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Department of
Agriculture

Animal and
Plant Health
Inspection
Service

Plant Protection
and Quarantine

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New Pest Response Guidelines

Potyviruses
(Family Potyviridae)

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PURPOSE AND DISCLAIMER

These New Pest Response Guidelines provide information concerning actions for mitigating the impact of any of the viruses of the family Potyviridae.

It is to be used as an aid for States when developing State action plans. The procedures described in this New Pest Response Guidelines were developed by Plant Protection and Quarantine (PPQ), Program Review and Planning (PRP) Staff through discussion, consultation, or agreement with other Animal and Plant Health Inspection Service (APHIS) staff, the Agricultural Research Service (ARS), and University advisors.

This document is not intended to be complete and exhaustive. The information given herein was taken from some of the available literature and synthesized into a specialized paper intended to assist further work, as stated above. Some key articles were not available at the time this was written, nor have all pertinent specialists and other members of the research community been consulted for their advice.

GENERAL INFORMATION

Action Statement

The information contained in this document is intended for use as guidance in designing a program to detect and respond to an infection of a Potyvirus (PotyV) of quarantine significance. These New Pest Response Guidelines provide information on implementing detection and control procedures for any of the Potyviridae and in reducing or suppressing spread to other locations. It provides technical and general information needed to implement any phase of a Potyvirus detection, control, containment or eradication program. Specific emergency program action must be based on information available at that time.

Initial Program Procedures

The following steps should help serve to initiate program efforts and to keep in mind throughout the beginning stages.

Step 1--Identification and Detection:

It will be most important to determine the identification and detection procedures that will be used throughout the program. Options that may be employed are given under Identification Procedures and Addenda 4 and 7 of this document.

Step 2--Scoping the Problem:

It will be necessary to determine the extent of the infestation and the difficulties faced by program managers through a good survey and a determination of the biological (see Addendum 7, Life History) and practical realities in advance of any active program to control, suppress, or eradicate a given PotyV. In this light, the kind of vector is important, i.e., if it is an aphid, a whitefly, a mite or a fungus, and its mode of transport.

Step 3--No Action to Eradication:

The effectiveness of the various control options must be considered, including regulatory action (see Regulatory Procedures), available options for control or suppression of the vector population, and destruction or treatment of the hosts (see Control Procedures and Addendum 5). From this information, and in the light of available information and resources, a decision must be made to either take no action (a program is impractical), or to control, suppress, or eradicate the viral population, if possible (see Control Procedures, Selection of Options and No Action for decision options).

Background Information

Potyviruses are the largest and economically most important group of plant viruses. A number of viruses could cause serious economic problems if they become established in new areas. This includes Plum pox virus and Potato virus Y - the necrotic strain. Others which could become serious are Barley yellow mosaic virus and Barley mild mosaic.

PotyV are rod shaped viruses characterized by flexuous, filamentous particles approximately 680-900 nm long and 10-13 (usually) or sometimes 15 nm wide. All potyviruses induce characteristic cytoplastmic inclusions in their hosts. Their distribution is world wide. PotyV are spread through the intervention of vectors and many are spread through seed transmission. The vectors are aphids, whiteflies, mites, and fungi.

Life Cycle Information of Vectors

Vector development is temperature dependent. Egg, nymphal, and adult development of arthropod vectors are influenced by the air temperatures. Development may also be influenced by the host. There is a minimum threshold below which no measurable development takes place.

For Green peach aphid, *Myzus persicae* (Sulzer) which has been chosen as an example, this threshold on *Solanum tuberosum* L. (White potato - chosen because this potato stock is common in the United States) is 39.2 °F (4 °C ±1 °C) in air (Whalon & Smilowitz, 1979). A temperature model that is designed to use modified air temperature data for all arthropod stages can be used to predict the entire life cycle. A number of degrees accumulated above the developmental threshold for a life stage are called day degrees. One day degree is one day with the average temperature one degree greater than the threshold for development.

For the model depicted in the table below, 265.60 day degrees in Fahrenheit (129.78° ± 11.66° in Celsius) must be accumulated before one life cycle has been completed (Komazaki, 1982).

Day Degree Calculations

Formula:

Minimum Daily		Maximum Daily		Total		Average Daily		Threshold		Day Degrees
Temp °F	+	Temp °F	=	$\frac{\text{Temp °F}}{2}$	=	Temp °F	-	Temp °F	=	# of DD

Example: (Air Temperature Model with 39.2 °F Threshold on potato)

Minimum Daily		Maximum Daily		Total		Average Daily		Threshold		Day Degrees
54 °F	+	74 °F	=	$\frac{\text{128 °F}}{2}$	=	64 °F	-	39.2 °F	=	24.8 DD

Other vectors may have different thresholds. Fungal vectors may follow general development of the host plant and the guidelines given here are not applicable.

Program actions are governed in part by vector life cycle data. Control and/or eradication treatments, length of survey activities, and regulatory functions are affected primarily by the length of time it takes for a vector to complete its life cycle.

Temperature data are available from the National Oceanic and Atmospheric Administration, the U.S. Department of Commerce, private, State, university, or industry sources, or from remote site weather monitoring stations run by any of the above. Unforeseen delays in completion of the life cycle must be anticipated.

IDENTIFICATION PROCEDURES

Introduction

Correct and proper identification is the key to determining if any program will be attempted at all, and if so, the extent, direction, and magnitude of the program. It will also help determine program changes and program failures, and in the latter case, the decision to discontinue a program will very likely be due to a determination that program efforts are not succeeding, based on identifications of perceived viral spread and/or finds.

Identification Characters

General Description of the Potyviridae:

Rod-shaped plant viruses with flexuous filamentous particles 680 - 900 nm in length which cause the formation of unique pinwheel shaped cytoplasmic inclusions in plant tissues when viewed in transverse sections and as bundles in longitudinal sections. The inclusions are cylindrical, conical, or ellipsoid hyperboloid in shape when viewed in 3-dimensions. Potyviridae are also identified by the "potybox" motif, the 12-nucleotide conserved sequence (TCAACACAACAT) or 5' non-coding and non-structural protein sequence, which is unique for this family.

Inclusions:

The inclusions consist of a central tubule with 5-15 plates or lamellae attached. The lamellae consist of a single virus-coded protein of M_r66-74.000, having a lattice with a periodicity of c. 5nm.

There are several characteristic structures, although inclusions are constant for individual viruses in different hosts and this fact may help in the specific identification of a virus.

- Some inclusions are rolled to form scrolls (Type 1).
- Others are stacked in flat layers to form laminated aggregates (Type 2).
- Others are a combination of the above (Type 3).
- Some have predominately short curved laminated aggregates (Type 4).
- Some are of a crystalline nuclear nature, consisting of equimolar concentrations of two virus-encoded proteins of M_r. These are c.49k (a polyprotein proteinase and VPg) and c.58k (probably an RNA-dependent RNA polymerase).
- Some consist of non-crystalline amorphous inclusions of one protein of M_r53-58k. This is serologically related to, and possibly an aggregated form of helper component protein.

Particles:

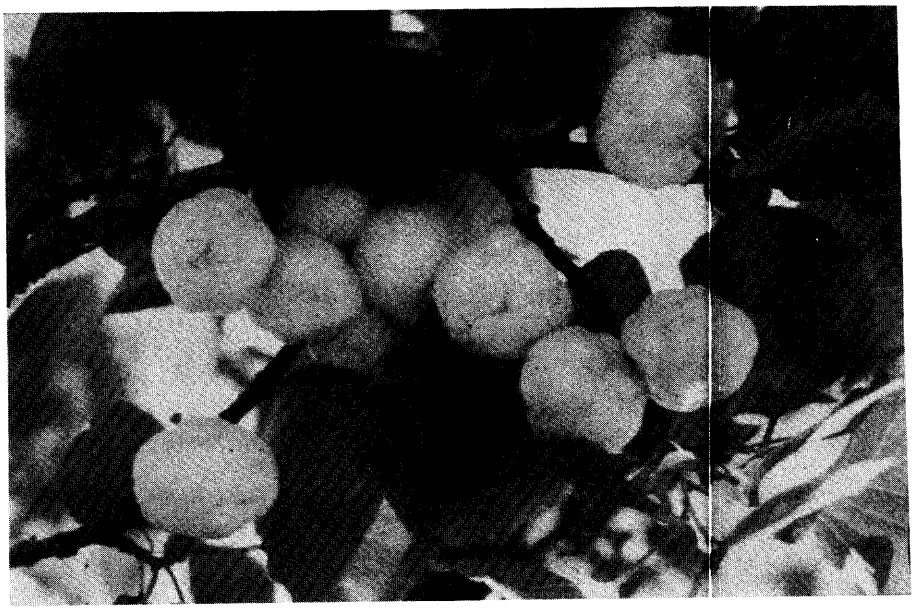
Potyviruses have slightly flexuous filamentous particles 11-13 (usually) rarely 15 nm in diameter. Those transmitted by:

1. Whiteflies are mostly 900 nm long. (Unassigned - 1)
2. Aphids are mostly 750 nm long. (Potyvirus; Unassigned - 2)
3. Mites are mostly 700 nm long. (Rymovirus; one Potyvirus)
4. Fungi are mostly either 275 or 550 nm long. (Bymovirus)

The particles contain roughly 95 percent protein and 5 percent nucleic acid. The capsid proteins consist of a single polypeptide, usually of M_l 32-36000. The coat proteins each contain about 300 amino acids. The protein helix has a pitch of 3.3-3.4 nm and there are 7.7 subunits per turn. The polymerized protein of PotyV reassembles with viral RNA into short filaments, but alone into long flexuous stacked discs or rings.

The monopartite potyviruses contain a single stranded positive sense RNA genome of $M_l 3.0\text{-}3.5 \times 10^6$ (8.8-10.25 kb) which is polyadenylated (20-160 adenosines) at its 3′ terminus and with a virus protein (VPg) covalently linked to the 5′ terminus.

The bipartite genome of the fungal-transmitted viruses has an RNA1 of 2.6×10^6 (7.6 kb) and an RNA2 contained within the shorter particles with a size of 1.5×10^6 (3.6 kb).



