiculata, Sesamum indicum*) and ELISA using specific antiserum. During such inspections, three species of *Crotalaria* (*C. incana, C. juncea,* and *C. spectabilis*) showing mosaic symptoms were confirmed to be CABMV-infected (1). During the early survey made by Shohara in 1990's (2), he found mosaic bearing *Crotalaria* sp. associated with the presence of potyvirus-like particles, and suggested infection by BYMV. It is likely that the virus that caused the infection was CABMV.
Ref.: (1) González-Segnana, L. R. et al., Tropical Plant Pathology 38(6): 539. 2013; (2) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Cucumis melo* L. (Melon) Cucurbitaceae**
Cucumovirus
***Cucumber mosaic virus* (CMV)**

Samples of melon plants, exhibiting mosaic symptoms, were used in mechanical transmission assays, which resulted in the infection of NN tobacco (mosaic) and cowpea (local lesions). Electron microscopy detected isometric particles with a diameter of around 30 nm, and a serology test was positive for CMV (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Cucumis sativus* L. (Cucumber) Cucurbitaceae**
Cucumovirus
***Cucumber mosaic virus* (CMV)**

Similar results to those reported above for cucumber were obtained with samples of cucumber with mosaic symptoms, indicating a case of infection by CMV (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Potyvirus
***Zucchini yellow mosaic virus* (ZYMV)**

The presence of 750 nm particles was found in leaf extracts of mosaic bearing cucumber when examined by electron microscopy. The causal virus was determined to be ZYMV because of a positive serological reaction against ZYMV antiserum (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Cucurbita maxima* Duch. (Pumpkin) Cucurbitaceae**
Cucumovirus
***Cucumber mosaic virus* (CMV)**

Isometric particles of approximately 30 nm were found in leaf extracts of field pumpkin plants with mosaic symptoms, by electron microscopy. Mechanical transmission assays resulted in infection of tobacco (mosaic) and cowpea (local lesions), while a serological test was positive for CMV antigen, confirming infection by this virus (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Potyvirus
***Watermelon mosaic virus* (WMV)**

Leaf extracts of *C. maxima* plants showing mosaic symptoms were analyzed by electron microscopy, revealing the presence of potyvirus-like, elongated particles. ZYMV antigen was found to be negative in the serological test. The identity of this potyvirus has been tentatively suggested to be watermelon mosaic virus (WMV), but it has not yet been confirmed (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Papaya ringspot virus-W* (PRSV-W)**
***Zucchini yellow mosaic virus* (ZYMV)**

Potyviruses infection of cucurbits has been considered a common occurrence in Paraguay. Shohara (1) reported a case that was tentatively determined to be caused by WMV. In 2017, during a routine survey, leaf deformation, chlorosis and stunting were observed in plants of *C. maxima* var. Zapallito in an experimental area located in the campus of the National University of Asuncion. A mixed infection with PRSV-W and ZYMV (2) was confirmed by both molecular and serologic detection.
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995; (2) Esquivel-Fariña, A. et al., Journal of Plant Pathology 102(1): 231. 2020.

F

***Fragaria x ananassa* Duch. (Strawberry) Rosaceae**
Potexvirus
***Strawberry mild yellow edge virus* (SMYEV)**

According to the European and Mediterranean Plant Protection Organization (EPPO), SMYEV has a localized presence in some regions of Paraguay (1). However, there are no research studies confirming the actual presence of the virus in the country.
Ref.: (1) CABI, EPPO, 2004. Map 937. doi:10.1079/DMPD/20066500937.

