James W. Demski and Gilbert R. Lovell
Georgia Experiment Station, Experiment

Peanut Stripe Virus and th

The peanut (groundnut), *Arachis hypogaea* L., is native to South America. The exact origin of the peanut is unknown and will probably continue to be a source of inquiry (3). The experience of 20 years of collecting peanuts throughout South America led Krapovickas (4) to postulate that *A. hypogaea* originated in Bolivia (1).

The early Spanish and Portuguese explorers found the Indians cultivating the peanut in the West Indian islands, Mexico, Brazil, Argentina, Paraguay, Bolivia, and Peru. From there the peanut was carried to Europe, both coasts of Africa, Asia, and the Pacific islands. It was also introduced to the colonial seaboard of the southeastern United States, on slave ships from Africa, according to a popular contention.

With increased production in America in the late 1800s, commercial shipments were made to other countries and peanuts for planting were imported into the United States. The first officially recorded introduction of a peanut through the USDA Section of Seed and Plant Introduction was from Egypt in 1899. Since that introduction, the exchange of peanut germ plasm has been continuous. The Southern Regional Plant Introduction Station (SRPIS), USDA-ARS, currently maintains over 6,000 plant introductions (PIs) from 81 countries. This unit distributes peanuts, on request, to numerous countries each year.

Since 1972, all peanut introductions received at SRPIS have been processed first through the USDA Plant Germplasm Quarantine Center and the Plant Introduction Office at Beltsville, Maryland. The new introductions are grown on the Georgia Experiment Station in Experiment, which houses SRPIS. The peanuts are grown for initial observation and seed increase before any germ plasm is distributed to other locations. Routinely, plants are observed and checked for disease symptoms by plant pathologists.

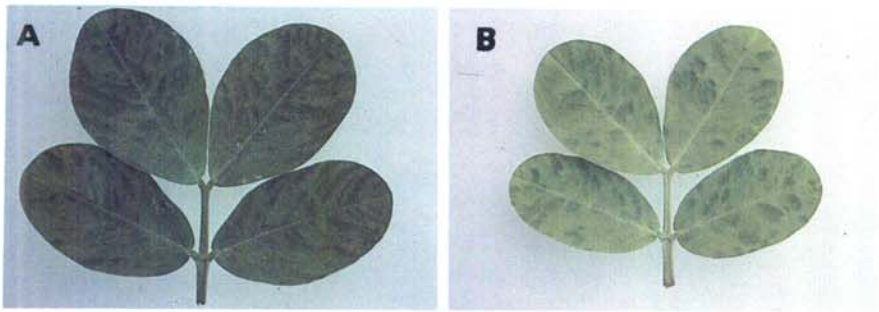


Fig. 1. Peanut cv. Argentine showing symptoms of (A) peanut stripe virus and (B) peanut blotch virus. Peanut blotch virus is serologically related to peanut stripe virus and is considered a symptom variant.

Discovery of Peanut Stripe Virus in the United States

In the summer of 1982, Grover Sowell, an SRPIS pathologist, inspected a field of peanuts planted with seed from the People's Republic of China, Zimbabwe, Sudan, Senegal, Japan, and India. He observed a viruslike symptom on the peanut foliage that appeared different from the endemic peanut mottle. He made mechanical virus transmissions to several hosts in the greenhouse and recovered a virus on peanuts and cowpeas.

One of us (J.W.D.) obtained virus isolates from field peanuts and from Sowell's greenhouse plants. During the fall of 1982 and spring of 1983, the isolates were manipulated in host range tests to detect mixed infections of viruses and to obtain "pure" cultures. Residual seed from lots used to make the 1982 field planting were planted in the greenhouse. Veinbanding and stripe symptoms were observed in seedlings from seed from the People's Republic of China but not in seedlings from seed from the other countries. Results of serological tests using antiserum to peanut mottle virus (PMV) were negative, but reactions to blackeye cowpea mosaic virus and soybean mosaic virus antisera were positive. The isolates that failed to react with PMV antiserum were used to inoculate *Chenopodium amaranticolor* and *C. quinoa*, both of which developed local lesions. Single lesions were removed from *Chenopodium* plants and used to mechanically inoculate individual peanut plants. The majority of these plants developed banding and dark stripes along the lateral leaf veins that in many cases resembled sergeant stripes, so the virus was named peanut stripe virus (PStV) (Fig. 1A). A few peanut plants inoculated from single lesions from *Chenopodium* developed dark green circular areas that were not associated with the veins, and these isolates were called peanut blotch (Fig. 1B). Peanut blotch virus could not be distinguished serologically from PStV and is considered a symptom variant of PStV. PStV is transmitted by aphids in a nonpersistent manner; is serologically related to blackeye cowpea mosaic, soybean mosaic, and clover yellow vein viruses; and has physical properties and morphological features that place it in the potyvirus group (2).