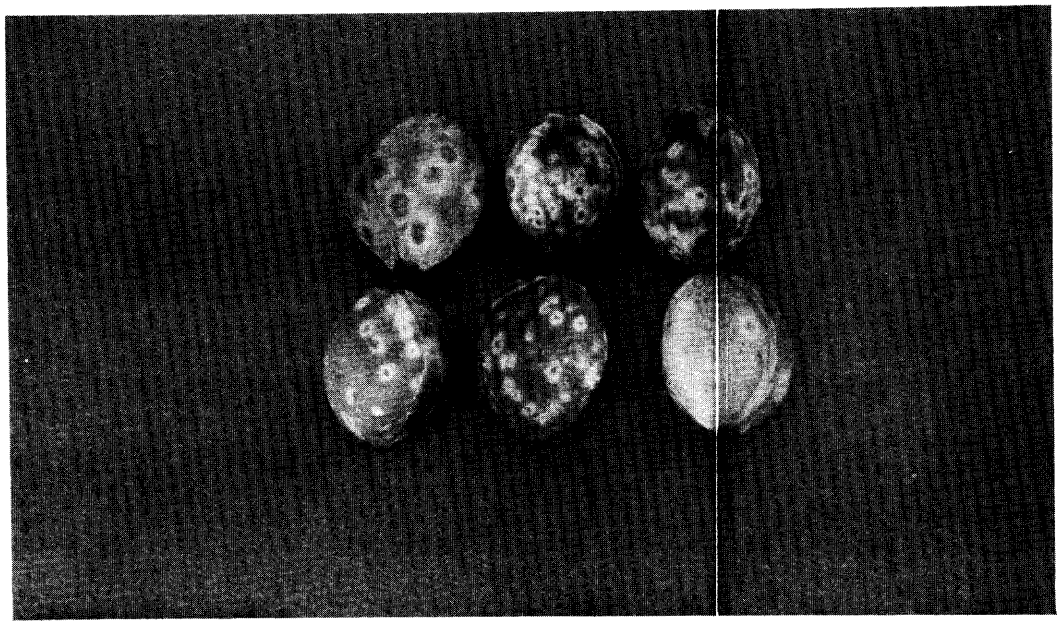


Figure 2: Typical Plum pox virus spots on apricot stones

Figure 3: *Plum pox virus symptoms on plums*

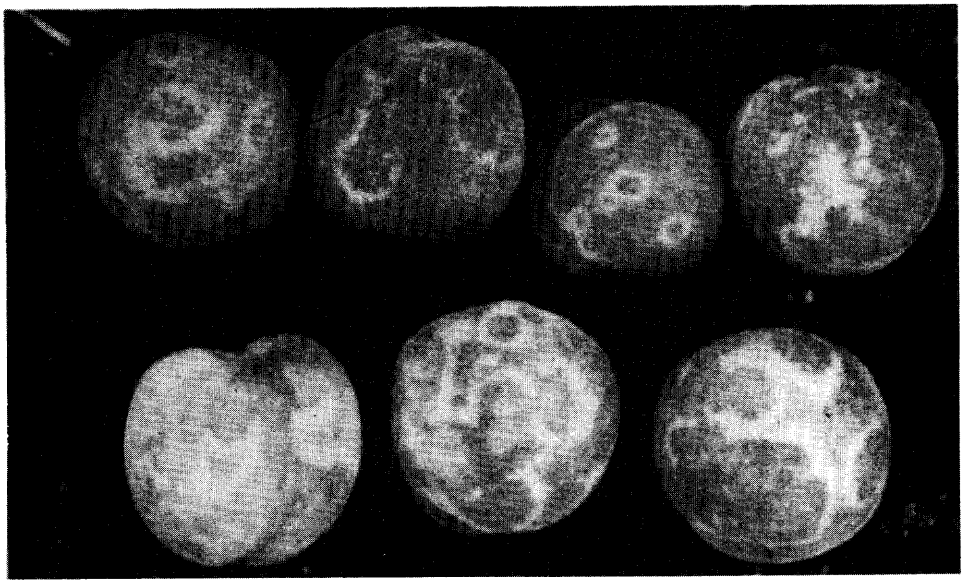


Figure 4: Plum pox virus symptoms on peach

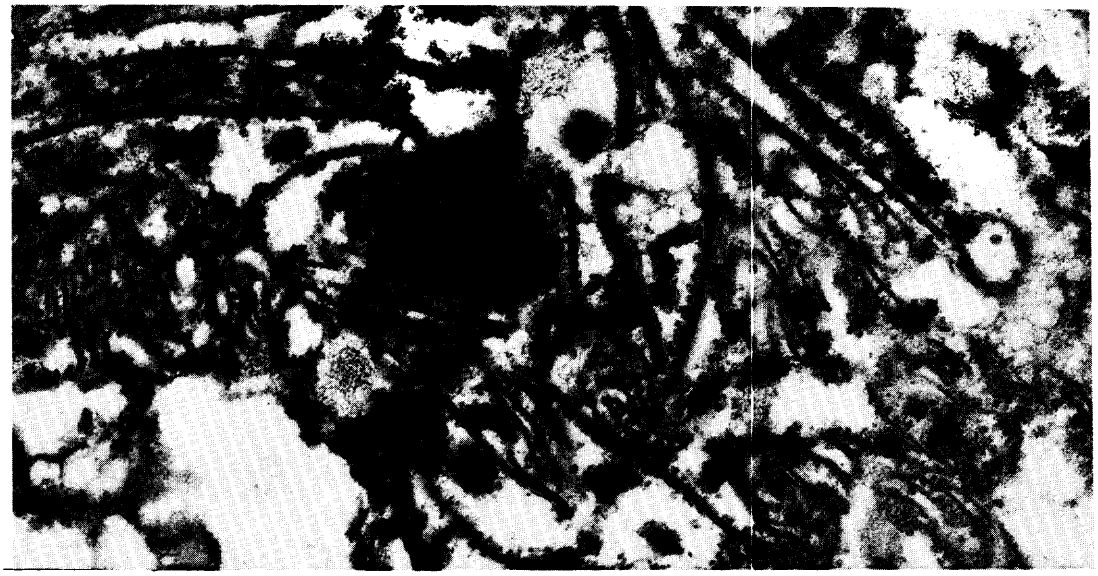


Figure 5: Inclusion bodies induced by Plum pox virus infection in sour cherry cells

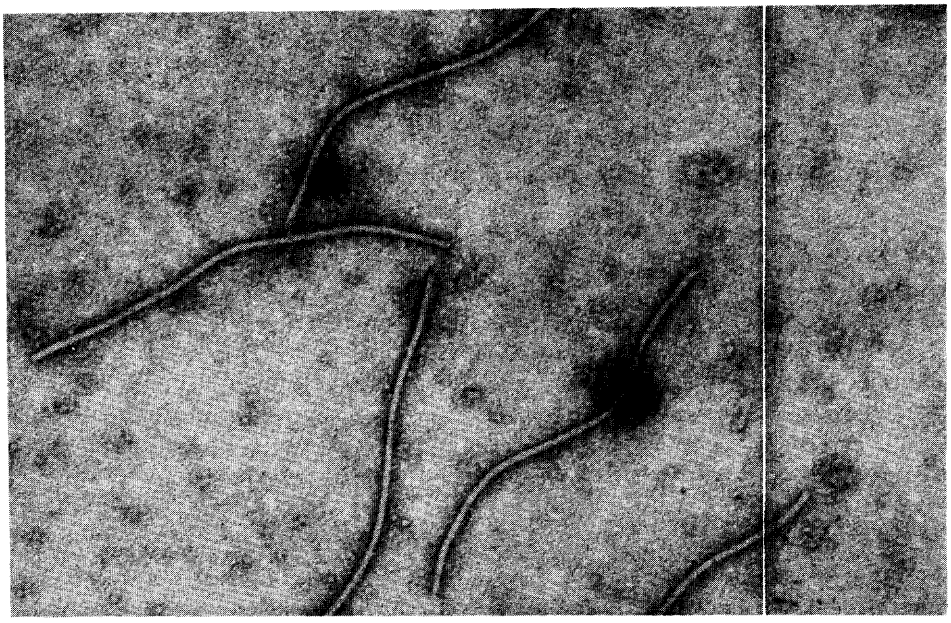


Figure 6: Virus particles of Plum pox virus

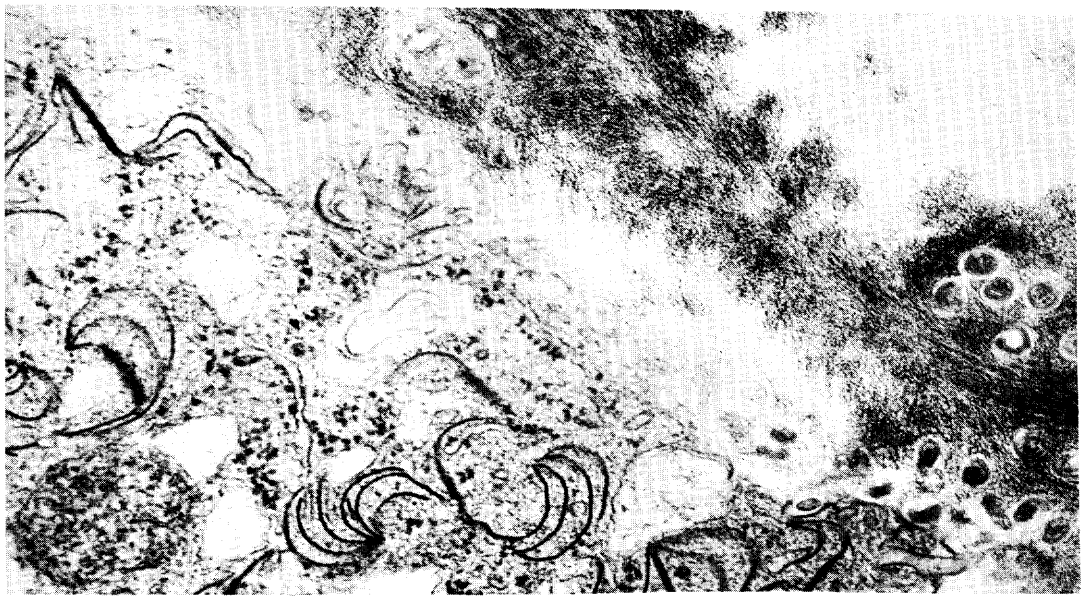


Figure 7: Inclusion bodies induced by Iris mosaic virus, Bearded iris strain, infection, in blackberry lily cells

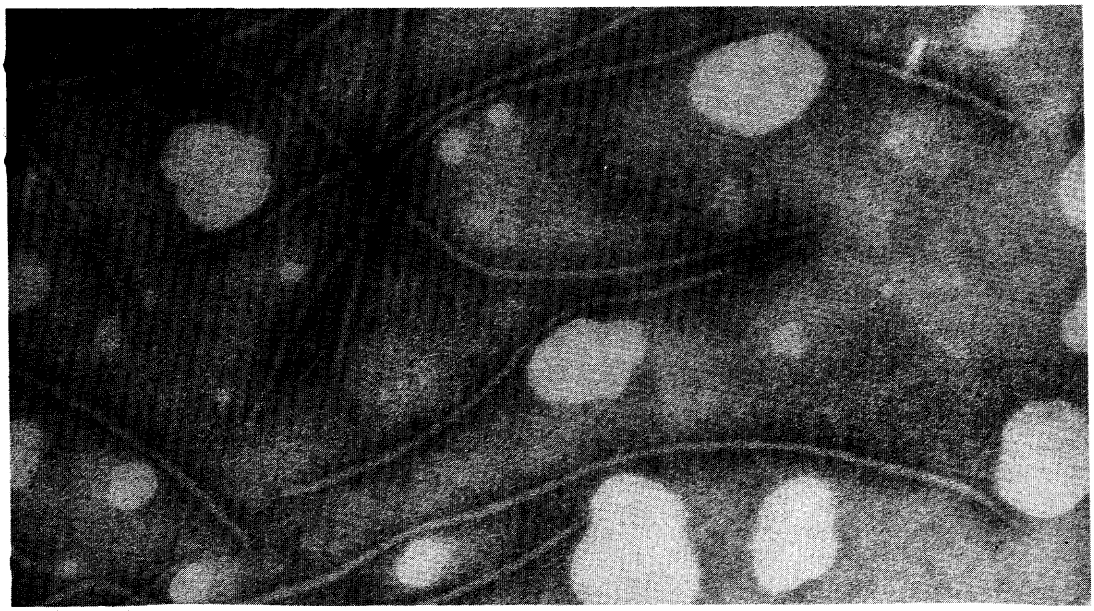


Figure 8: Virus particles of Iris severe mosaic virus, Bearded iris strain

Collection of Specimens

As many specimens as possible of suspect samples are to be collected for screening/identification by the local designated identifier.

Preservation and Shipment of Samples:

The following procedures were developed for the Canadian/U.S.A. PVY^n Management Plan. In general, this may be followed for leaf samples. Different procedures may be necessary for other plant parts and for vectors. Field procedures may also differ depending on the identification technique used.

Instructions for the Preservation and Shipment of Leaves for Laboratory Diagnosis of PVY^n

- The normal sample size per plant is the terminal three leaflets, attached (and should remain connected) to the petiole of a compound leaf from the upper portion of the plant. However, if the leaflets are less than 4 centimeters (cm.) long, the number of leaflets collected (still attached to a single petiole or stem) should increase in compensation to provide a total tissue mass equivalent to three leaflets 4 cm. in length. If this cannot be done, then take the whole compound leaf.

- The leaf samples should be bagged in composites of 100. Loosely folding over the opening of the bag and stapling shut is a good way of sealing the bag. The bag should not be sealed air-tight, particularly if it is warm or damp; if necessary make breathing holes.

- The leaf samples should be cooled (BUT NOT FROZEN) to 5° C as soon as possible. This should be done within hours of picking (particularly on warm days). If ice-packs (-15 to -20° C) are used, they should be insulated with two or three layers of paper or other packing material and be placed in the middle or top of the cooler. Two 6" x 6" ice-packs per cooler are usually sufficient. Avoid packing the leaves too tight.

- If the leaves are to be shipped to the lab by courier, the leaves should be held overnight in a refrigerated storage. For shipment, the bags of leaves should be packed loosely in styrofoam containers and placed in cardboard boxes. An ice-pack should be included, but it should be sufficiently insulated with paper so as not to freeze any leaves.

- A complete list of contents should be placed on the top of the samples or with the bill of lading (if an overnight courier is used) and signed (if possible) by the person collecting the sample.

- A field log of sampling dates, samples submitted, etc. is recommended to assure sample continuity from the field to the lab.
- Shipment of samples should be postponed if it is apparent that the package will be held in transit over a holiday or a weekend.
- Regular communication (e.g., phone and/or fax) between collectors and the destination lab is recommended in order to optimize the use of testing resources.
- Initial identification should be confirmed with more than one technique. If confirmatory testing after screening test is to be performed at another laboratory, the leaf samples should be placed in good quality paper bags, then packed and shipped as above.

Identification Techniques

The identification technique(s) used for a given program should should be appropriately sensitive, accurate, rapid, and suitable for the specific situation. To achieve these ends, any single technique or combination of techniques may be utilized. In most cases, initial identification of a possible find should be followed by specific identification, using a different technique in order to ensure the accuracy of the process.

Before identification can begin, it may be necessary to assess the quality of the sample. The following classification scheme may be used as a guide:

Good - Sample tissue contains no broken-down tissue and entire sample is in good condition.

Fair - Sample tissue is almost completely intact with some breakdown evident.

Poor - Sample tissue contains some breakdown, but intact tissue is present from each sample and can be bioassayed.

Very Poor - Sample tissue is largely broken-down with no intact tissue from each sample. **Such samples should NOT be bioassayed.**

The following are various procedures for identification. The technique selected for a given PotyV may depend on program needs and goals.

Biological Indicators:

Biological indicators may be used for initial identification in some cases. Sometimes, under limited circumstances, they can be used to give a specific identification.

