

**James W. Moyer**

North Carolina State University, Raleigh

**Luis F. Salazar**

International Potato Center, Lima, Peru

# Viruses and Viruslike Diseases of Sweet Potato

Renewed interest in the sweet potato (*Ipomoea batatas* (L.) Lam.) by the international agricultural community has resulted in a dramatic rise in the need to exchange primitive and improved sweet potato germ plasm. Estimates by the Food and Agriculture Organization of the United Nations rank sweet potato seventh in total production among the world's crops. Sound horticultural practices and national quarantine regulations mandate that sweet potato germ plasm intended for international distribution be free from known viruses. Sweet potato germ plasm free from known viruses is also needed for commercial production and research purposes. Unfortunately, our ability to certify plants free from viruses and from agents responsible for the recognized diseases of unknown etiology has not kept pace with this burgeoning need. The problem of certification is most severe when international exchange of germ plasm is involved, because mutually acceptable guidelines for virus testing are lacking.

Field observations and assays have

revealed virus symptoms and the presence of one or more viruses in virtually all sweet potatoes grown from nonvirus-tested material. In many instances, the endemic nature of these viruses has facilitated the natural incorporation of high levels of tolerance to local viruses, via selection and propagation of asymptomatic plants. Although tolerance to viruses has improved production of sweet potatoes, it has made diagnosis difficult and, in some areas, resulted in a general complacency about the importance of virus diseases in sweet potatoes. Concern is justified, however, that a virus isolate mild or latent in one location on one group of cultivars may have considerably greater effects, either by itself or combined with other viruses, when introduced into a new geographic location where local cultivars have a different genetic background. Thus, the necessary precautions must be taken to prevent the inadvertent distribution of viruses with germ plasm.

A concerted effort is being made in several laboratories to discover the etiology of these diseases with symptoms frequently associated with virus infections. Although there are many sweet potato

"virus" diseases described in the literature, the etiology of many of these diseases has not been determined and reliable detection procedures have not been documented. The absence of this information is the most important factor inhibiting the international movement of sweet potato germ plasm.

Sweet potato feathery mottle virus (SPFMV) is frequently isolated from naturally infected sweet potatoes, often obscuring associated viruses. We are also beginning to recognize a number of diseases that are synergistic complexes of SPFMV with other viruses (5,6,16,21). Further, there are many viruslike diseases for which acceptable levels of tolerance or resistance are not available. Thus, there remains a distinct need for research emphasis on elucidation of the identity, importance, and detectability of sweet potato viruses.

Progress is being made around the world on sweet potato virus identification and detection. Our intent is to summarize the current status, rather than give a historical perspective, and to encourage the continuation of ongoing research and stimulate the initiation of new projects in this area. The impetus for this article came from a planning conference on





Fig. 1. Typical leaf symptoms of sweet potato feathery mottle virus in sweet potatoes consist of chlorotic veinbanding with purple borders that develop on older leaves.

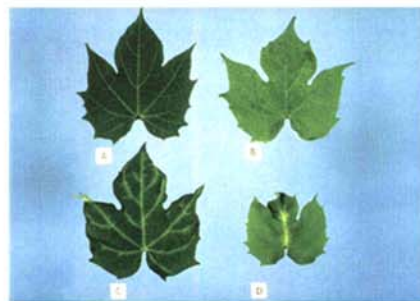


Fig. 2. (A) Healthy leaf of *Ipomoea setosa* and (B-D) leaves showing sequential symptoms of sweet potato feathery mottle virus. Typically, recovery follows a flush of symptoms. Apparently symptomless leaves (not shown) may show faint chlorotic spots.



Fig. 3. Root necrosis caused by strains of sweet potato feathery mottle virus. (A) Russet crack symptoms expressed in the roots of the cultivar Jersey. (B) The internal cork disease observed in many sweet potato cultivars.



Fig. 4. (A) Stunted sweet potato plants infected with sweet potato vein mosaic virus (SPVMV). Distribution indicates infected plants were propagated from a single infected plant. (B) Foliar symptoms of SPVMV in the sweet potato cultivar Morada-INTA.

sweet potato research held at the International Potato Center (CIP), Lima, Peru, 23-27 February 1987 (10). Pathologists, including individuals with research experience in sweet potato viruses, were in attendance from the Asian Vegetable Research and Development Center (AVRDC), Tainan, Taiwan; the CIP; the International Institute for Tropical Agriculture (IITA), Ibadan, Nigeria; Australia; and the United States. This conference provided a timely opportunity for the majority of scientists investigating sweet potato viruses to discuss common problems.