Distribution of PStV

In the early summer of 1983, routine serological assays (enzyme-linked immunosorbent assay [ELISA]) of peanut plants for virus infection were made in Georgia. PStV was again detected at the Georgia

Distribution of Peanut Seed

Experiment Station, at the Plant Materials Center near Americus, and at the Coastal Plain Experiment Station at Tifton. Infected peanuts growing at the Georgia Experiment Station and the Plant Materials Center originated from seed from the People's Republic of China. In addition, PStV was found infecting peanut plants originating in other countries, including the United States, and planted near the "China" plants. At the Coastal Plain Experiment Station, seed from China had been planted in previous years and PStV was found infecting experimental U.S. peanut lines. PStV was not detected in any of 57 commercial fields seeded with Georgia certified seed. The results of this survey were the first indication that PStV was not restricted to the Georgia Experiment Station, as previously thought.

During the latter half of the 1983 growing season, surveys were made in other peanut-growing states in the Southeast. PStV was identified in naturally infected peanuts in North Carolina, Virginia, Florida, and Texas. The situation was similar to the Georgia experience—the virus was found in research and institutional test plots but not in commercial plantings. In one state, the virus was detected in a foundation seed field. The seed harvested from this field was used for processing and not for planting.

In the 1983 surveys, the virus was found in the Uniform Peanut Performance Trial in all states cooperating in the tests. Seeds for these tests were provided by various researchers so that all seeds of each entry came from the same seed lot and would be uniform in all test locations. Residual seed not used in the field tests were obtained and planted in the greenhouse. One seed lot had a PStV seed transmission frequency of 2%.

Testing Peanut Seed

Tests to detect PStV were made on numerous seed lots known to have been grown or received in specific years. Original seed received from the People's Republic of China in 1979 and later that had never been increased in the United States gave rise to PStV-infected seedlings when grown in greenhouse tests. Also, seed from U.S. lines that had been grown near plantings from China seed produced plants infected with PStV. The earliest known contaminated U.S. peanut seed were from 1980 plantings.

Fig. 3. Peanut cv. Argentine showing symptoms of a virus reported from China by Xu et al (6) that produces a mild mottle. This virus is serologically related to peanut stripe virus and induces similar but milder symptoms.

Fig. 2. Peanut increase plots at the Southern Regional Plant Introduction Station at Experiment, Georgia. Planting different lines or cultivars close to each other increases the chances of infection in all entries.

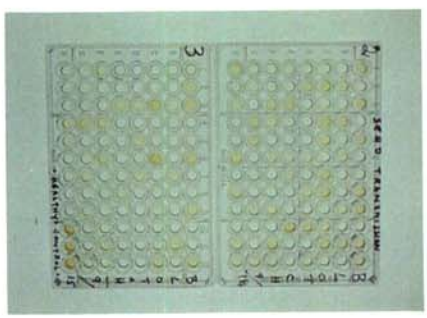


Fig. 4. Microtiter plate of the direct enzyme-linked immunosorbent assay used to detect peanut stripe virus in peanut seeds.

Table 1. Potential losses in peanuts induced by peanut stripe virus (PStV), based on percentage of plants infected and reduction in yield

Percent plants infected with PStV	Percent reduction per plant	Percent reduction per crop	Total reduction in dollars (millions)[a]
20	5	1.0	8.5
	10	2.0	17.0
	20	4.0	34.0
50	5	2.5	21.3
	10	5.0	42.5
	20	10.0	85.0
80	5	4.0	34.0
	10	8.0	68.0
	20	16.0	136.0

[a] Assuming U.S. peanut production of 1.7 million tons at $500 per ton, for a total value of $850 million.

Apparently, the virus was undetected from 1980 until observed by Sowell in 1982 and in the meantime spread to numerous U.S. cultivars and breeding lines. PStV is especially prevalent in peanut lines of the researchers and breeders who frequently exchange germ plasm with other persons and institutions. The common practice of planting different lines or cultivars close to each other (Fig. 2) increases the chances of infection in all entries. Where a seed-transmitted pathogen is involved, the probability of dissemination is enhanced.