Host(s)--Discovery of known symptoms in a host is a good indicator, especially if the vector(s) is present.

Inclusions--The discovery of characteristic inclusions in samples of known hosts is also a good indicator.

Light Microscope--The use of a good light microscope to study and/or confirm any of the above observations, may, under program conditions, be used to verify finds, if it is certain that no other viral pest is likely to be confused with the virus in question.

Advanced Laboratory Techniques:

The following include techniques completed in the laboratory. Unless it is possible to fully verify a find through biological indicators, one or more of these methods may be used as the final authority for a find.

Polymerase chain reaction (PCR) and molecular hybridization (MH) could be used with universal probes to identify potyviridae in general, or in some cases with a specific probe to identify the virus of concern.

Enzyme-Linked Immunosorbent Assay--This procedure, called ELISA for short, is currently the easiest detection method for most potyviruses. A sample of the plant part most likely to contain the virus must be collected from hosts, especially from parts showing suspect symptoms, and sent to the lab, with full collection data (Klein & Wyatt, 1989).

In general, a small sample of the specimen is ground in a buffer and incubated for a few hours before mixing with a monoclonal antibody. This is again incubated for a few more hours on a substrate in a ELISA plate and then diagnosed with the help of a reader.

In some cases, specimens may have to be grown for weeks or months from germplasm to determine the presence of a given virus through an ELISA test. This particular procedure is not recommended for a program if samples from suspect host plants can be processed and determined within a reasonable time frame (Bravo-Almonacid, et al., 1992).

Direct Tissue Blot Immunoassay--The Direct Tissue Blot Immunoassay (DTBI) is an immunoassay technique that utilizes direct blotting of plant or animal tissue onto nylon (preferred-Navot, et al., 1989) or nitrocellulose membranes. The assay is specific, sensitive, reliable, and rapid. Large numbers of samples may be assayed in this way. The technique precisely locates any antigens present in plant hosts or animal tissue.

The blots can be carried out in the field with just a few instructions and then transported to diagnostic laboratories for processing. Results will still be valid for at least a month after the sample was taken. Blots can be stored permanently after processing (Hsu, et al., 1993; Bravo-Almonacid, et al., 1992).

Field Procedures (Navot, et al., 1989)

Plants - leaves, flowers and other plant parts may be squashed onto a dry nylon membrane, using a hard object such as a glass rod or pen. Stems are cut longitudinally or sliced serially from the apex to the crown and squashed. Fruits are cut open and imprinted on the membrane.

Insects and Mites - Carry live to the lab for immediate freezing at -20° C. When frozen, vector bodies may be squashed on a nylon membrane as above.

Squash-Blot Molecular Hybridization (Bravo-Almonacid, et al., 1992)--Use of genomic libraries is essential to this technique. Clones need to be prepared from the samples and double stranded DNA obtained by plasmid purification and restricted with endonucleases to liberate the inserts. These are subjected to electrophoresis in agarose gels and cDNA viral fragments are obtained. These are in turn purified by electroelution and labeled with radioisotopes through a random oligonucleotide priming method. The samples are then subjected to molecular hybridization. If of the right virus, even a small amount of suspect RNA equivalent to about 1 ng of virions can be detected after an 8 hour exposure of membrane to auto radiograph film. This procedure is therefore more sensitive than ELISA for virus detection.

Reverse Transcription-Polymerase Chain Reaction--The most sensitive identification utilizes reverse transcription-polymerase chain reaction (PCR). This technique amplifies a specific segment of the virus' unique nucleic acid sequence and makes enough additional copies of it for quick and reliable detection. Amplification takes only 3-5 hours and the results are available in a day or two. The following PotyV can be directly diagnosed by PCR (Becker, 1993):

PPV
PLV

Immunodiffusion Test--If antisera for virus identification is available, virus isolates taken from vectors may be identified serologically in a sodium dodecyl sulfate solution, in gel diffusion plates (Adlerz, 1987). It should be kept in mind that this test is the least sensitive procedure of the advanced techniques listed here.

Field Procedures (R.P. Singh, 1988)

Collect 500 leaves from each site or 10 woody hosts at each locality outlined in the survey, in batches of 100. If not immediately used, store at about 5 - 10° C until time to extract the nucleic acids.

SURVEY PROCEDURES

Introduction

The objective of the survey is to determine the extent of viral and means of viral spread in order to make a regulatory decision (see Control Procedures, Selection of Options and No Action). Aside from determining where a local vector(s) may have spread the virus, human and other natural means of dispersal must also be considered. Such pathway dispersal must be factored into an active survey if it is not adequately covered under Regulatory Procedures.

Vectors

It may first be necessary to determine the local vectors present for a given PotyV, if this is not already known. Aside from Direct Tissue Blot Immunoassay (DTBI) from field collected possible vectors (See II.B.2.b), trials may be necessary to determine local transmission of the PotyV (i.e., see Webb & Kok-Yokomi, 1993). This is because DTBI does not confirm vectoring, but only that a virus reservoir is in the sample. The carrier, in fact, may or may not, be able to transmit the virus to a susceptible host.

In the meantime, the following parameters shall govern vector aspects of the survey.

1. If the vector(s) is known and it is determined that no other vector(s) or suspect vector(s) is present, then the survey will be based on that vector(s).

2. If a vector(s) is known and suspect vectors are also present, the known vector(s) takes priority in survey activities until competent investigation eliminates or confirms one or more suspect vectors.

3. If a vector is not known, then suspect vectors shall be monitored until competent investigation eliminates or confirms one or more suspect vectors.

Once the vectors are verified, they may be rated in effectiveness (Webb & Kok-Yokomi, 1993). However, since even an inefficient vector can transmit the PotyV, all vectors must be monitored for the purposes of an active program.

Detection Survey

Cross Transit Surveys are recommended for a rapid detection survey for a PotyV. This type of survey will also be used in support of a delimiting survey. The survey proposed here is biased towards the primary host(s) of concern, and in areas where the PotyV, if introduced, might be expected first to be found. Owing to the possibility of air dispersal of the vector, a special survey may be warranted for certain downwind areas.

There are three types of areas to cover in this survey:

High Risk Areas:

Major cities and towns where residents and visitors may be expected to travel to and from areas where the PotyV already exists.

Windward Areas:

- Those areas where winds may reasonably be expected to carry the vector(s) from areas where the PotyV already exists.

- If there is significant wind movement due to low pressure areas during dispersal stages of a vector, it is possible that viruliferous vectors from an infected area could be drawn toward such a system, locally increasing their density up to the level of inversion close to the cloud base. A downdraft could deposit these vectors over a relatively small area a considerable distance from the infected area. Vectors could also be deposited when winds die away in the evening.

  Provided that such a system was observed during vector dispersal and noted to rain or disperse elsewhere by evening, exposed downwind with hosts could be surveyed. This should be done in 3 to 4 weeks or longer, allowing any presumed vectors time to settle and develop to the point where they can be more readily observed by visual survey and samples for the PotyV are more likely to be positive. Any effort expended on such a survey should not be at the expense of regular program needs (APHIS, 1985).

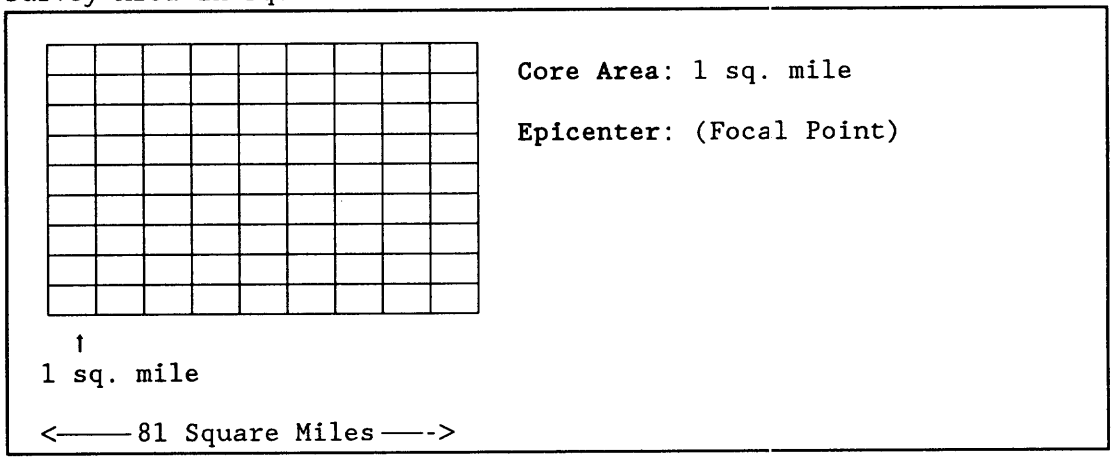
Commercial Host Production Areas:

Those areas where commercial hosts are grown.

Delimiting Survey

When one or more PotyV finds are confirmed in an area, a delimiting survey should be implemented immediately to determine the population distribution. Using the site of the detection as the epicenter (focal point), the survey should employ the following methods to delimit the prevalence of the pathogen.

Survey Area in Square Miles



Cross Transit Survey:

Cross Transit Surveys are recommended for a rapid delimination survey for the PotyV when a find is verified or suspected. The objective is to find and delimit the infected area in the shortest possible time with minimum labor and expense but with a high degree of confidence that, if present, it will be found.

The survey proposed here is biased in the same way as it is for the detection survey. It is biased towards the primary host(s) of concern and in areas where PotyV, if introduced, might first be expected to be found. Owing to the possibility of air dispersal of vectors, a special survey to track these vectors during the growing season may be warranted for certain areas.

There are three types of areas to cover in this kind of survey:

High Risk Areas--Major cities and towns where residents and visitors may be expected to travel to and from areas where the PotyV already exists.

Windward Areas--Those areas where winds may reasonably be expected to carry the vector(s) from locations where the PotyV already exists.

Host Production Areas--Those areas where large numbers of host material are found, as on commercial nurseries or farms where hosts are brought in for propagation and sale, grown for commercial purposes, or stored for replanting purposes.

Block Survey:

If a find is verified and the cross transit survey indicates the infected area is small and perhaps well defined:

- Conduct a block to block survey in the suburban/urban areas up to 7.2 km (4 1/2 miles) from each find.
- In rural areas, conduct a property by property survey up to 7.2 km (4 1/2 miles) from each find.
- Each block or property can be scored, if PotyV is present on any combination of host species, as:

  --**Light** PotyV only on one or a few hosts.

  --**Medium** PotyV on 6 or more hosts.

  --**Heavy** Entire area with numerous PotyV-infected plant hosts.

  The above will permit survey personnel to more accurately plot the area, extent, and nature of the infection, taking into account such variations as host range and availability of host(s), unequal distribution in infected hosts, and the influence of temperature (i.e., summer) on the titers obtained.

Each find may be considered a primary site. A primary site is the property on which an initial detection of a disease or pathogen occurs or a potentially infected site within 1 1/2 miles of an infected property, that is, those host areas within the infected area.

A satellite site is a potentially infected property more than 1 1/2 miles from any infected property. A satellite site, by definition, can be anywhere except within the 1 1/2 mile area around any infected property.

Delimiting surveys will be carried out on all primary sites. They also will be conducted on satellite sites when there is evidence of the possible spread of the pathogen to or from the infected property. The following conditions define those properties that will be surveyed as satellite sites.

- Any property that has received (within 3 years) propagative material from an infected property.
- Any property that has been the source (within 3 years) of propagative material planted on the infected property.

Fungal Vectors Only:

- Any site from which contaminated equipment may have originated, or to which contaminated equipment may have moved, provided conditions suitable for the development of the fungal vector are or have been present (excluding decontaminated storage sites).
- Any site exposed to infection by the movement of owners, consultants, and farm personnel.
- Any site to which contaminated soil has been moved.

The frequency of the delimiting survey will depend on the time it takes to cover the area, the resources available for repeat surveys, and if a decision is made to suppress or eradicate the PotyV involved. A maximum interval should be determined by program managers or based on the results of a review by a technical committee. In lieu of any decision, a suggested maximum interval would be 1 month between surveys.

Monitoring/ Evaluation Survey	A decision to suppress or eradicate the PotyV will require a monitoring/evaluation survey to check the PotyV population. Generally, a cross transit survey would be employed.
Orientation of Survey Personnel	New personnel will be trained on the job by experienced personnel. A period of up to 3 working days may be needed to do this.
Survey Records	Records noting the areas surveyed, sites trapped, dates, locations, and hosts in which detections were made will be maintained.

REGULATORY PROCEDURES

Instructions to Officers

Regulatory actions should be required until the pest is eradicated or declared established with no further suppression or control actions. Officers must follow instructions for regulatory treatments or other procedures when authorizing the movement of regulated articles. Understanding the instructions and procedures will serve as a basis for explaining such procedures to persons interested in moving articles affected by the quarantine and regulations. Only authorized treatment procedures may be used.

General instructions that are to be followed in regulatory treatments may be found in State regulatory manuals or in the PPQ, APHIS, Treatment Manual (PTM).