A consensus was reached at the conference on two overall objectives. First, investigations should emphasize the identification, detection, geographic distribution, and importance of sweet potato viruses. Although considerable knowledge is available about sweet potato feathery mottle virus, it was apparent from the formal presentations and discussions that there are many virus diseases of sweet potato with unknown etiology. Second, every effort should be made to establish a standard set of guidelines based on current information for virus testing of sweet potato germ plasm with the knowledge that these guidelines will need to be revised as new information becomes available.

#### Status of Known Viruses and Virus Diseases

**Sweet potato feathery mottle virus.** SPFMV is found nearly everywhere

sweet potatoes are grown. Many strains of SPFMV have been identified, and worldwide it has been referred to by many different names. Some of the synonyms used for different strains or isolates of SPFMV include russet crack virus, sweet potato virus A, sweet potato ringspot virus, sweet potato leaf spot virus, and probably internal cork virus (3-5,15,16,22,24). The ubiquitous nature of SPFMV has hindered the identification of many other viruses whose presence has been indicated by preliminary experiments. Coinfection by SPFMV is most frequently a problem when the host range of the unknown virus is also limited to the Convolvulaceae.

The symptom types associated with SPFMV infection are as much a function of the host genotype and environment as they are of the virus strain or isolate (1,4,5,16-18). Symptoms on sweet potato leaves may consist of the classic irregular chlorotic patterns (feathering) associated with the leaf midrib as well as faint or distinct chlorotic spots that have purple pigmented borders in some genotypes (Fig. 1). These symptoms are observed predominantly on the older leaves. Vein clearing, veinbanding, and chlorotic spots are the predominant symptoms observed in the indicator host *I. setosa* Kerr (Fig. 2). Symptoms may be mild, however, and leaves produced after the initial flush may be symptomless. Some strains of SPFMV cause necrotic lesions on the exterior of the roots (russet crack disease, Fig. 3A), while another strain induces symptoms on the interior of the root (internal cork disease, Fig. 3B).

SPFMV is the most thoroughly characterized (5,17,18) sweet potato virus, and serological procedures have been developed (3,8). SPFMV has many biological characteristics and cytopathic effects that support its classification as a potyvirus (4,5), even though such biochemical properties as capsid protein CM, 38,000 daltons, cRNA  $3.65 \times 10^6$  daltons (17), and virion length 850 nm (4,20) make it an atypically large potyvirus.

**Sweet potato vein mosaic virus.** Sweet potato vein mosaic virus (SPVMV) has been reported only in Argentina (19). Direct comparison of the particle morphologies of SPFMV and SPVMV indicate that SPVMV has a modal length of 761 nm, significantly shorter than SPFMV. SPVMV is also transmitted nonpersistently by aphids (20). The virus has not been purified, however, and consequently antiserum is not yet available to compare this virus with other known potyviruses or to assay sweet potatoes from other countries. Sweet potato plants infected by this virus are severely stunted (Fig. 4A) and produce fewer new roots. The virus also causes severe foliar symptoms in sweet potato (Fig. 4B) and symptoms similar to those of SPFMV in *I. setosa*.



**Sweet potato latent virus.** Sweet potato latent virus (SPLV), formerly designated sweet potato virus N, has been reported only from Taiwan (6). As the name suggests, infection of many sweet potato cultivars by SPLV does not result in obvious foliar symptoms. The host range of SPLV includes many *Convolvulus* species, *Chenopodium* species, and some *Nicotiana* species, including *N. benthamiana* Domin. Although SPLV induces mild symptoms in *I. setosa*, it is easily detected by serology.

SPLV also has many characteristics of a potyvirus, including production of characteristic cytoplasmic inclusions. All attempts at aphid and whitefly transmission have been unsuccessful, however. Reciprocal serological tests have demonstrated that SPLV and SPFMV are not serologically related (Moyer, unpublished). Thus, definitive classification of this virus awaits further characterization.