G

***Glycine max* (L.) Merr. (Soybean) Fabaceae**
Potyvirus
***Soybean mosaic virus* (SMV)**

Potyvirus-like particles were found by electron microscopy in leaf extracts of soybean plants with mosaic symptoms, and this case was tentatively considered to be caused by SMV infection (1).
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

H

***Hibiscus rosa-sinensis* L. (Hibiscus) Malvaceae**
Cilevirus
Unidentified cilevirus

H. rosa-sinensis plants collected in Asunción were naturally found infected by the *Brevipalpus* mite-transmitted virus, tentatively identified as HGSV, still uncharacterized (1).
Ref.: (1) Kitajima, E. W. et al. Scientia Agricola, 67(3): 348. 2010.

I

***Ipomea batatas* (L.) Lam. (Sweet potato) Convulvulaceae**

Potyvirus

***Sweet potato feathery mottle virus* (SPFMV)**

***Sweet potato* virus *G* (SPVG)**

Begomovirus

***Sweet potato leaf curl virus* (SPLCV)**

During an investigation on synergistic interactions of begomoviruses and the crinivirus Sweet potato chlorotic stunt virus (SPCSV), at the International Potato Center in Peru. SPFMV and SPLCV were detected in mixed infection with sweet potato virus G (SPVG) in samples originated from Paraguay, maintained in the collection of sweet potato accessions. Detection was based on grafting onto the indicator plant *I. setosa,* followed by PCR (1).

Ref.: (1) Cuellar, W. J. et al. Molecular Plant Pathology 16(5), 459. 2015.

L

***Leonurus sibiricus* L. (Chinese motherwort, Honeyweed) Lamiaceae**

Begomovirus

***Tomato yellow spot virus* (ToYSV)**

ToYSV was identified, based on molecular assays, infecting two *L. sibiricus* plants displaying viral symptoms within citrus orchards in Major Otaño, Itapúa, Paraguay (1).

Ref.: (1) Fernandes-Acioli, N. A. N., et al. Plant Disease 98(10): 1445. 2014.

M

***Manihot esculenta* Kranz (Cassava) Euphorbiaceae**

Potexvirus

***Cassava common mosaic virus* (CsCMV)**

Symptomatic cassava leaf samples were collected in the early 1990s during a virus disease survey in Paraguay, and leaf extracts were loaded onto ELISA plates and dried. ELISA reactions were later carried out at CIAT, Colombia, and CsCMV was detected in cassava samples collected in Paraguay (1). Molecular characterization studies carried out on Brazilian, Colombian and Paraguayan isolates of CsCMV indicated that they were essentially similar (2).

Ref.: (1) Nolt, B.L. et al. Annals of Applied Biology 118(1): 105. 1991; (2) Calvert, L. et al., Journal of General Virology 77(3): 525. 1996.

Potyvirus

Potyvirus unidentified

Leaf extracts of cassava plants showing viral symptoms were analyzed by electron microscopy, revealing the presence of particles with 760 nm in in length, which were interpreted as being of potyviral nature. Further confirmation is needed for this finding (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Unidentified isometric virus

Isometric particles measuring 28 nm in diameter were observed in leaf extracts of cassava plants showing viral symptoms using transmission electron microscopy. No further confirmation of their viral nature is available.

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

N

***Nicotiana longiflora* Cav. (Longflower tobacco) Solanaceae**

Orthotospovirus

***Tomato spotted wilt orthotospovirus* (TSWV)**

TSWV was detected infecting *N. longiflora* plants by serology (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49(1): 32. 1995.

***Nicotiana tabacum* L. (Tobacco) Solanaceae**

Cucumovirus

***Cucumber mosaic virus* (CMV)**

Potyvirus

***Potato virus Y* (PVY)**

Tobamovirus

***Tobacco mosaic virus* (TMV)**

Tobacco plants with mosaic symptoms were examined using electron microscopy and serology. Presence of rod-like and flexuous particles, as well as of isometric particles ca. 30 nm diameter was observed in leaf extracts by electron microscopy. Serological analysis confirmed the presence of TMV, PVY and CMV in these samples (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

O

***Orchids* (several genera) Orchidaceae**

Dichorhabdovirus

***Dichorhavirus orchidacea* [*Orchid fleck virus* (OFV)]**

Orchid fleck virus (OFV) was first reported to infect plants of *Dendrobium moschatum* in 2013. Plants exhibiting chlorotic and necrotic lesions on the leaves were observed in the municipalities of Asunción and Caacupé (1). Leaf samples showing virus-like symptoms were found in plants grown in commercial greenhouses in the Paraguayan municipalities of Asunción and Caacupé during 2014 and 2015. Mixed infections with *Cymbidium mosaic virus* (CymMV) and *Odontoglossum ringspot virus* (ORSV) were reported (2).