If a fungal vector is involved, all activities that involve entry into a field or plot in which the disease is suspected presents a danger of the inadvertent spread of the disease. To minimize this possibility, disposable gloves will be used, or hands will be washed thoroughly with soap and water before leaving each field or garden. Hands must be washed on site in order not to contaminate other areas. Rubber boots will be disinfected with quaternary ammonium (here assumed to have strong inhibitory activity against PotyV - See Nakajima, et al., 1983) between gardens or fields. In addition, all tools and equipment that come in contact with plants or soil will be disinfected between fields by washing with a quaternary ammonium compound.

Regulated Articles

A variety of articles may present direct or indirect risks of spreading PotyV. The movement of these articles will be regulated to prevent the infection from spreading. Regulated articles include:

1. Fresh leaves, stems, and tubers of hosts listed in Addendum 3 which exist in the regulated area (Reeves, 1992; Bell, 1988).

2. Host nursery plants, seeds, tubers, or other material with or without leaves and stems, including propagative material intended for planting.

3. Soil and plant products with soil attached, such as those vegetables considered to be root crops, from within the drip area of host plants when arthropod vectors are involved and from the regulated area when fungal vectors are involved.

4. Buildings such as seed houses, storage cellars, and bins which may have been used for storage of infected plant parts.

5. Bags, tools, farm implements, and vehicles used for transporting host material, especially if fungal vectors and under certain circumstances, mite or insect vectors are involved, as the potential exists for the virus to move with the vector as well as with host material.

6. Manure, if fungal vectors are involved.

7. Any other product, article, or means of conveyance of any character whatsoever when it is determined by an inspector that it presents a hazard of spread of the PotyV and the person in possession thereof has been so notified.

Quarantine Actions

Regulatory action will be required if:

1. A find is detected. When detections are made, the following steps should be taken:

a. State notifications are issued by field personnel to the property owners or managers of all establishments within 4 1/2 miles of the epicenter that handles, moves, or processes host material which may include material and/or conveyances capable of spreading the PotyV or the vector. Notifications will be issued pending authoritative confirmation and/or further instructions from the Head of the State Plant Protection Service and/or the Deputy Administrator, APHIS, PPQ.

b. If necessary, the Deputy Administrator will issue a letter directing PPQ field offices to initiate specific emergency action under the Federal Plant Pest Act (7 U.S.C. 150 dd) until emergency regulations can be published in the Federal Register. For information on other legal authorities, see Section II, Parts A and B of the APHIS Emergency Programs Manual (for plant pests).

c. The Head of the State Plant Protection Service and/or the Deputy Administrator of APHIS will notify other State cooperators of the PotyV detections, actions taken, and actions contemplated.

d. A narrative description of the regulated area with supporting documents should be developed by State personnel. The regulated area normally will be within an approximate 4 1/2 mile (mi) radius around the find, and may contain a 1 sq. mi or greater core area where premises may be treated.

e. The State may need to publish an interim rule covering the emergency regulations. The interim rule will announce a date for submitting written comments.

f. After receipt of written comments, a final determination specifying the action decided upon will be published.

Regulated Establishments

Efforts to detect the pest within the regulated area will be made at establishments where host material is sold, handled, processed, stored, or moved. Establishments that might be involved include airports, storage or store areas, landfill sites, fruit stands, farmer's markets, produce markets, flea markets, nurseries, and any other establishments that handle host material.

Use of Authorized Chemicals

The appropriate State manual and these New Pest Response Guidelines identify chemicals authorized for vector control, methods and rates of application, and any special application instructions. Concurrence by the appropriate State regulatory agency is necessary for the use of any other chemical or procedure for regulatory purposes. If treatments selected or proposed, including those listed in this New Pest Response Guidelines, are not in compliance with current pesticide labels, emergency exemptions will need to be obtained under Section 18, or 24C, Special Local Need (SLN) of The Federal Insecticide, Fungicide, and Rodenticide Act (FIFRA), as amended. Regulated articles may be certified for movement after treatment.

Approved Regulatory Treatments

Sanitation:

The removal and destruction of hosts and other material which may be associated with the regulated items.

Steam Sterilization:

The use of steam as a treatment alone, to conveyances, storage, or other holding areas to destroy any vectors present.

Cleaning:

The use of hot soapy water or quaternary ammonium compound as a treatment to conveyances, storage or other holding areas, tools or boots, or to host material to destroy any life stages of a vector which may be present.

Fumigation:

The application of an approved fumigant (methyl bromide) as a treatment alone, to hosts to destroy any vectors.

Hot Water:

The application of hot water at a specified temperature, as a treatment alone, to hosts in order to destroy any vectors present.

Ground Spray:

An approved insecticide/miticide or fungicide or biological insecticide/miticide or fungicide applied to the above-ground parts of nursery stock to destroy any insect, mite, or fungal vectors present.

Soil Treatment:

An approved systemic insecticide, miticide, or fungicide applied to the soil on nursery stock to destroy any vectors present, including any root feeding or soil borne vectors which may be present.

Polymer Webs:

Sheets of polypropylene fleece covering herbaceous hosts, especially crops and nursery plants in order to prevent feeding by aerial vectors (Harrewijn, et al., 1991).

Certified Virus-Free Propagative Material:

The planting of certified virus-free progagative material in the regulated area, away from infected localities.

For Fungal Vectors:

Disinfection or Fumigation of Tools and Boots:

All tools and boots that have come in contact with hosts or soil must be disinfected before removal from any property where survey, regulatory, control, or eradication work is conducted. Equipment will be thoroughly washed with a quaternary ammonium compound. Equipment must be washed on roadways or at the edges of fields or plots, owing to phytotoxicity.

If an infected site is fumigated, this disinfection requirement remains in effect until monitoring surveys determine that the fumigation is successful. If the site is not fumigated, this requirement remains in effect until the quarantine is lifted.

Disinfection of Vehicles:

If at all possible, vehicles should not be driven in fields, orchards, or gardens that may be infected. Vehicles which have come in contact with host plants or soil must be disinfected before removal from any property where survey or regulatory work is conducted. Portions of vehicles where soil is likely to adhere, such as tires, wheel wells, and the bottom of the chassis, should be washed thoroughly with quaternary ammonium. For large pieces of equipment, a high pressure delivery system is recommended to penetrate the soil and debris which may adhere to them.

If an infected site is fumigated, this requirement remains in effect until monitoring surveys determine the treatment is successful. If the site is not fumigated, this requirement remains in effect until the quarantine is lifted.

Disinfection or Fumigation of Storage Sheds, Bins, and Cellars:

Any shed, bin, cellar, or other structure that may have been contaminated with infected host material or contaminated with soil or equipment will be drenched with a quaternary ammonium compound or fumigated with methyl bromide. This requirement remains in effect until the quarantine is lifted. May be modified for household situations.

Prohibition on the Movement of Soil, Manure, Plant Parts, and Other Objects Contaminated With Soil and Manure:

No soil, whether free or attached to plant parts or objects, or manure will be removed from an infected property. This includes soil adhering to tools, boots, and vehicles. This requirement remains in effect until the quarantine is lifted.

Prohibition on the Movement of Root and Tuber Crops:

Root and tuber crops, and any below ground part of a host, will not be removed from any property which is known to be infected, unless they are moved under limited permit to an approved processing facility. Note that only resistant host varieties, if available, may be removed from infected properties for processing. Compliance agreements will be designed to prevent spread of contaminated soil during movement. This remains in effect until the quarantine is lifted.

Prohibition on the Movement of Nursery Crops:

Nursery crops with adhering soil will not be removed from any property which is known to be infected. This prohibition remains in effect until the quarantine is lifted.

Principal Activities

The following identifies principal activities necessary for conducting a regulatory program to prevent the spread of a PotyV. The extent of regulatory activity required is dependent on the degree of infection. For example, to safeguard fruit stands throughout the entire regulated area when these stands are only engaged in local retail activity may not be necessary during a localized and light infection. On the other hand, mandatory checks of passenger baggage at airports and the judicious use of road patrols and roadblocks may be necessary where general or heavy infections occur.

Principal regulatory activities include:

1. Contacting and advising regulated industry of regulations and required treatment procedures.

2. Issuing compliance agreements, certificates and permits.

3. Supervising, monitoring, and certifying treatments of host material.

This may (or may not), if determined by program managers or by a technical committee to be practical, include the sampling of commercial shipments from the regulated area for zero tolerance for plant diseases; such as that given by:

$$PEA = e^{-np}$$

where PEA is the probability of erroneous acceptance of a field, e is the base of natural logarithms, n is the sample size, and p is the probability that a plant is diseased (Clayton & Slack, 1988).

4. Conducting compliance inspections at regulated establishments such as:

a. Nurseries
b. Fruit stands
c. Local growers, gardeners, and packers
d. Farmers, produce, and flea markets
e. Farm equipment and implement dealers
f. Farm and garden supply dealers
g. Commercial haulers of regulated articles
h. Public transportation officials
i. Post office contacts
j. Canneries and other processing establishments
k. Storage locations (i.e., potato storage-Panayotou & Katis, 1986; Bell, 1988)

5. Monitoring the movement of host material to landfills to ensure adequate disposal of regulated articles.

6. Monitoring the destruction of regulated articles to ensure adequate destruction of any life forms of the vector, and thus the PotyV, which may be present.

7. Monitoring the movement of regulated articles through airports and other transportation centers.

8. Observing major highway and quarantine boundaries for movement of regulated articles.

9. Notifying homeowners near detection sites of applicable regulations.

10. If applicible, monitoring to insure that only resistant host varieties are planted within the regulated area.

11. If subsurface vectors are involved (some aphids, mites, and fungi), supervising and monitoring the fumigation of all land found to be infected and the subsequent assays of fumigation effects.

12. If fungal vectors are involved, supervising and monitoring the disinfection and fumigation of tools, equipment, and buildings that may have come in contact with infected host or contaminated soil.

13. Visiting processing establishments, if present, in regulated areas. If fungal or mite vectors are involved, sampling of sweepings from these establishments should be carried out.

14. Monitoring sale and transfer of infected property to insure that property users are aware of restrictions on land use.

Removing Areas From Quarantine

Areas placed under regulation may be removed from quarantine requirements after the PotyV has been declared eradicated. Program management will identify areas to be removed when the equivalent of 3 years has passed since the last pathogen recovery. One year must have elapsed since the cessation of control activities. A Notice of Quarantine Revocation will need to be published when areas are removed from quarantine requirements.

Orientation of Regulatory Personnel

Only trained or experienced personnel will be used initially. Replacement personnel will be trained by the individual being replaced.

Regulatory Records

Records will be maintained as necessary to carry out an effective, efficient, and responsible regulatory program.

Records may include:

- Maps
- Chronology of events/actions
- Personnel movement
- Treatment records
- Regulatory activities
- Meeting notes

CONTROL PROCEDURES

Introduction

As control procedures are developed, they will be made available to involved States. There will be no Federal involvement in direct control programs. If treatments selected or proposed are not in compliance with current pesticide labels, an emergency exemption will need to be obtained under Section 18, or 24C, special local need (SLN), of FIFRA, as amended.

Eradication or suppression of a PotyV infection in the continental United States may not be possible (Schoulties et al., 1987). However, under some conditions, it may yet be feasible to eradicate or control an infection. This has been demonstrated for the unrelated Potato Spindle Tuber Viroid (PSTV) on Prince Edward Island. In this case, the infection had been severely limited and reduced in size since the 1950's by a combination of planting of high-quality viroid-free seed, application of seed certification regulations, and the use of sensitive methods of testing to prevent reintroduction of viroid in the crop. This program was probably greatly assisted by the absence of a vector for PSTV (Singh, et al., 1988).

More recently, a clean culture (suppression of infected host stock) option management plan (E.6.c) was agreed to between the U.S.A. and Canada for PVY^n (Anon., 1993c). Since this virus has a number of endemic vectors, control may be more difficult but this arrangement should allow the continuation of commercial activities. This option has its roots in the successful eradication of Pea seed-borne mosaic virus (PSbMV) from the USDA Germ Plasm Collection of *Pisum sativum* (peas), which also has vectors (Hampton, et al., 1993).

The following provides approved procedures available for use in most situations. These procedures include biological, mechanical, and chemical controls. Local conditions will determine the most acceptable procedure or combination of procedures to achieve suppression, control, or eradication.

Recommended Pesticides

The treatments prescribed are predicated on an adequate survey. The following list of pesticides is those given for these treatments. However, newer treatments, pesticides, or other means of control may be available at the time of a given program. Therefore, at the initiation of a program, an evaluation will be made of all available treatments, methods and insecticides/miticides/fungicides for use on program operations.

1. Dimethoate
2. Immidacloprid
3. Pirimicarb
4. Diosulfoton
5. CGA-215944
6. Cyromazine
7. Glyphosate
8. Dithane
9. Dicrotophos
10. Monocrotophos
11. Methyl bromide
12. Acephate
13. Mineral oils
14. Sulphur
15. Safers soap
16. Mancozeb
17. Abamectin
18. Quinalphos
19. Malathion
20. Pyrethroids
21. Lambda-cyhalothrin
22. Nicotine sulfate
23. Chlorothalonil

Selection of Options

Program options may be selected through a decision-making process, such as embodied in the Potyviridae decision table below.