**Sweet potato mild mottle virus.** Sweet potato mild mottle virus (SPMMV) was isolated in East Africa from sweet potatoes showing leaf mottling, veinal chlorosis (Fig. 5A), dwarfing, and poor growth (14). SPMMV-infected *I. setosa* show a bright yellow veinal chlorosis in as many as four leaves after inoculation (Fig. 5B). Subsequent leaves are symptomless. This virus is the best described of the whitefly-transmitted viruses reported from sweet potatoes. It has been referred to as SPV-T in preliminary reports and may be the same as virus B, which was also isolated from sweet potatoes in East Africa (22).

Although the morphology of SPMMV and its cytoplasmic inclusions is similar to that of other potyviruses, its biological characteristics differ greatly from the type member. Most notable among the divergent characteristics is the host range of SPMMV, which includes 45 species in 14 plant families. Additionally, SPMMV is vectored by the whitefly *Bemisia tabaci* (Genn.), and its virions are relatively unstable compared with those of other potyviruses (18; Moyer, unpublished).

**Sweet potato yellow dwarf virus.** Sweet potato yellow dwarf virus (SPYDV) was described recently in Taiwan (6). The virion morphology and vector of SPYDV are similar to those of SPMMV. Neither virus is adequately characterized, and a direct comparison has not been made to determine the extent of biochemical relationships, but sufficient differences have been reported to continue designating SPYDV as a separate virus.

Symptoms on sweet potato plants infected with SPYDV consist of mottling, chlorosis, and dwarfing. Expression of the symptoms is favored by poor fertility and low temperatures. The root systems of infected plants are poorly developed, and the fleshy roots are not marketable. SPYDV frequently occurs in combination with SPFMV. The host range of SPYDV

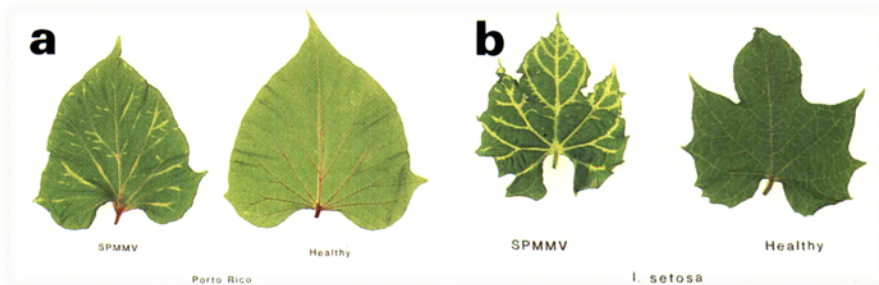


Fig. 5. Foliar symptoms in (A) the sweet potato cultivar Porto Rico and (B) the indicator *Ipomoea setosa* caused by sweet potato mild mottle virus (SPMMV).

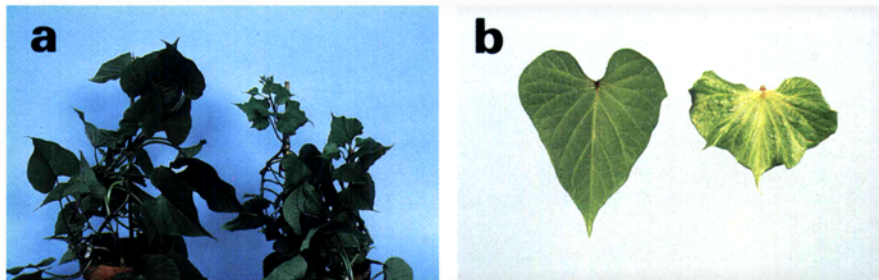


Fig. 6. Symptoms in the sweet potato indicator clone TIB 8 of the sweet potato virus disease (SPVD) complex caused by the synergism of sweet potato feathery mottle virus (SPFMV) and a whitefly-transmitted agent. (A) The plant at left is infected with SPFMV alone and the plant at right is infected with SPFMV and the whitefly-transmitted agent. (B) Healthy leaf at left and leaf with SPVD at right.

also extends beyond the Convolvulaceae to include *Chenopodium* species, *Gomphrena globosa* L., *Sesamum orientale* L., *Datura stramonium* L., and *Cassia occidentalis* L. (S. Green, personal communication).