Results of tests on the frequency of seed transmission of PStV have been variable. Seed from parents of U.S. lines inoculated at the third true-leaf stage and maintained in the greenhouse until maturity had 37% seed transmission in a Spanish type (Argentine) and 19% in a runner type (Florunner). Seed of peanut lines from the People's Republic of China not inoculated but contaminated with PStV (percentage of seed infection unknown) were increased in the field in Georgia. PStV spread from infected seedlings to healthy plants until over 90% of all plants became infected. Thus, some plants were infected early and some were infected late in the season. When seed from these lines were assayed, the seed transmission frequency ranged from 2 to 17%, with an average of 7%. Thus, it appears that seed transmission frequencies above 2% are readily attainable and that preventing dissemination of contaminated seed is critical for possible control practices.

Discussions with persons involved with peanut production, research, and quarantine indicate that PStV could have entered and been disseminated in the United States by various ways. Original seed from China in the U.S. plant introduction collection is one obvious means of entry and dissemination. In 1980, when a drought reduced the production of U.S. peanuts, a commercial shipment of peanuts from China entered the United States for processing, but some of the seed were used for planting. In 1981, a visiting delegation of scientists from China toured the United States and distributed small samples of certain lines of peanuts, some of which may have been planted. Also, individuals representing personal interest, business, or research groups may have exchanged contaminated seed.

Importance of PStV

The importance of PStV in U.S. agriculture is not restricted to peanuts. PStV is considered a legume virus because some cultivars of soybeans, cowpeas, lupines, and forage legumes such as arrowleaf, crimson, and subterranean clovers are susceptible. The effects of PStV on these hosts, whether the virus is transmitted through their seed, and the role of the hosts as reservoirs are not known. Furthermore, the importance of weed hosts that may serve as sources of the virus to future crops is unknown. Sesame and beggarweed growing next to infected peanuts were found to be infected. In 1984, however, over 1,000 peanut seeds were planted in an area at the Georgia Experiment Station known to have had PStV-infected peanuts during the two previous years. None of these bait peanut plants became infected, indicating that, at least at that location, weed hosts may not have been infected or did not serve as virus sources.

In a 1984 survey for virus diseases of peanuts in Southeast Asia by D. V. R. Reddy from the International Crops Research Institute for the Semi-Arid Tropics in India (*personal communication*), PStV was found naturally infecting peanuts in Thailand, Indonesia, and the Philippines. He stated that PStV appears to be the most prevalent peanut virus in the Philippines.

Yield Effects

Peanuts are infected by a number of different viruses that can cause extensive yield losses. Fortunately, some of these viruses are restricted geographically. In India, peanut production is severely hampered by infection with tomato spotted wilt virus (TSWV), which causes bud blight. Migrating thrips disseminate TSWV presumably from a nonpeanut host. Different geographic areas may not have the infected reservoir hosts for the migrating vector to acquire TSWV. In Africa, peanut production is restricted by groundnut rosette (GR). Aphids transmit the causal agent(s) in a persistent manner. GR is not known to be seed-transmitted in peanuts and thus must be carried to peanut fields by the aphid vector, which then must spend sufficient time on the peanuts for inoculation. Secondary spread is accomplished by aphids that colonize peanuts and migrate to neighboring plants. In other areas of the world, aphids may not extensively colonize peanuts. Again, different environmental conditions may not be favorable for this disease to become universally established. PMV naturally infects peanuts on all continents where peanuts are grown. This wide distribution undoubtedly resulted from the virus being seed-transmitted and seed-disseminated. Thus, a source of virus was provided. Aphid vectors for PMV are present in all areas where peanuts are grown. Since peanuts are a long-season crop, requiring 4.5 months to reach maturity in the southeastern United States, aphids have abundant time to acquire and transmit sufficient PMV to cause an epidemic. This ensures that harvested seed will provide a virus source for the next crop.