If the finds are:	And the viral population appears to be:	And the hosts are:	Then the option is:
Established in a large, contiguous area	→	→	NO ACTION
Present in a number of widely separate and discrete areas	Well established, as measured by: • population estimates • competition • environment OR • climatological considerations	→	NO ACTION
	Not well established and population estimates felt to be due to recent (within 1 year) establishment	Large number of hosts over an extensive area	Biological and cultural controls
Established in a small contiguous area		Moderate number of hosts over a well-defined area	Suppression, cultural, and biological controls
Present in only one or a few closely separate and discrete areas		Confined to a limited number of hosts	Control, suppression, and eradication

This decision table follows certain limited basic statements, and can be considered generally true in a biological sense, provided no other factors intervene. There are some underlying assumptions. For example, it is assumed that the PotyV in question will be able to survive in the same ecological and environmental circumstances as its host(s).

No Action

Factors involved in arriving at a decision of "No cooperative program action" include the following:

That the PotyV in question has firmly established itself in the infested area and that:

1. No reasonable effort will be successful in eradicating it (vs. a reasonable effort may be successful);

or

2. Regulatory and/or suppressive measures will not be worth the cost, owing to the area involved and/or the rate of spread (vs. affordable measures);

or

3. On the basis of measurable ecological factors, that the PotyV will not be present in sufficient amounts in the environment to warrant control or suppression efforts (vs. a serious threat);

or

4. Control of the PotyV is best left to normal cultural means of virus control (such as host destruction) and other regulatory resources utilized to find ways of controlling the spread and effects of the disease (vs. an urgent need to augment natural controls).

If any of these statements are not true, and the contrary is true instead, then a decision to take "No Action" should be carefully evaluated.

Approved Eradication/ Suppression/ Control Options

Various combinations of treatments to achieve a predetermined goal for a specific program may be either eradication, suppression, or control. This goal, and the strategies useful for eradication, containment, or control will be determined by State and local personnel and/or their technical advisory committees or equivalent advisory boards.

Approved Treatments

The following is a list of suggested treatments that may be applicable under certain conditions. The treatments selected should be determined by State and local personnel concerned with a given program and their Technical Advisory Committees or equivalent Advisory Boards. Addendum 5 lists certain additional treatments which may be available.

1. For control of Aphid Vectors

NOTE: Since vector specificity among the viruses appears to be the exception, many aphid species may be capable of transmitting these viruses. For that reason, noncolonizing aphids are often implicated in the spread of a potyvirus in a given host. These noncolonizing aphids may be the primary reason for spread of a given potyvirus, since causal, probing contact during the wanderings of migrant or transient alate aphids through a field or grove of a given crop or other susceptible plant species are all that may be necessary for an epidemic (Klein & Wyatt, 1989).

Should this appear to be the case in a given program, use of pesticidal vector controls may not be of great value (Klein & Wyatt, 1989).

In addition to the above, the use of insecticides in field applications, other than certain of the synthetic pyrethrins which have a quick knockdown effect, may actually increase the spread of a virus. This may be due to scattering the vector population(s) as a result of treatment.

In order to limit vector populations, and thus local viral spread, it may be advisable to treat the area around the documented site of the infection with persistent insecticides.

In view of the above, vector avoidance, cultural controls, and the use of a clean culture option (E.6.c) should play as large a role in program efforts as is possible.

a. Biological Insecticides

(1). Bacteria
(2). Viruses
(3). Nematodes

Items (1) to (3). Use commercial products listed for the vector(s) or suspect vector(s) identified by the program.

(4). Fungi

(a). Vertalec

Agent: *Verticillium lecanii*

This has been discontinued by Novo Biokontrol in the United States (Farm Chemicals, 1992).

Apply as per directions at the highest possible rate given for that host. An exemption may be needed for outside applications. Extremely toxic to aphids and whiteflies (Rondon, et al., 1980).

(b). *Cladosporium* sp. (Samways & Grech, 1986)

Not available in the United States.

Apply 4×10^8 conidia per ml as a spray in water with 0.1 percent Tween added as a wetting agent. Use as a cover spray, paying particular care to spray the shoots and the area immediately surrounding them. Repeat every 2 weeks as necessary.

(c). Naturalis-L (Wright, 1992)

Agent: *Beauveria bassiana* strain ATCC 74040

Apply 2.3 x 10^7 conidia per ml as a spray in an emulsifiable oil formulation. Use as a cover spray at the highest possible rate given for that host. Repeat every week as necessary. Excellent activity against aphids and whiteflies.

(5). Juvenile Hormones

(a). Kinoprene (ZR - 777) (Anon., 1976)

Discontinued 1985 by Zoecon Corp. (Farm Chemicals, 1992)

Apply at a rate of 0.1 to 0.13 percent to hosts. Extremely effective against homopterans.

b. Introduction of Exotic Natural Enemies.

This technique is carried out by USDA, ARS, and other agencies and institutions. It is assumed that the PotyV will be vectored by endemic, local aphids and the need here would be to find exotic natural enemies to help suppress the local population of these aphids.

c. Augmentation of Predators/Parasites in Infected Area(s).

This technique is applied by mass rearing of the most highly efficient parasites or predators for mass release in infected areas. The use of Beneficial Insect Planes (BIP), a type of model airplane controlled by radio, may be utilized to release parasites with less mortality than with conventional airplanes. Such craft can cover a 50 acre field in 6-7 minutes (Anon., 1993b).

Commercially available predators in the United States whose efficacy needs to be tested on aphids are:

(1). *Aphelinus mali*
A parasitoid of the wooly apple aphid and the black citrus aphid (Stoezel, per. com.) among many others (Farm Chem. Hand., 1992).

(2). *Aphidoletes typhlocybae*
A predatory midge which attacks all types of aphids (Farm Chem. Hand., 1992).

(3). *Chrysoperia carna* and *C. rufilabris*
Two generalist predators (Farm Chem. Hand., 1992).

(4). *Diaretiella rapae* (For Grain Aphids)
A parasite (Farm Chem. Hand., 1992).

(5). *Hippodamia convergens*
A generalist predator (Farm Chem. Hand., 1992).

(6). *Orius tristicolor*
Predator of eggs, etc. (Farm Chem. Hand., 1992).

NOTE: Some care must be made in the selection of predators, as these also may cause the prey population to scatter, thus spreading the virus.

d. Conservation of Predators/Parasites

This treatment refers to the conservation of natural enemies, native or introduced, through integrated procedures with highly selective predator/parasite friendly insecticides or techniques, biological insecticides, and cultural practices favoring predators and parasites.

(1). Soil Treatment (Milne, 1977)

Apply a 40 percent emulsifiable concentrate of Dimethoate at a rate of 0.1 m^2. Alternatively, dilute 0.5 ml ai in 250 ml of water and pour around the base of each individual plant. Repeat after 5-6 weeks. This is particularly pertinent if root feeding aphids (Panayotou & Katis, 1986) are present.

(2). Trunk Injection (Buitendag and Bronkhorst, 1980)

For woody hosts, trunk injection of selected insecticides will effectively curtail the pest population attacking an injected host, while protecting the predator/parasite population, except those individuals which may feed on or parasitize poisoned pests.

This technique is effectively limited to backyard situations or small areas, owning to its labor intensive nature and expense. Herbaceous hosts cannot be treated in this manner.

Materials

Dicrotophos or Monocrotophos 40 percent water soluble concentrate 20 ml disposable plastic syringes. Drill with 3.8 mm by 30 mm bit (minimum length).

Procedure

Drill 3.8 mm by 25 mm deep holes in the host, following the chart below.

Prepare a locking hole in the syringes. This is a small hole drilled through and near the top of the cylinder when the plunger is two-thirds of the way out. The hole goes through both cylinder and plunger and is large enough to permit a nail to pass completely through the syringe.

Fill the syringe up to one third full (never more) with the undiluted insecticide; then fill it up completely with air.

The syringe is now ready for use. It is inserted with a turning action into the hole prepared for it. The air in it is then compressed with the plunger, which is then held in position by passing the nail through the locking hole.

Absorption takes only a few minutes. This process is quicker when the hole is drilled through the longitudinal ridges of the trunk.

If the trunk's diameter, measuring 25 cm above the ground, is:	Then, for each tree, you will need to use:
Less than 50 mm	1 syringe filled with 0.5 ml of insecticide
50 mm to 74 mm	2 syringes, each filled with 1.25 ml of insecticide
75 mm to 100 mm	4 syringes, each filled with 1 ml of insecticide
101 mm to 125 mm	4 syringes, each filled with 1.25 ml of insecticide
126 mm to 150 mm	4 syringes, each filled with 2 ml of insecticide
151 mm to 174 mm	6 syringes, each filled with 3 ml of insecticide
175 mm or more	6 syringes, each filled with 3.75 ml of insecticide

NOTE: It will take approximately 3 minutes per person to fill four syringes and attach them to the tree, and only a few seconds to remove same, after absorption.

Treatment will be repeated every 4 - 6 weeks or following the advice of an advisory panel.

(3). Band treatment (Buitendag & Bronkhorst, 1986)

This treatment, consisting of the free application of insecticide to the tree trunk with a trunk applicator or paint brush, is obviously less selective and somewhat more likely to endanger a parasite/predator population. However, the area of application is still out of the way of most parasite/predator and prey activity.

Materials

Dicrotophos (Azodrin 400 g/l)
Azodrin fork applicator (see Figure 9)
Azodrin brush applicator (see Figure 10)

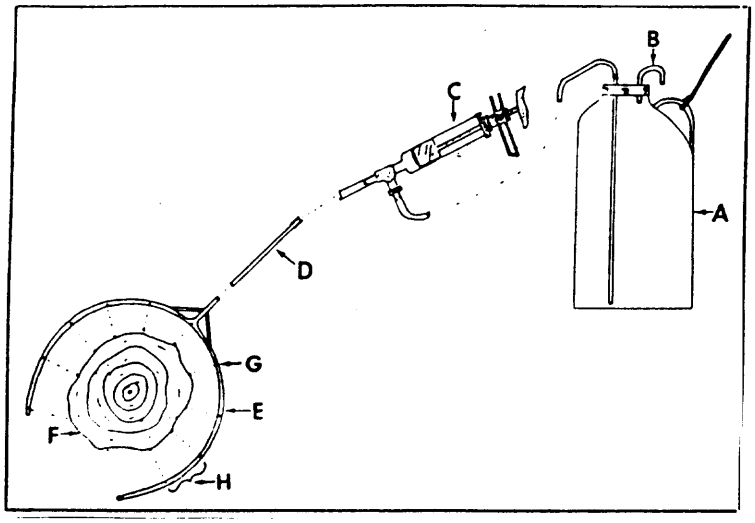


Figure 9: Azodrin trunk applicator for bearing trees (branch applicator). A = Azodrin plastic container; B = air inlet; C = 20 ml automatic syringe; D = 5 mm diameter supply pipe; E = spray fork; F = tree trunk; G = 0.75 mm orifice; and H = 50 mm for small fork and 20 mm for large fork

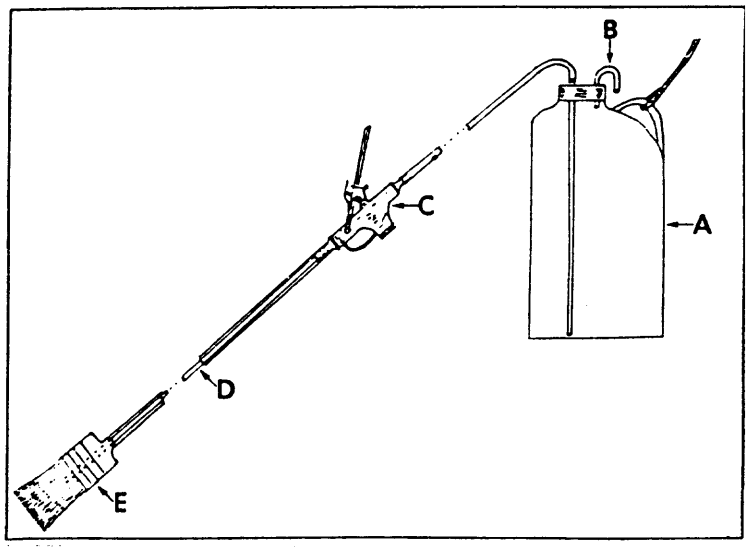


Figure 10: Azodrin trunk applicator for small trees (brush applicator). A = Azodrin plastic container; B = air inlet; C = stop valve; D = 5 mm diameter supply pipe; and E = brush

Procedure

Spray or brush the required amount of undiluted insecticide as given in the chart below. Cover the trunk with a wet band at the width given in the third column. Monthly treatments will be required.