Ref.: (1) Ramos-González, P.L. et al. Journal of Phytopathology 164(5): 342. 2016; (2) Esquivel-Fariña, A. et al. New Disease Reports 37(1): 3. 2018.

Potexvirus

***Cymbidium mosaic virus* (CymMV)**

During surveys carried out by Shohara in the 1990', *Cattleya* and *Dendrobium* plants showing viral symptoms were analyzed by electron microscopy, which detected elongated particles 460–480 nm long and tentatively identified as CymMV (1). Further surveys carried out on commercial and private collection of orchids, during 2014 and 2015, virus-like symptoms were observed in plants of five orchid genera (*Cattleya, Dendrobium, Miltonia, Oncidium* and *Phalaenopsis*) grown in commercial greenhouses in the Paraguayan municipalities of Asunción and Caacupé. Presence of CymMV was confirmed in samples of all these genera by electron microscopy and RT-PCR assays (2).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995; (2) Esquivel-Fariña, A. et al. New Disease Reports 37(1): 3. 2018.

Tobamovirus

***Odontoglossum ringspot virus* (ORSV)**

ORSV is believed to be the first virus formally studied in Paraguay. It was characterized during González-Segnana's master's dissertation in

1989 (1, 2), which analyzed ORSV isolates from Minas Gerais, Brazil, and Paraguay by biological analysis and electron microscopy. During surveys made by Shohara in the 1990's, ORSV was found in *Cattleya* and *Oncidium* orchids also by biological tests and electron microscopy (3). Recent surveys confirmed the presence of ORSV, in mixed infection with CymMV in plants of several orchid genera, as shown by electron microscopy and molecular assays (4).

Ref.: (1) González-Segnana L.R., Universidade Federal de Viçosa, MSc Dissertation, 1989; (2) González-Segnana, L.R. et al. Fitopatologia Brasileira 15: 152. 1990; (3) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995; (4) Esquivel-Fariña, A. et al. New Disease Reports 37(1), 3. 2018.

P

***Petunia x hybrida* (Petunia) Solanaceae**

Orthotospovirus

***Groundnut ringspot orthotospovirus* (GRSV)**

In 2018, flower growers in Luque County, Central Department, were forced to eliminate entire sets of GRSV-infected petunias due to a high incidence of necrotic ringspot symptoms on their leaves. Identification of the causal agent as an isolate of GRSV was made by serology and RT-PCR (1).

Ref.: (1) Esquivel-Fariña, A. et al. Australasian Plant Disease Notes 14(1): 5. 2019.

***Phaseolus vugaris* L. (Common bean) Fabaceae**

Potyvirus

***Bean yellow mosaic virus* (BYMV)**

Flexible, elongated particles were found in leaf extracts of bean plants exhibiting mosaic symptoms. These particles were tentatively identified as Bean yellow mosaic virus (BYMV). Further confirmation is required by serological or molecular assays (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Bean common mosaic virus* (BCMV), *Bean common mosaic necrosis virus* (BCMNV)**

Worrall et al., in their review on BCMV and BCMNV, they mention the presence of these viruses in Paraguay (p.16), possibly affecting bean plants, without details (1).

Ref.: (1) Worrall, E.A., et al. Advances in Virus Research 93: 1–46. 2015.