**A caulimolike virus.** A virus with some properties like those of caulimoviruses was isolated from sweet potato by grafting and has been provisionally designated as sweet potato caulimolike virus (SPCLV). It was first isolated in Puerto Rico and has since been isolated from sweet potatoes grown in Madeira, New Zealand, Papua New Guinea, and the Solomon Islands (2).

Diagnostic symptoms have not been associated with sweet potatoes infected by this virus. Early symptoms on *I. setosa* include chlorotic flecks along the minor veins with interveinal chlorotic spots. These symptoms may develop into a general chlorosis resulting in wilting and premature death of the leaves. Virions associated with SPCLV are typical of caulimoviruses, but some of the inclusions are similar to the fibrillar ring inclusions induced by geminiviruses. The SPCLV inclusions are not observed in the nuclei of infected cells, however. Serological tests have failed to reveal any serological affinities with selected caulimoviruses, and SPCLV is not transmitted in a semipersistent manner by *Myzus persicae* Sulzer or *Aphis gossypii* Glover. Definitive classification of this virus will require elucidation of additional characteristics.

**Other whitefly-transmitted agents.**

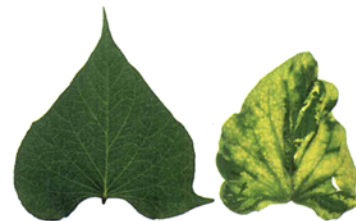


Fig. 7. Sweet potato leaf at right is coinfecting with sweet potato feathery mottle virus and tobacco streak virus. Leaf at left is healthy.

Other whitefly-transmitted agents isolated from sweet potato in Nigeria, Israel, Taiwan, and the United States (7,9,13, 15,21) are also considered as separate agents but have not been definitively characterized and compared. They have properties distinctly different from those of SPMMV, i.e., they are not mechanically transmitted, they have a narrow host range, and no virions have been identified for them. In each of these diseases, the agent transmitted by *B. tabaci* has not been transmitted mechanically and a virion has not been identified.

The sweet potato virus disease (SPVD) described in Nigeria is one of the most thoroughly investigated (11,12,21). This disease is due to the synergism of a strain of SPFMV and a whitefly-transmitted agent (Fig. 6). Diseases similar to SPVD, designated as Georgia mosaic and yellow dwarf, have been reported in the United

States (9,13). Sweet potato vein-clearing virus reported in Israel also induces symptoms similar to those of SPVD (15). Agents associated with each of these diseases have components that are transmitted by the whitefly but cannot be transmitted mechanically. Sweet potato leaf curl (SPLC) is another disease whose causal agent has been reported to be transmitted by *B. tabaci* (7,23).

**Other viruses isolated from sweet potato.** At least three viruses with broad host ranges—tobacco mosaic virus (TMV), cucumber mosaic virus (CMV), and tobacco streak virus (TSV) (Fig. 7)—have been isolated from sweet potato. Although the status of the TMV-infected host is unknown, CMV and TSV were isolated from plants coinfecting with SPFMV (J. Cohen and G. Lobenstein, *personal communication*; Moyer, *unpublished*).

**Other viruslike diseases of unknown etiology.** Many sweet potato disease syndromes typical of diseases caused by viruses have been described. Although mosaic has been used to designate several diseases, an apparently distinct disease of sweet potato has been described in Taiwan (6). Chlorotic leaf distortion (SPCLD) was recently described in Louisiana (C. A. Clark, *unpublished*) and has been observed throughout the

southeastern United States; the diagnostic symptom is a bright chlorosis of the young leaves on infected plants. Host genotype differences, different viruses, or novel combinations of known viruses may explain the apparently distinct symptoms of the diseases of sweet potato with unknown etiology.

### Guidelines for Virus Testing of Sweet Potatoes

The following proposed guidelines are intended to serve as a framework that will accommodate current as well as future information and facilitate testing of sweet potatoes for specific viruses.