If the circumference of the trunk is:	Then the amount of Azodrin needed is:	And the width of the Azodrin band needs to be:
30-39 mm	0.1 ml	9 mm
40-49 mm	0.15 ml	13 mm
50-99 mm	0.3 ml	16 mm
100-149 mm	0.8 ml	32 mm

e. Enablement of Predators/Parasites

This treatment refers to augmenting the ability of predators and parasites to attack the host with greater efficiency or to be more tolerant of insecticides or other practices through selective breeding of the most efficient predators/parasites. Gene manipulation may also be involved (Hoy, 1989, 1990; Caprio, et al., 1991). The work of Marjorie Hoy (now at the Univ. of Florida, Gainesville) in this area is instrumental to the concept and she should be consulted in designing any enablement program.

f. Ant Control

As an adjuvant to biological control options, ant control measures may be required to prevent ants from protecting aphids from parasites and predators. There are several types of options, depending on the situation.

(1). Backyard Hosts

Trees may be banded about 1 foot wide at the base of the trunks with an appropriately registered insecticide for ant control. The following insecticides are recommended for this use in the United States (Schwartz, 1982):

Bendiocarb	Carbaryl	Chlorpyrifos	Dichlorvos
Diazinon	Fenthion	Lindane	Malathion
Propoxur	Pyrethrins	Disulfoton	Acephate

In Brazil, it is recommended that dimethoate be sprayed on the trunk (Trevizoli & Gravena, 1978).

A recently developed South African control which avoids phytotoxic burns to the trunk is given below.

Bidim-plus-Gladwrap® Band

A 4 inch wide strip of Bidim U24® (a polyester fiber) is wrapped around the tree with an overlap of over an inch. It is then covered in turn with a double layer, 6 inch strip of Gladwrap®. A 2 1/2 inch strip of Formex® (a polybutene stickim) is then smeared over the masking tape, but not on the Bidim (Samways & Tate, 1984).

This barrier has a half-life of 18 weeks under South African conditions.

Hosts other than trees (such as soybeans) cannot be treated directly, but ant mounds or nests on the premises should be treated with an appropriately registered insecticide for nest control.

(2). Commercial Hosts

Broadcast application of an appropriately registered insecticide applied to the ground should be carried out. Under certain limited situations where the acreage is not too great, individual application to nests or mounds where ants are a problem may be employed.

g. Insecticides

The following are effective against an array of pests, including mites. Specifics are mentioned, where possible, under each insecticide. The pyrethroids are also efficient in controlling the spread of viruses, apparently because the vectors are intoxicated particularly fast. Intoxication results in feeding inhibition and flight induction; two obvious features in the prevention of vector inoculation.

(1). Dimethoate

Apply only when host is in flush growth. Use as a full-cover spray in water, taking care to wet flush leaves. Do not use on rough lemon trees on non-budded lemon stock (Hill, 1975).

NOTE: Broad spectrum insecticide.

(2). Immidacloprid

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host, or between 25 to 150 g/hectare a.i., at a biweekly rate (Mullins, 1993).

NOTE: Narrow spectrum insecticide with unknown effect on predators/parasites of aphids.

(3). Safers Soap

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host. Repeat every 2 weeks. This is a "safe" natural insecticide.

(4). Malathion

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host. Repeat every 2 weeks (Ware, 1980).

(5). Nicotine Sulfate

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host (Ware, 1980).

NOTE: Many aphids are resistent to nicotine sprays, hence it may be necessary to observe and quantify the effect on the target aphids.

(6). Disulfoton

Apply in granular form (i.e., DiSyston 15G) as a broadcast application at the highest rate given for that host or at the rate of 4.48 kg a.i./ha immediately before transplanting (Pirone, et al., 1988).

NOTE: This is a wide-spectrum systemic insecticide effective against both mites and insects. To be used in conjunction with (7). below (Pirone, et al., 1988).

(7). Acephate

Apply as a foliar spray (ie, Orthene® 75 percent EC) at the highest rate given for that host or at the rate of 0.84 Kg ai/ha at approximately 2 week intervals, or more often if aphid colonies are evident (Pirone, et al., 1988).

NOTE: This is a broad-spectrum insecticide effective against aphids, whiteflies, and other insects.

(8). Quinalphos

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host (Shevale, 1987).

NOTE: Wide-spectrum insecticide with unknown effects on parasites and predators of aphids.

(9). Pirimicarb

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host. In Brazil, this rate is 0.025 kgm ai/1.000 citrus trees.

NOTE: Relatively selective insecticide which spares some of the predators, vis, *Chrysopa* sp. and *Cycloneda sanguinea* in Brazil. Used in an integrated control program with dimethoate sprayed on the tree trunks to control ants (see 6.a. below) (Portillo, 1975; Trevizoli & Gravena, 1979).

(10). Lambda-Cyhalothrin

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host. In England, this rate is 7.5 gm ai/ha on potatoes for control of both vector and PVY (Perrin & Gibson, 1985).

NOTE: Effective against many insect pests and mites.

(11). CGA-215944

Apply whenever aphids are found as a foliar spray to hosts at the highest rate given for that host. A novel and still experimental insecticide in a new class. Very selective for aphids and whiteflies, but relatively nontoxic to mites. It is, however, also relatively nontoxic to predators of aphids and whileflies. About four times as effective as Primicarb. This insecticide may not yet be registered in the United States (Fluckiger, et al., 1992).

h. Mineral Oils

Mineral oils appear to interfere with the transmission of nonpersistent plant viruses by aphids. While not completely understood, the oil seems to interfere with the attachment or removal of virus particles from aphid mouthparts (Lowery et al., 1990; Qiu & Pirone, 1989). In combination with an insecticide, especially a pyrethroid, and a whitewash, very effective (Lowery, et al., 1990). The following are suggested oils:

Sunoco Sunspray 6 E®	(Lowery et al., 1990)
Sunoco Sunspray 7 E6 V®	(Makkouk & Menassa, 1985)
Bayol 52®	(Gibson & Rice, 1986)
SC811®	(Gibson & Rice, 1986)
Luxan Oil H®	(Asjes, 1991)
Duphar-7E Oil®	(Asjes, 1991)
JMS Stylet Oil®	(Qiu & Pirone, 1989)

Suggested application times: weekly

i. Cultural Control

(1). Sticky Ribbons

Sticky plastic ribbons (yellow) for control of (among other pests), aphids (Farm Chem. Hand., 1992).

(2). Yellow Sticky Strips/Traps

Plastic yellow sheets coated with an insect trapping compound for control of aphids (Farm Chem. Hand.). These are larger sheets used for mass trapping to impact the pest population, such as Chroma-line Bright® Yellow No. 611-L or Reuter Laboratory Sticky Bars®, item no. 142.

(3). Polymer Webs

Polymer webs laid over crops may decrease the number of aphids present, especially of apterous aphids. See 6.b. (Berlinger, et al., 1988).

(4). Whitewash

Whitewash is another reflective material which repels aphids. This property deters aphids from alighting on the treated hosts, thereby reducing spread of the virus. Whitewash (a water-soluble latex), applied at a weekly rate, has been able to reduce the incidence of PotyY by 68 percent on its own. However, it reduces

potato yields by 30 percent. This is in contrast to increased yields noticed in rutabagas (15 - 30 percent), cotton, and artichokes. Combinations with insecticides and oils provide the most effective means of control (Lowery, et al., 1990).

(5). Water Spray

Application of a strong jet of water spray to dislodge and injure as many aphids as is possible. Work all around the host plant, if possible, directing the spray at tender flush where aphids will most likely be found. (see Shevale, et al., 1987; Samways & Grech, 1986; for examples of the effectiveness of water sprays)

A nontoxic liquid soap could be added to the water to increase its effectiveness, but no studies have been carried out on the effectiveness of this technique. Soap dilutions have long been used for control of soft-bodied insects, such as aphids (Ware, 1980) and Safer® soap or Ivory® soap works well (Barnett, pers. comm.). However, some studies seem to conclude that such applications have to be applied so frequently as to be impractical and could injure the plant (Koehler, et al., 1983). Hence, it may be necessary to test the effectiveness of a given treatment under program conditions.

(6). Bug Vacuum

The use of an industrial vacuum to remove insect pests from crops. This technique would seem to work best with low canopy herbaceous hosts such as vegetables, though no comparative studies appear to have been done with woody hosts.

A commercial vacuum such as the Beetle Eater® (Thomas Equipment Ltd., Centreville, New Brunswick) or the Bug Beater® (Sukup Manufacturing Co., Sheffield, Iowa) may be employed. All aphid hosts in the area around an infection of the virus, both commercially grown and wild, should be vacuumed several times. Use of this equipment apparently does not spread the virus in the area through mechanical means (Boiteau, et al., 1992).

(7). Host Destruction

See 6.c. (page 5.25). Direct destruction of all vector hosts in the area around an infection of the virus, including wild and domesticated hosts that support aphid vector populations, in order to reduce aphid presence in the area as much as possible (Ullman, et al., 1991). Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved (Jones, 1991).

(8). Vector Avoidance

If the vector(s) is present only at certain times of the year, it may be possible to schedule commercial plantings at times when the vector is not present, especially if in greenhouse situations during unseasonable weather conditions (Klein & Wyatt, 1989).

The destruction of host around an area as given in 1.i.(7). (page 5.15) could also be considered as a form of vector avoidance.

Reflective mulches, consisting of aluminium foil, aluminium coated paper or aluminium painted polythene sheeting may be placed between rows of host or around the base of host plants to repel the majority (about 96 percent) of incoming aphid vectors and thus to cut down on the spread of any virus present (Jones, 1991).

A possible negative side to the above treatments that must be carefully considered is that the aphids may go elsewhere, so that aside from host protection, suppression, or eradication of the virus is not achieved and it could be spread if careful planning in conjunction with other control measures is not carried out.

2. For Control of Whitefly Vectors

For chemical controls, see applicable insecticide applications under 1.g. (page 5.11) and 1.h. (page 5.14)

a. Sugar Esters

Certain esters produced by leaf hairs on the surface of tobacco leaves are toxic to whiteflies and environmentally safe for use as insecticides. Under development. Contact:

Horicultural Crops Quality Laboratory, Beltsville, MD;
J. George Buta - (301) 505-5598 or;
Florist & Nursery Crops Laboratory
John W. Neal, Jr. - (301) 504-9159
(Anon., 1993a)

b. Polymer Webs

The use of polymer webs may result in fewer whiteflies. See 6.b. (page 5.24). This technique is especially effective in greenhouses (Berlinger, et al., 1988).

c. Mulches

The use of a yellow mulch to attract whiteflies and which kills them by the heat generated in the mulch (Cohen, 1984).

d. Cultural Control

(1). Yellow Sticky Strips/Traps

Plastic yellow sheets coated with an insect trapping compound for control of aphids (Farm Chem. Hand.). These are larger sheets used for mass trapping to impact the pest population, such as Chroma-line Bright Yellow® No. 611-L or Reuter Laboratory Sticky Bars®, item no. 142.

(2). Bug Vacuum

The use of an industrial vacuum to remove insect pests from crops. This technique would seem to work best with low canopy herbaceous hosts such as vegetables, though no comparative studies appear to have been done with woody hosts.

A commercial vacuum such as the Beetle Eater® (Thomas Equipment Ltd., Centreville, New Brunswick) or the Bug Beater® (Sukup Manufacturing Co., Sheffield, Iowa) may be employed. All whitefly hosts in the area around an infection of the virus, both commercially grown and wild, should be vacuumed several times. Use of this equipment apparently does not spread the virus in the area through mechanical means (Anon., 1990; Boiteau, et al., 1992).

(3). Host Destruction

See 6.c. (page 5.25). Direct destruction of all vector hosts in the area around an infection of the virus, including wild and domesticated hosts that support whitefly vector populations, in order to reduce whitefly presence in the area as much as is possible. Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved. (Jones, 1991)

e. Vector Avoidance

If the vector(s) is present only at certain times of the year, it may be possible to schedule commercial plantings at times when the vector is not present, especially if in greenhouse situations during unseasonable weather conditions (Klein & Wyatt, 1989).

The destruction of host around an area as given in 2.d. (page 5.17) could also be considered as a form of vector avoidance.

3. For Control of Mite Vectors

For chemical controls, see applicable insecticide applications under 1.g. (page 5.11) and 1.h. (page 5.15).

a. Sulphur

Dusting sulphur may be used to control mites at the rates recommended for a given host. This technique has the advantage of being compatible with predatory mites. (Berlinger, et al., 1988).

b. Predatory Mites

If available, predatory mites may be acquired and released on hosts in high concentrations. May be used in conjunction with 3.a. (this page) (Berlinger, et al., 1988).

c. Cultural Control

See 6.c. (page 5.25). Direct destruction of all mite hosts in the area around an infection of the virus, including wild and domesticated hosts that support mite vector populations, in order to reduce mite presence in the area as much as possible. Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved (Jones, 1991).

d. Vector Avoidance

If the vector(s) is present only at certain times of the year, it may be possible to schedule commercial plantings at times when the vector is not present, especially if in greenhouse situations during unseasonable weather conditions (Klein & Wyatt, 1989).

The destruction of host around an area as given in 3.c. (this page) could also be considered as a form of vector avoidance.