Although PMV induces a relatively low yield loss of about 20% (compared with losses induced by TSWV, GR, and peanut stunt), it probably induces more yield loss on a world basis than any other peanut virus, owing to its ubiquitous nature in most peanut-producing areas. PStV is similar to PMV in that both are seed-transmitted, are vectored by aphids in a nonpersistent manner, and efficiently infect peanuts. PStV, however, has a higher percentage of seed transmission and thus could provide more primary inoculum, which could lead to higher disease incidence early in the season and ultimately to greater yield losses. Therefore, we view PStV as a potential worldwide problem that needs immediate attention if further dissemination is to be restricted.

The effect of PStV infection on peanut yields is not known at this time. Two greenhouse tests comparing peanuts inoculated with PStV in the third- to fifth-leaf stage with an equal number of healthy peanuts and one field test under screen cages where the peanuts were inoculated 5 weeks after planting have been completed. The greenhouse tests resulted in a 20% reduction in both seed numbers and seed weight, and the field screen cage test gave a 5% reduction for the inoculated plants. Because of variation, however, the results of the three tests were not significant.

Although studies thus far have not provided definitive evidence of yield loss, the economic importance of PStV should be considered in other ways. Clearly, PStV-infected peanut plants can have fewer and smaller seeds. Also, the prevalence of PMV in the southeastern United States ensures that mixed infections of the two viruses will occur if PStV becomes established in commercial plantings. In fact, 22% of the peanuts in a 1983 research planting in Georgia were infected with both viruses. In 1984, 33% of the peanut samples sent from various southeastern states to the Georgia Experiment Station for virus assay had both viruses. Furthermore, most viruses have variants, some of which can cause serious disease problems. As we mentioned, the peanut blotch isolate is considered a variant of PStV.

Potential Economic Losses

PStV is currently restricted to institutional seed and peanut field plots. If PStV cannot be contained or eliminated in the United States, however, the dollar loss in peanut crops alone could be large. Assuming that U.S. peanut production is 1.7 million tons at a value of $500 per ton for a total value of $850 million, then Table 1 is a scenario of possible losses that could occur if PStV becomes established in the United States. The 20% yield loss is based on the yield of plants that are infected early (two- to four-leaf stage or seed-transmitted). Yield reduction should be less in plants infected at mid-growing season and may be only slight in plants infected late. Thus, even though 100% of the plants may become infected, the true yield loss for the crop may be 10% or less because of late-season infection. On the basis of our experience with PMV, we believe that a 5% initial seed transmission could result in 80% of the plants becoming infected by the third month after seeding. An 80% infection at an effective 10% yield reduction would result in a $68 million loss.

Detection and Control

Resistance to PStV is not known. Twelve commonly grown U.S. cultivars and 20 selected PIs were inoculated with PStV or peanut blotch. All became 100% infected after two mechanical inoculations. In addition, PStV is serologically related to a virus reported from China by Xu et al (6) that produces a mild mottle in peanuts (Fig. 3); they did not find resistance to the virus in 663 lines tested. Therefore, other approaches to control must be considered at this time.

The direct ELISA (Fig. 4) can detect PStV in peanut seed without harming germination. In a routine test, approximately 0.02 g of cotyledonary tissue, removed from the seed on the end opposite the radicle, is triturated in 0.5 ml of antigen buffer and 200 μl placed in a microtiter plate well. PStV can be readily detected in the embryo or cotyledonary tissue, but reactions using only seed coat are questionable. In multiple seed tests, one sample from a PStV-infected seed can be detected when triturated with nine healthy samples but not when triturated with 29.

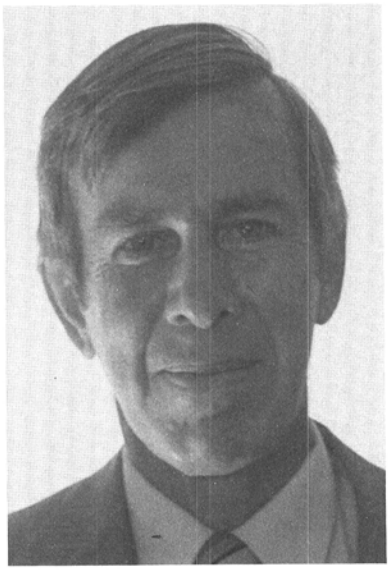
The distribution or movement of peanut seed is undoubtedly the reason why PMV is found in all areas of the world where peanuts are grown. Sufficient evidence is available to indicate that PStV could follow this same pattern if precautionary measures are not implemented. Indeed, PStV has entered the United States in peanut seed, and contaminated seed has been documented as a vehicle of dissemination in the United States. Although PStV is present in most U.S. peanut-producing states, its "isolation" at institutional sites gives hope that containment or elimination is possible, since these are the places where the greatest expertise in disease prevention is located. The problem has been identified—and this is the first step toward control. The key to preventing further spread of PStV rests with eliminating contaminated seed and permitting only virus-free seed to be distributed. If the problem is recognized by personnel in all areas where PStV is located, there is a chance that this virus can be eliminated. Working relationships among agronomists, plant pathologists, and extension personnel are needed. If personnel in all states do not work together, then PStV will continue to be dispersed in peanut seed and the virus will be distributed to commercial seed peanuts, where control will be extremely difficult.