***Physalis sp.* Solanaceae**

Orthotospovirus

***Tomato spotted wilt orthotospovirus* (TSWV)**

Physalis spp. plants with virus-like symptoms were collected by Shohara during surveys carried out in the 1990's. The biological assays were negative, but serology confirmed TSWV infection (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Pisum sativum* L. Fabaceae**

Fabavirus

***Broad bean wilt virus* (BBWV)**

Isometric particles, ca. 25 nm, were detected by electron microscopy of leaf extracts from symptomatic pea plants during a survey of plant viruses in the 1990's, and tentatively identified as Broad bean wilt virus (BBWV), pending confirmation (1).

Ref.: (1) Shohara, K. et al. *Shokubutsu boeki* 49 (1): 32. 1995.

S

***Saccharum officinarum* L. (Sugar cane) Poaceae**

Potyvirus

***Sorghum mosaic virus* (SrMV)**

During studies developing a large-scale rapid identification of viruses causing sugarcane mosaic by direct sequencing of RT-PCR products from crude extracts made at Chacra Experimental Agricola, Argentina, SrMV were detected in samples collected at Guairá department (1). The exact presence and/or distribution in the country is not known.

Ref.: (1) Gómez, M. et al. Journal of Virological Methods 157(2): 188. 2009.

***Sugarcane mosaic virus* (SCMV)**

In the extensive review made by ISSCT, the presence of SCMV in Paraguay was registered, but without details (1).

Ref.: (1) International Society of Sugar Cane Technologists (ISSCT). Elsevier. 341. 1989.

***Sesamum indicum* L. (Sesamum) Pedaliaceae**

Potyvirus

***Cowpea aphid-borne mosaic virus* (CABMV)**

A sesame's disease, observed in the Department of San Pedro, characterized by yellowing and curling down of leaves, was coined locally as "ka'are", for the resemblance of affected plants with *Chenopodium ambrosioides,* known by this name. Until 2005, it was of marginal importance, but since then it has become widespread, causing significant losses. An intensive cooperative study was carried out by researchers of FCA/UNA and ESALQ/USP, to determine the causal agent and its epidemiology, as well as of control measures. As a result, CABMV was identified as the etiological agent by biological tests, electron microscopy, aphid transmission, serology and RT-PCR (1,2). Further studies identified many legume plants as alternative hosts for CABMV (3). The transmission of CABMV by cowpea (*Vigna unguiculata*) suggests that seeds may be involved in the epidemiology of sesame 'ka'are' disease (4).

Ref.: (1) González-Segnana, L. R. et al., Plant Disease 95(5): 613. 2011; (2) González-Segnana, L. R. et al., Identificación, detección y transmission de la enfermidad del Ka'are del sésamo. FCA-UNA/INBIO. 2011; (3) González-Segnana, L.R. et al. Tropical Plant Pathology 38(6): 539. 2013; (4) Delgado-Godoy, M.L. et al. Investigación Agraria 16(2): 93. 2014.

***Solanum lycopersicum* L. (Tomato) Solanaceae**

Tobamovirus

***Tobacco mosaic virus* (TMV)**

TMV was detected on tomato plants with mosaic symptoms during Shohara's survey. Identification was based on biological assays, electron microscopy and serology (1).

Ref: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Orthotospovirus

***Tomato spotted wilt orthotospovirus* (TSWV)**

Tospovirus-like symptoms (necrosis and ringspots on the leaves) have frequently been observed in tomato fields. In the 90s, TSWV was serologically detected infecting tomato plants, which showed necrosis (1). TSWV is quoted as causing "vira-cabeza" in Ishijima's manual on fruit vegetable crops, and considered to be transmitted by the dark form of *Frankliniella schultzei* (2), which was confirmed experimentally by Sakurai (3).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995; (2) Ishijima, T. (Ed.) Manual de técnicas de cultivo de hortalizas de frutas (tomate, melón, frutilla). Inst.Nac.Agric., Caacupé. 240p. 2002; (3) Sakurai, T. Applied Entomology and Zoology, 39(1), 189. 2004.