4. For Control of Fungal Vectors

When local conditions permit and landowners or operators opt for chemical control, methyl bromide should be the eradicant of choice for soil borne fungi. If fumigation is not chosen, the infected area will be taken out of production of host crops and other eradicants will be applied. Under certain conditions, resistant varieties may be grown in the infected area.

a. Methyl Bromide

The control, suppression, or eradication of a soil borne fungal vector requires that several treatments be used. The following sequence will be appropriate for most outbreaks in commercial fields when methyl bromide is used. As indicated, some of the treatments are necessary until fumigation, and others are necessary for a longer period until the quarantine is lifted.

(1). Destruction of Current Crop

If the virus is detected early during the growing season, then all host plants at and contiguous to the site where the find was made will be treated with glyphosate or a similar compound at the labeled rate. After 10 to 14 days, or when the plants are dead, all parts of these plants will be burned in place, removed and incinerated, autoclaved, or buried in landfills at an approved location. It is essential to take precautions to avoid contamination of other areas when plants are removed from the site.

(2). Destruction of Infected Host After Harvest

If the virus is detected after harvest, all remaining host and host plant parts on the known infected property will be collected. This material will be destroyed by incineration, autoclaving, fumigation, or burial in an approved landfill.

(3). Field Treatment

Following the above, the infected site will be cleared of weeds, boulders, trash, and other objects which prevent penetration of chemicals through the soil. These objects must be disinfected or incinerated. The field or plot will be worked to a seedbed condition before fumigation with methyl bromide.

If subsequent monitoring surveys reveal the presence of viable fungal spores, viruliferous or not, or infected plants, the field will be retreated. Removing any plant material with adhering soil, such as root crops or nursery crops is not permitted. Crops will not be grown in the treated area and any "volunteer" growth will be destroyed.

b. Sulphur

Sulphur applications are recommended for certain fungi (Farm Chemicals Handbook, 1992). This treatment does not eliminate the vector, but does cut down on its numbers. Treatment should follow the guidelines given above.

c. Zinc

Zinc is as effective as sulphur in control of spread, but like it, is not able to eliminate the virus-carrying fungus by itself (Cooper, et al., 1976). Treatment should follow the guidelines above. Zinc Omadine® is registered for use in the U.S.A. (Farm Chemicals Handbook, 1992).

d. Biofungicide

This new area of biocontrol uses fungi to control fungi, such as one developed recently by Ecogen, Inc. to control powdery mildew. Since biofungicides are most likely to be very specific, it will be necessary to check with all possible sources for a suitable biofunicide at the time a program is under consideration.

e. Mineral Oils

Mineral oil applications are recommended for certain fungi (Farm Chemicals Handbook, 1992). Treatment should follow the guidelines given above.

f. Cultural Control

See 6.c. (page 5.25). Direct destruction of all fungal hosts in the area around an infection of the virus, including wild and domesticated hosts that support fungal vector populations, in order to reduce fungal presence in the area as much as is possible. Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved (Jones, 1991).

g. Air Borne Fungi

It is possible, in the course of survey and program efforts that an air borne fungus will be found responsible for viral dissemination as well as the main vector. This has been documented for Maize dwarf mosaic virus, which is carried by uredospores of *Puccinia sorghi*, maize rust (Wechmar, et al., in Barnett, 1993). Maize rust is controlled by dithane, chlorothalonil, or mancozeb (Mcgee, 1988).

In this situation, treatments applicable for that fungus should be applied as soon as possible. Maize rust, for example, is controlled by Bravo (40 percent chlorothalonil) at the rate of 2.25-2.75 pts/acre at 4-5 day intervals (McGee 1988).

Methyl bromide shall not be employed, as this treatment is for soil borne fungi. However, as many as is possible of the other treatments above as can be applied should be carried out. This should include rouging of the current crop, including stubble, and rouging or fungicide treatment of alternate fungal hosts (such as *Oxalis* spp. for Maize rust), the planting of resistant varieties and the application of chemical controls for those fungi with above ground infection of the host.

5. For Control of Leafminer Vectors

If leafminers are present, they may prove to be a potential, if less effective vector of viruses (Zitter & Tsai, 1977). Some of the insecticide applications under 1.g. (page 5.11) and 1.h. (page 5.14) and cultural applications such as host destruction may be applicable to these insects as well.

If any control is necessary, an insecticide should be applied in the early morning hours before 10 a.m., since adults are emerging from pupae or laying eggs and larvae are emerging from the leaves to pupate in the soil at this time. In addition, perimeter plants should be thoroughly sprayed, since they are usually more heavily infected. It should be borne in mind that sprays have a limited effect on the adults and mainly affect the larvae in the leaf and those about to pupate. No registered insecticide is effective against the egg stage (Parrella & Robb, 1982).

a. Abamectin

Apply at a rate of 0.04 lb ai/100 gal water. Apply directly on leaves to runoff (Parrella & Robb, 1982). This formulation is also effective against mites.

b. Cyromazine

Apply at a rate of 0.5 lb ai/100 gal water. Apply directly on leaves to runoff (Parrella & Robb, 1982). This formulation is an Insect Growth Regulator.

NOTE: Leafminers have not been shown to play a significant role in the spread of potyviruses under natural conditions. There should be no concern over these possible vectors unless evidence surfaces during the course of a program that indict them as a vector of the particular target PTV.

6. For Control of Potyviruses

a. Virus Inactivation

In certain cases, it may be possible to inactivate the virus. This can be done in several ways. Note that these treatments are only practical for small quantities of young, valuable plants such as research material.

(1). Heat Therapy (Thermotherapy).

Plants may be grown under confined conditions and at specified high temperatures which will inactivate the virus.

There are four major treatment approaches towards thermotherapy (Spiegel, et al., 1993). The selection of an effective thermotherapy method for a given host requires an empirical approach if no information is available about its heat tolerance.

Constant High Temperature. This basic procedure involves maintaining plants at a constant high temperature within the limits of the physiological tolerance of the host (usually 36-38° C). This is maintained for several weeks or months, during which parts of plants or entire plants may become virus free.

Alternating High/Low Temperatures. By changing the temperature from high to low to high again, it is sometimes possible to reduce stress on the plants while still eliminating the virus.

Preconditioning. If the plants are potted, they can be preconditioned by growing them under ideal conditions. They should be grown in large pots in order to allow a large root system to develop. The temperature can then be raised gradually over a few days to the desired treatment temperature.

In some cases, increasing the CO_2 and/or reducing the O_2 concentration in the heat chamber will improve host survival.

Thermotherapy/Tissue Culture. In some cases, it may be desirable to excise shoot tips from new growth produced during heat treatment and establish these in vitro to regenerate new plants. Shoot tips may also be grafted to virus-free plants or seedlings in pots.

(2) Chemical Therapy.

Only the true chemotherapeuticals, which are capable of completely preventing the replication of viruses in systemically infected host plants, should be considered. This method, properly done, can result in plants free of the virus from infected stocks and as in 6.(1). (page 5.22) is primarily a way to obtain virus-free plant material.

There are four major methods of introducing chemotherapeuticals into virus-infected plants: foliar application, root drench, injection or wick application, and incorporation into solid or liquid artificial medium for meristems or shoots.

The three most effective inhibitors known at this time are: Ribavirin, Tiazofurin and DHT (2,4-dioxo-hexahydro-1,3,5-triazine) (Hansen, 1988). More recently, a DHT derivative, (DA-DHT or diacetyl-dihydro-5-azauracil) (Spiegel, et al., 1993) has been utilized.

(3) Gene Expression.

If a gene is known that provides resistance to the effects of a virus, it may be transferred through plant breeding or other means to a susceptible host. For example, Watermelon mosaic virus (WMV) can be nullified by a cantaloupe gene which permits melon plants to recover from the initial symptoms, causing yield and quality of the fruit to be significantly better. The same is true for corn engineered for resistance to Maize dwarf mosaic virus (MDMV)(Clark, 1993).

There are also transgenic plants with virus genes:

--Positive Sense
--Negative Sense

This new technology for resistance is not commercially viable at present.

Note that the virus is still present as the host is not rendered immune by these treatments. However, since virus replication is inhibited, the virus loses its infectivity due to the normal process of viral degradation.

Selection of the appropriate treatment and procedures will need to be made at the time a program is under consideration.

Antisense Technology

Aside from the direct destruction of host, this new technology offers an alternative for growers of commercial hosts during the regulatory period. At present, such technology is available for only a few hosts, such as tobacco, for Barley yellow mosaic virus (BYMV). (Becker, 1993)

b. Passive Protection

Polymer Webs

Sheets of polypropylene fleece may be employed to cover low-lying herbaceous hosts, especially crop or garden hosts. Aphids and whiteflies cannot penetrate the web of synthetic fibers with their stylets. Provided the sheets are regularly inspected for damage, the host will be fully protected against virus transmission. In a passive way, this method will also cut down on aphid and whitefly numbers, especially of apterous aphids, by reducing the available food supply (Harrewijn, et al., 1991; Berlinger, et al., 1988). To boost yields of crops or garden hosts, weeds under the cover should be eliminated as these compete for available resources and may shade the hosts. Consideration should also be given, for those hosts which require it, to uncovering crops or garden hosts at the 50 percent flowering stage to provide for pollination by bees (or other insects) and/or good growth. This removal cannot take place if it will occur during vector pressure, as the plants will be very rapidly infected (Perring, et al., 1989). Timing of any removal must also take into account the objectives of the program, and if eradication or just suppression is the goal.

Pyrethroids

The pyrethroids are also efficient in controlling the spread of viruses, apparently because the vectors are intoxicated particularly fast. Intoxication results in feeding inhibition and flight induction; two obvious features in the prevention of vector inoculation. See also 1.g. (page 5.11) (Perrin & Gibson, 1985).

Mineral Oils

Mineral oils appear to interfere with the transmission of nonpersistent plant viruses by aphids and possibly other arthropods. While not completely understood, the oil seems to interfere with the attachment or removal of virus particles from aphid mouthparts (Lowery et al., 1990; Qiu & Pirone, 1989). In combination with an insecticide, especially a pyrethroid, and a whitewash, very effective in the control of viral spread (Lowery, et al., 1990). See also 1.h. (page 5.14).

Suggested oils are:

Sunoco Sunspray 6 E®	(Lowery et al., 1990)
Sunoco Sunspray 7 E6 V®	(Makkouk & Menassa, 1985)
Bayol 52®	(Gibson & Rice, 1986)
SC811®	(Gibson & Rice, 1986)
Luxan Oil H®	(Asjes, 1991)
Duphar-7E Oil®	(Asjes, 1991)
JMS Stylet Oil®	(Qiu & Pirone, 1989)

Suggested application times: Weekly or biweekly, depending on local conditions.

Clean Culture Option - Virus Free Propagative Material

Planting only certified virus-free propagative material in the regulated area, away from infected localities, and in conjunction with other measures such as the use of resistant or tolerant cultivars, is an important means of exclusion. This option is the keystone to the Canada/U.S.A. PVY^n Management Plan (Anon., 1993c).

c. Direct Destruction

The only other way to eradicate or suppress the disease is to destroy the contaminated host. The limits of destruction must be determined, based on specific conditions at the time of the action. This is often necessary in order to destroy adjacent asymptomic plants in order to get ahead of the infestation.

Once the host or hosts have been destroyed, no new hosts will be planted for a minimum of 2 years in commercial areas, or for 5 years on a case-by-case basis, if control of a grass free condition is not possible.

On residental properties, no new hosts will be planted for 5 years within 50 feet of each find.

In nurseries where an infected host is found, all host plants in the nursery will be removed and burned or disposed of in an approved landfill. No host material will be planted in the nursery for a period of 2 years, or for 5 years if control of a grass free condition is not possible.

All flats and equipment that may have come into contact with the infected material will be decontaminated using steam or an approved chemical. Decontamination will be accomplished by means of washing or dipping the exposed equipment in 75 percent ethanol or 6 percent quatenary ammonium.

(1). Woody Hosts

(a). Burning

Any infected host will be destroyed by burning in place. A kerosene-oil mixture should be applied to the host(s) to faciliate complete burning. When an infected host is located on a residential property or at any other location where the host cannot be safely burned, the host will be removed or transported to a place where it can be buried or safely burned.

The host will be covered to prevent the loss of plant parts in transit. Tools used in the removal of infected plants will be decontaminated.

Since viruses can persist in live roots and can be transmitted through root grafts, it becomes critical to subsequently check or destroy adjacent trees and roots or other hosts to get ahead of the infection.

(b). Stump Treatment

If the host is a large tree or shrub, and is cut down, leaving a stump, then the stump will be treated with Tordon® or Amate® solution to prevent the growth of shoots.

Plant roots must still be removed, as they may harbor the virus.

(c). Adjacent Hosts

In commercial plantings, host trees or shrubs, including wild hosts, adjacent to and surrounding any infected host will be defoliated, using the herbicide Diquat 2® or other approved herbicides. Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved (Jones, 1991).

On residential properties, all host plants on the property, including wild hosts, plus any hosts on bordering properties adjacent to the infected property, will be using the herbicide, Diquat 2®. Rigorous weed control/destruction should be practiced, where possible, especially where wild hosts are involved (Jones, 1991).

In some cases, this defoliation may need to be repeated.