Control Guidelines

The University of Georgia has issued the following guidelines for controlling and/or eliminating PStV in Georgia:

1. With the exception of breeding and variety performance tests, only Georgia certified peanut seed shall be used to plant research plots (foundation, registered, and certified seed are not contaminated with PStV).

2. Peanut seed from research plots shall not be processed through commercial



James W. Demski

Dr. Demski is associate professor of plant pathology with the University of Georgia but is located at the Georgia Experiment Station in Experiment. He received his B.S. in biological sciences from Clarion State College and taught high school biology and general science for 3 years. He earned his Ph.D. in plant pathology at Pennsylvania State University. Dr. Demski is project leader on peanut virus diseases for the Peanut Cooperative Research Support Program, funded by the Agency for International Development. He works on peanut virus diseases in the southeastern United States and in Africa, with direct linkage with Ahmadu Bello University in northern Nigeria.

Gilbert R. Lovell

Gil Lovell is the USDA-ARS location leader/research leader for the Southern Regional Plant Introduction Station in Experiment, Georgia. He received his B.S. degree in agronomy from the University of Southwestern Louisiana and his M.S. degree in range management in 1961 from Colorado State University. He also serves as coordinator of the S-9 Plant Germplasm Regional Project. The S-9 project is responsible for maintaining the peanut collection, as well as other crop collections, introduced through the National Plant Germplasm System.

cleaning and shelling facilities where mixing can occur.

3. Peanuts from experimental plots shall be processed or sold for processing only—and not be used for seed except in breeding tests.

4. All residual peanut seed and debris shall be removed from harvesting, handling, and transporting equipment before such items are moved from areas "contaminated" with PStV to "clean" areas.

5. All research plots containing plants inoculated with virus shall be grown under screen cages, with proper precautions to prevent spread, and be planted only on experiment station land.

6. Breeders shall release only seed that has been tested and found to be free from PStV.

7. Virus-free seed that is to be retained for future seed production shall not be planted in areas where PStV-infected peanuts have been grown previously.

8. Virus-free seed shall not be planted in proximity to leguminous crops or other hosts, and rigid weed control shall be practiced in and around virus-free plots.

9. Researchers shall not import peanuts from other states or nations unless the peanuts are either tested for PStV before planting or grown in screened isolation for one growing season to allow for visual inspection and serological assay if necessary.

10. Peanut-breeding plots shall be isolated from other research plots to the greatest practical extent possible.

11. The Uniform Peanut Performance Trial shall be planted at one university farm exclusively.

12. Soybean, cowpea, and other legume crop breeding nurseries shall be separated as far as possible from peanut research plots.

13. Every effort shall be made to remove all seed from PStV-infected research plots, and postharvest fumigation shall be applied where feasible.

14. Infected seed, except breeders' seed, shall be destroyed by burning, autoclaving, or fumigation.

In addition, breeders' seed and plant introduction seed in Georgia that are known to be contaminated with PStV are being tested by the direct ELISA. Individual seed that test positive will be destroyed and only those that test negative will be used for future plantings.

The exchange of germ plasm within and between countries is invaluable. The title of the paper by Waterworth and White (5), "Plant Introductions and Quarantine: The Need for Both," applies to PStV and the distribution of peanut seed. The improvement of peanut production rests, to a large extent, on the incorporation of new germ plasm. Germ plasm exchange needs to be continued but it must be balanced with adequate safeguards to prevent the dissemination of disease agents.

Acknowledgment

Research for the material presented in this article was supported in part by state funds allocated to the Georgia Experiment Station and in part by the Peanut Cooperative Research Support Program (CRSP), U.S. Agency for International Development (AID) grant DAN-4048-G-SS-2065-00.

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