***Groundnut ringspot orthotospovirus* (GRSV)**

In 2018, tomato plants (cv. 'Santa Clara') showing typical tospovirus-like symptoms including chlorotic spots, concentric and necrotic rings on the leaves and stunting were found in high incidence (ca 50%), at the experimental field of FCA/UNA in San Lorenzo. The infection of GRSV on these tomato plants was confirmed by both serology and molecular assays.

Ref.: (1) Esquivel-Fariña, A. et al. Australasian Plant Disease Notes 14(1): 5. 2019.

***Solanum tuberosum* L. (Potato) Solanaceae**

Potexvirus

***Potato virus X* (PVX)**

Electron microscopy and serology were used to detect PVX in samples from symptomatic potato leaves (1). The actual presence and distribution in the country is unknown.

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Potyvirus

***Potato virus Y* (PVY)**

Potato plants showing mosaic, dwarfism, vein necrosis and leaf rolling were analyzed by electron microscopy, resulting in the detection of flexible particles ca. 750 nm long. The causal agent was tentatively identified as PVY, but this requires confirmation (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Carlavirus

Unidentified carlavirus

Potato plants showing mosaic, dwarfism, vein necrosis and leaf rolling were sampled during a Shohara's survey in 1990's. Electron microscopy examination of leaf extracts revealed the presence of carlavirus-like particles, which was considered evidence for the presence of Potato Virus S or Potato Virus M, not yet confirmed (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

***Sorghum bicolor* L. (Sorghum) Poaceae**

***Sugarcane mosaic virus* (SCMV)**

Teyssandier in his review on sorghum diseases in Paraguay mentions the presence of the sugarcane mosaic virus in sorghum, but without providing any details. The actual presence and/or distribution of the in the country is unknown.

Ref.: (1) Teyssandier, E. In Millano, W.A.J. et al. Sorghum diseases: a second world review. ICRISTAT. p.63. 1992.

***Stevia* sp. Asteraceae**

Fabavirus

***Broad bean wilt virus* (BBWV)**

Leaf extracts from *Stevia* plants with yellow symptoms were examined by electron microscopy revealing the presence of isometric virus-like particles ca. 25 nm. The virus has been tentatively identified as *Broad bean wilt virus* (BBWV), but it is still awaiting confirmation (1).

Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

T

***Triticum aestivum* L. (Wheat) Poaceae**

Benyvirus

***Wheat stripe mosaic virus* (WhSMV)**

WhSMV is the only virus associated with a soil-borne wheat mosaic disease in Paraguay. It is transmitted by the soil-borne plasmodiophorid *Polymyxa graminis*. In June 2016, randomly irregular patches of wheat plants (cv. 'Itapúa 65') exhibiting streaking mosaic on the leaves and stunting were observed in an experimental field at IPTA, located in the district of Capitán Miranda, Itapúa Department, Southeast of Paraguay. Based on electron microscopy observations of virus particles in symptomatic leaf and molecular assays, the virus was identified as WhSMV, which was recently described in Brazil (1).

Ref.: (1) Esquivel-Fariña, A. et al. Australasian Plant Disease Notes 14(1): 24. 2019.

Luteovirus

***Barley yellows dwarf virus* PAV and MAV types (BYDV)**

BYDV is a virus widely distributed in the world affecting various Poaceaeas. It has a persistent relationship in their aphid vectors. The presence of BYDV in Paraguay was reported since 1987 (1), and during the nineties (2, 3), and more recently during the agricultural periods 2013 and 2014 in wheat crops in the Southern region of Paraguay. In the analyzed samples, serology revealed a broad prevalence of BYDV-PAV, with only one positive case for BYDV-MAV (4).