We recommend that all sweet potato clones be placed in in-vitro culture by meristem-tip culture accompanied by heat or chemotherapy as necessary to obtain plantlets free from pests as determined by subsequent pathogen testing. All clones should be stored in in-vitro culture for multiplication and distribution whenever possible to minimize opportunities for reinfection during maintenance. Each in-vitro plantlet should be subcultured for pathogen testing. The youngest portion of the plantlet (apical two or three nodes) should be used to propagate plantlets as in-vitro reference cultures; the remaining

stem and roots can be used to propagate the plant in a screened greenhouse for pathogen testing. This strategy favors propagating that portion of the plant with the lowest probability of containing virus (the youngest) for maintenance and propagating that portion with the highest probability of containing virus for testing.

At the present time, strategies are not available to test in-vitro cultured plantlets for all of the known viruses. However, plantlets may be assayed biochemically at the time of subculturing as a preliminary virus testing step. It must be recognized, however, that virus may not be detectable in all tissues but only in clones supporting high virus titers. We recommend that plants for virus testing be grown in the greenhouse to produce stems with at least 10–15 nodes. These plants should then be assayed by making grafts to two separate *I. setosa* plants and to the sweet potato clone TIB 8, which is infected with a mild strain of SPFMV. The TIB 8 clone is used to detect the whitefly component of the SPVD complex. These plants should be closely monitored for symptom production, and the *I. setosa* plants should be assayed with available biochemical assays to detect any mild infections. Nearly all known viruses infecting sweet potatoes also infect *I. setosa*. Although *I. setosa* is susceptible to many viruses that infect sweet potato and is a good assay host, the symptoms are not of diagnostic value. Some viruses, such as CMV and TSV, may not be reliably detected by these methods. Thus, we strongly suggest mechanical assays directly from sweet potato to other virus indicators such as *N. benthamiana*, *N. clevelandii* Gray, and *Chenopodium quinoa* Willd.

The known viruses that infect sweet potato do so in a nonuniform manner, and thus the sampling strategy should be a carefully considered aspect of the virus testing process. TSV is isolated most easily from young tissue, whereas SPFMV reaches its peak concentrations in older leaves. Samples should be taken from young and old regions of the stem for grafting and biochemical assays. In addition, we recommend that each sweet potato plant be tested multiple times, as for other vegetatively propagated crops. Sweet potato plants should be severely pruned and allowed to grow to at least 10–15 nodes between each test.

A major concern exists for the potential for seed transmission of sweet potato viruses. Although viruslike symptoms are observed frequently in seedling plantings, no virus infection has been confirmed to result from seed transmission. Seed transmission of sweet potato viruses is an area that needs research. Users of sweet potato seed, particularly seed of exotic origin, should monitor seedlings closely for evidence of virus infection.



James W. Moyer

Dr. Moyer is a professor in the Department of Plant Pathology at North Carolina State University. He received his B.S. degree in agronomy from Washington State University and his M.S. and Ph.D. degrees from Pennsylvania State University. His responsibilities since joining NCSU in 1976 have included research for all diseases of sweet potatoes and evaluation of sweet potato cultivars for disease resistance. Since 1987 his research assignment has been virus diseases of cereal, floral, and vegetable crops.



Luis F. Salazar

Dr. Salazar received his B.S. and M.S. degrees from the Universidad Agraria, La Molina, Lima, Peru, and, in 1977, his Ph.D. degree from the University of Dundee, Scotland. His Ph.D. work was done at the Scottish Crop Research Institute in Dundee under the supervision of B. D. Harrison. He then joined the International Potato Center in Lima, Peru, to study general potato virus diseases and their control. He is the leader of the virus thrust at the center, where his research interests include plant virus and viroid interactions in potato and sweet potato.



## Acknowledgments

We are grateful for the discussions and information provided by P. Beetham, A. A. Brunt, C. A. Clark, J. Dodds, S. Green, and H. Roessel. Portions of our research were supported by USDA Southern Regional Cooperative Agreement No. 5-46764 and the International Potato Center.