Ref.: (1) de Viedma et al., (No. CIS-1090. CIMMYT.) 1987. (2) Ramirez Araya, I. C1990, (91-061795. CIMMYT.) 1990. (3) Webby, G.N. et al. Annals of Applied Biolology 123: 63. 1993; (4) Gonzáles-Segnana, L.R. et al., Investigación Agraria 17(1), 60. 2015.

V

***Vigna unguiculata* (L.) Walp. (Cowpea) Fabaceae**

Comovirus

***Cowpea severe mosaic virus* (CPSMV)**

CPSMV was first reported in Paraguay in cowpea, during investigations on seed-borne viruses of cowpea in Paraguay, related to the epidemiology of "ka-are" of sesame. Cowpea seeds were collected from cowpea plants that were experiencing symptoms at the IPTA experimental site in Choré, Department of San Pedro. ELISA was used to detect CPSMV on germinated plants. CPSMV was detected only in cultivars 'Negro' and 'Moteado' (1). More recently, a screening program for cowpea genotypes for resistance to CABMV and CPSMV identified resistant genotypes/cultivars that can be used in breeding programs (2).

Ref.: (1) Delgado-Godoy, M.L., et al., Investigación Agraria, 16(2): 93. 2014; (2) Alonso, G., et al., Agric. Sci. Dig, 43(5), 593-597. 2023.

Potyvirus

***Cowpea aphid-borne mosaic virus* (CABMV)**

CABMV was first described in Paraguay infecting sesame plants (*Sesamum indicum*). Simultaneously, several cowpea fields and nearby sesame diseased crops also contained plants exhibiting mosaic symptoms, which revealed that they were also infected with CABMV (1). Subsequent surveys conducted to identify alternative hosts of CABMV have detected this virus in cowpea plants in several regions of the country. *Aphis crassivora* proved to be vector of CABMV in

Paraguay (3). This virus may have been what Shohara (4) detected by electron microscopy during his survey in the 1990's. Seed transmission of CABMV occurs in most of the cowpea cultivars studied (5).
Ref.: (1) González-Segnana, L. G. et al., Plant Disease 95(5): 613. 2011; (2) González-Segnana, L.R. et al., Tropical Plant Pathology 38(6): 539. 2013; (3) Zelada-Cardozo, N.J.J. et al., Investigación Agraria 12(2): 85. 2010. (4) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995; (5) Delgado-Godoy, M.L., et al., Investigación Agraria, 16(2): 93. 2014.

Z

***Zea mays L.* (Maize) Poaceae**

Cucumovirus

***Cucumber mosaic virus* (CMV)**

Serology detected CMV in maize samples that displayed mosaic symptoms. The presence of isometric particles was confirmed by electron microscopy of leaf extracts.
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32. 1995.

Potyvirus

***Sugarcane mosaic virus* (SCMV)**

Maize plants displayed mosaic and yellowing symptoms, as observed by Shohara. The presence of particles 750 nm long in symptomatic plants was detected by electron microscopy analysis of leaf extracts, resulting in the tentative identification of the causal agent SCMV (1). This information still is pending by further confirmation.
Ref.: (1) Shohara, K. et al. Shokubutsu boeki 49 (1): 32.

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Author Contributions

Arnaldo Esquivel-Fariña: writing the original draft, data collection, manuscript preparation, and critical revision, adding intellectual content.

Luis R. Segnana-González: data analysis and results interpretation, and critical revision, adding intellectual content.

Elliot W. Kitajima: concept and design, data collection, substantial contribution in critical revision, data analysis and results interpretation, adding intellectual content.

Conflicts of Interest

The authors declare that they have no conflict of interest related to the publication of this manuscript.

Ethics

This study did not involve human beings and/or clinical trials that should be approved by one Institutional Committee.

Data Availability

The data collected and generated during this study includes the available literature on plant virus description in Paraguay used in the analysis and can be accessed at https://zenodo.org/records/8387860. The authors confirm that all data necessary for reproducing the study findings are available in the designated dataset.

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