## Literature Cited

- Alconero, R. 1972. Effects of plant age, light intensity and leaf pigments on symptomatology of virus-infected sweet potatoes. *Plant Dis. Rep.* 56:501-504.
- Atkey, P. T., and Brunt, A. A. 1987. Electron microscopy of an isometric caulimovirus-like virus from sweet potato (*Ipomoea batatas*). *J. Phytopathol.* 118:370-376.
- Cadena-Hinojosa, M. A., and Campbell, R. N. 1981. Serological detection of feathery mottle virus strains in sweet potatoes and *Ipomoea incarnata*. *Plant Dis.* 65:412-414.
- Cali, B. B., and Moyer, J. W. 1981. Purification, serology, and particle morphology of two russet crack strains of sweet potato feathery mottle virus. *Phytopathology* 71:302-305.
- Campbell, R. N., Hall, D. H., and Mielinis, N. M. 1974. Etiology of sweet potato russet crack disease. *Phytopathology* 64:210-218.
- Chung, M. L., Hsu, Y. H., Chen, M. J., and Chiu, R. J. 1986. Virus diseases of sweet potato in Taiwan. Pages 84-90 in: *Plant Virus Diseases of Horticultural Crops in the Tropics and Subtropics*. FFTC Book Series 33. Food and Fertilizer Technology Center for the Asian and Pacific Region, Taipei, Taiwan, Republic of China.
- Chung, M. L., Liao, C. H., Chen, M. J., and Chiu, R. J. 1985. The isolation, transmission and host range of sweet potato leaf curl disease agent in Taiwan. *Plant Prot. Bull. (Taiwan)* 27:333-342.
- Esbenshade, P. R., and Moyer, J. W. 1982. Indexing system for sweet potato feathery mottle virus in sweet potato using enzyme-linked immunosorbent assay. *Plant Dis.* 66:911-913.
- Girardeau, J. H. 1958. The sweet potato white-fly, *Bemisia inconspicua* Q., as a vector of a sweet potato mosaic in South Georgia. *Plant. Dis. Rep.* 42:819.
- Gregory, P., ed. 1988. *Exploration, Maintenance and Utilization of Sweet Potato Genetic Resources*. International Potato Center, Lima, Peru. 369 pp.
- Hahn, S. K. 1979. Effects of viruses (SPVD) on growth and yield of sweet potato. *Exp. Agric.* 15:1-5.
- Hahn, S. K., Terry, E. R., and Leuschner, K. 1981. Resistance of sweet potato to virus complex (SPVD). *HortScience* 16:535-537.
- Hildebrand, E. M. 1958. Two syndromes caused by sweet potato viruses. *Science* 128:203-204.
- Hollings, M., Stone, O. M., and Bock, K. R. 1976. Purification and properties of sweet potato mild mottle, a white-fly borne virus from sweet potato (*Ipomoea batatas*) in East Africa. *Ann. Appl. Biol.* 82:511-528.
- Loebenstein, G., and Harpaz, I. 1960. Virus diseases of sweet potatoes in Israel. *Phytopathology* 50:100-104.
- Moyer, J. W. 1986. Variability among strains of sweet potato feathery mottle virus. (Abstr.) *Phytopathology* 76:1126.
- Moyer, J. W., and Cali, B. B. 1985. Properties of sweet potato feathery mottle virus RNA and capsid protein. *J. Gen. Virol.* 66:1185-1189.
- Moyer, J. W., and Kennedy, G. G. 1978. Purification and properties of sweet potato feathery mottle virus. *Phytopathology* 68:998-1004.
- Nome, S. F. 1973. Sweet potato vein mosaic in Argentina. *Phytopathol. Z.* 77:44-54.
- Nome, S. F., Shalla, T. A., and Petersen, L. J. 1974. Comparison of virus particles and intracellular inclusions associated with vein mosaic, feathery mottle, and russet crack diseases of sweet potato. *Phytopathol. Z.* 79:169-178.
- Schaefer, G. A., and Terry, E. R. 1976. Insect transmission of sweet potato disease agents in Nigeria. *Phytopathology* 66:642-645.
- Sheffield, F. M. L. 1957. Virus diseases of sweet potato in East Africa. I. Identification of the viruses and their insect vectors. *Phytopathology* 47:582-590.
- Yamashita, S., Doi, Y., and Shin, K. A. 1984. Short rod particles in sweet potato leaf curl virus infected plant tissue. *Ann. Phytopathol. Soc. Jpn.* 50:438.
- Yang, I. L. 1972. Transmission of the feathery mottle complex of sweet potato in Taiwan. *Taiwan Agric. Q.* 8:123-134.