Leaves and fruit removed by defoliation will be burned or buried in an approved landfill. At residental locations, the leaves and fruit will be collected and removed to an approved site where they may be safely burned or buried.

(2). Herbaceous Hosts

Herbaceous hosts, including wild hosts, will be destroyed by cultivation and/or herbicides. Roundup® or a similiar herbicide will be used to eliminate all herbaceous hosts in a 50 foot radius from any find. This area will be kept free of herbaceous or other hosts and weeds for a period of 2 years.

Orientation of Control/ Eradication Personnel

Only trained and experienced personnel will be utilized initially. Replacement personnel will be trained by the individual being replaced.

Eradication/ Control Records

Records noting the locations, dates, number and type of treatments, and materials and formulations used will be maintained for all areas treated.

Monitoring

An effective monitoring program will be implemented to aid in the evaluation of program efforts and environmental immpact. The application of pesticides will be assessed through the use of appropriate monitoring program criteria. The evaluation must effectively address Agency, cooperator, and public concerns.

The program plan should include at least the following elements:

1. Determine the efficacy of any pesticide used against the target pest.

2. Evaluate dye needs to monitor aerial applications, especially;

a. Droplet size
b. Droplet distribution
c. Identification of drift components
d. Verification of spray block boundaries
e. Identification of skips

3. Sampling to evaluate the effect of a PotyV program on the environment will be conducted in accordance with a Environmental Monitoring Plan. These plans include pre and post application sampling and observations to determine the impact on soil, water, vegetation, and non-target species. Carcass searches are a part of this monitoring.

CONTACTS

Involved Groups

When a PotyV program is implemented, its success will depend on the cooperation, assistance, and understanding of many involved groups. The following groups should be continually informed of all operational phases of an emergency program.

1. Federal, State, county, and municipal agricultural officials
2. Grower groups
3. Commercial interests
4. Universities
5. State and local law enforcement officials
6. Public health
7. Foreign agricultural interests
8. National, State, and local news media, and
9. The general public.

PATHWAY EVALUATION

Natural Means

PotyV are spread by alate aphids or whiteflies and these can be carried by wind currents in the upper atmosphere. These vectors have the potential to carry PotyV over hundreds of miles. The aphid alates have the ability to efficiently find suitable hosts in the area where they find themselves (Roistacher & Bar-Joseph, 1987).

Mites are moved more passively by wind, insects, birds, and other animals than are aphids or whiteflies. The principal means of dispersal is wind, and the ability to disperse is almost as good, save for lack of a choice in finding a suitable host.

Fungi are transmitted by the zoospores and cystosori, in water, dust or wind. This type of transport is also passive, and depends on a suitable host at the end of the journey.

Direct natural dispersal of a PotyV is by seed transmission, and would depend on the natural dispersal mechanisms of a given type of seed. This includes wind and water-borne movement and movement by animals, including man.

Backtracking:

It may be necessary to trace the source(s) of an infestation. As all vectors of Potyviruses are generally assumed to have low (i.e., aphids and whiteflies) or no (i.e., mites and fungus) flight speed capabilities, it is possible to measure long distance movement. The potential exists for good resolution of source regions under all meteorological conditions. An objective trajectory model has been developed to accomplish this (Scott & Achtemeier, 1987).

The next step would be the development of a predictive model to determine where the vector(s), and the related pathogen, may travel next. Preliminary data indicate that aphids, at least, prefer prefrontal conditions of moderate to strong southwesterly air flows.

Travel and Commerce

Fresh leaves, young stems, tubers, and fruit appear to present a risk. Leaves, fruit, or tubers may be transported illegally for consumption or for medical or propagative reasons by individuals.

Some aphid vectors may be more strongly attracted to green or yellow than are many other aphids and may therefore be transported on yellow or green packaging or aircraft parts (EPPO, 1992).

Introduction of any PotyV through plants brought in for planting and associated materials is said to be much more likely than through natural means. Deliberate seed transmission and clonally propagated hosts are probably the most important single factors in viral dispersal; however, Chang (1987), raises the possibility of Plum pox virus (PPV) introduction through aphid vectors imported on infected cut flowers or of suitable domestic aphids feeding on imported infected cut flowers.

ADDENDUM 1

Definitions

Aerial Treatment--Applying an insecticide/pesticide by aircraft over a treatment area.

Array--The vector trapping pattern in the delimiting survey area located around a detection.

Array Sequence--The intensity of traps within an array, beginning with the core area and continuing outward through each buffer area, ending with the outer buffer area.

Buffer Area--The area extending a prescribed distance beyond the boundary of the core, the 1-, 2-, 3- and 4- mi buffers.

Commercial Host--A host capable of supporting PotyV reproduction and grown in large quantities for wholesale or retail markets.

Commercial Production Area--An area where host material is grown for wholesale or retail markets.

Confirmed Detection--A positive laboratory identification of a submitted host sample containing a PotyV of concern.

Core Area--The one square mile area surrounding any confirmed PotyV detection.

Day Degrees--An accumulation of heat units above a developmental threshold.

Delimiting Survey--Determining whether infected hosts exist and if so, the extent of the area the infected hosts occupy.

Detection--The collection and identification of any PotyV from a host.

Detection Survey--An activity to determine the presence of PotyV, conducted on susceptible hosts in an area where the virus has not been observed.

Developmental Threshold--The minimum (or maximum) temperature below (or above) which physiological development stops (peaks).

Epicenter/Focal Point--The initial site of an infection.

Eradication--The confirmed removal of the targeted PotyV in a specified geographical area, as determined by a negative survey for 3 years.

Fumigation--The application of an approved fumigant to hosts.

Generation--The period of time required for the pest to (Life Cycle) complete all stages of development.

Ground Spray--Using ground spray equipment to apply an insecticide/pesticide to the above-ground parts of host vegetation in a PotyV infected area.

Host--A plant species capable of supporting PotyV replication.

Infected Area--A distance of 1 1/2 miles from all detection sites unless biological factors indicate the need for more or less area.

Infection--The collection of one or more PotyV infected host or the detection of a single infected host determined to be associated with a current infection.

Monitoring/Evaluation Survey--Using interdependent visual and perhaps vector trapping surveys in an area where a control or eradication treatment is in progress to evaluate the effectiveness of the application.

PPQ-APHIS-USDA--Plant Protection and Quarantine, Animal and Plant Health Inspection Service, U.S. Department of Agriculture.

Primary Site--A property on which an initial detection of a disease or viable pathogen occurs, or a potentially infected site within 1 1/2 miles of an infected property.

Regulated Area--An area that extends at least 4 1/2 miles in all directions from an infected property.

Regulated Articles--All known or suspected hosts of PotyV or any other suspected product or article.

Regulatory Inspection--Visual examination of host material and containers at establishments where regulated articles are grown, handled, processed, or moved. Under some circumstances this can include discretionary trapping of vectors around selected establishments.

Satellite Site--A potentially infected property which is beyond 1 1/2 miles from an infected property.

Trap Survey--Determining the presence or absence of a vector by the use of traps placed in a predetermined pattern and serviced on a given schedule.

Urban/Residential Area--An area containing multiple or single family dwellings, and/or commercial and industrial facilities.

Visual Survey--Examining hosts for visual signs of infection, either in the field or in regulated establishments, or in monitoring the movement of regulated articles.

ADDENDUM 2

Safety

Personal and public safety must be a prime consideration at all times. Safety practices should be stressed in preprogram planning and through the duration of actual program operations. Supervisors must enforce on-the-job safety procedures.

ADDENDUM 3

Hosts

Hosts for most of the Potyviruses are given below. These lists are not complete, but are intended to serve as a guide in the decision-making process. Many of the hosts listed repeatedly are those used in laboratory studies. It is not known, in fact, if these or related hosts will be infected in nature in a new environment for a given Potyvirus.

Potyviruses may reside in various secondary hosts, such as herbaceous weeds and shrubs. These may serve as natural reservoirs and must be determined through a survey of those plants in the area which demonstrate typical symptoms of a given potyvirus. For example, as weeds, *Chenopodium* spp. and *Trifolium* spp. will carry Bean Yellow Mosaic Virus (Vicchi & Bellardi, 1988).

Association of Applied Biologists (AAS) citations are given below for most of the host lists. Separate citations are not given in the References, due to their number, and the fact that they are all part of one continuing series.

ARS Handbook # 505 by Terrell, et al., 1986, was used to decide on the common and specific names of plant hosts given in this list. The handbook lists Lambsquarters as *Chenopodium album album*. The form, *Chenopodium album amaranticolor* is given as an unnamed subspecies. To avoid confusion, *Chenopodium album amaranticolor* is referred to as a lambsquarters biotype.

	Host	
Virus:	**Scientific Name:**	**Common Name:**
Agropyron Mosaic Virus	*Agropyron cristatum*	Fairway crested wheatgrass
	Agropyron elongatum	Tall wheat grass
	Agropyron inerme	Beardless wheat grass
	Agropyron intermedium	Intermediate wheat grass
	Agropyron junceum	
	Agropyron pertenue	
	Agropyron repens	Couch grass
	Agropyron rigidum	
	Bromus japonicus	
	Elymus canadensis	Canada wildrye
	Elymus trachycaulus	Slender wheatgrass
	Festuca rubra	Red fescue
	Hordeum murinum	
	Hordeum vulgare	Barley

Virus:	Host	
	Scientific Name:	**Common Name:**
Agropyron Mosaic Virus	*Lolium multiflorum*	Prussian fall rye
	Secale cereale	Rye
	Triticum aestivum	Wheat
	Triticum durum	Durum wheat
NOTE: Natural infections occur in hybrids of some of the above hosts (Smith, 1972).		
Alstroemeria Mosaic Virus	*Alstroemeria* spp.	Flower, a (SRPQS, 1984)
Amaranthus Leaf Mottle Virus	*Amaranthus* spp.	Pigweed
	Cirsium arvense	Canada thistle (Casetta, et al., 1986)
NOTE: Host range in 6 plant families, but not recorded on cultivated plants. May be a potential pathogen of cultivated plants in the Leguminosae and Chenopodiaceae (Lovisolo & Lisa, 1979).		
Araujia Mosaic Virus	*Araujia angustifolia*	
	Araujia hortorum	
	Araujia sericofera	Bladder-flower
	Cynanchum spp.	
	Hoya carnosa	Waxplant
	Hoya coronaria	
	Matelea floridana	
	Morrenia brachystephana	
	Morrenia odorata	Strangler vine
NOTE: Host range as given by Charudattan, et al., 1980. All are in the Asclepiadaceae.		
Artichoke Latent Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Cynara scolymus	Artichoke
	Nicotiana clevelandii	
	Zinnia violacea	Zinnia
NOTE: Various species of Compositae, Chenopodiaceae, Solanaceae, and other families may serve as hosts (Smith, 1972).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Asparagus Virus I	*Asparagus officinalis*	Asparagus
NOTE: (From Evans & Stephens, 1989.)		
Barley Mild Mosaic Virus	*Hordeum vulgare*	Barley (Ordon & Friedt, 1993)
	Secale cereale	Rye (Ordon, et al., 1992)
	Triticum durum	Durum wheat (Proeseler, 1993)
Barley Yellow Mosaic Virus	*Hordeum vulgare*	Barley
NOTE: Barley is the only known host (CMI/AAB-143, 1975).		
Bean Common Mosaic Virus / Bean Common Mosaic Necrosis (Serotype A)	*Cajanus cajan*	Pigeon pea
	Canavalia ensiformis	Jackbean
	Cassia tora	Sickle senna
	Chenopodium quinoa	Quinoa
	Cicer arietinum	Chickpea
	Crotalaria pallida (=straita)	Smooth crotalaria
	Crotalaria spectabilis	Showy crotalaria
	Cyamopsis tetragonoloba	Guar
	Glycine max	Soybean
	Gomphrena globosa	Globe amaranth
	Lens culinaris (=esculenta)	Lentil
	Lupinus albus	White lupine
	Lupinus angustifolius	European blue lupine
	Lupinus luteus	European yellow lupine
	Macroptilium atropurpureum	Siratro
	Macroptilium lathyroides	
	Melilotus alba	White sweetclover
	Nicotiana benthamiana	

Virus:	Host	
	Scientific Name:	**Common Name:**
Bean Common Mosaic Virus / Bean Common Mosaic Necrosis (Serotype A)	*Nicotiana clevelandii*	
	Phaseolus spp.	Bean
	Rhynchosia minima	
	Sesbania macrocarpa (=exaltata)	Colorado river hemp
	Trifolium incarnatum	Crimson clover
	Trifolium subterraneum	Sub clover
	Trigonella foenum-graceum	Fenugreek
	Vicia faba	Broadbean
	Vicia sativa	Common vetch
	Vicia villosa	Winter vetch
	Vigna angularis	Adzuki bean
	Vigna radiata	Mung bean
	Vigna unguiculata	Cowpea
NOTE: In nature, mainly found in *Phaseolus* spp., especially *P. vulgaris* (CMI/AAB-337, 1988). **NOTE:** The hosts of several recent synonyms are listed below, owing to frequent usage in the literature.		
(=Blackeye Cowpea Mosaic Virus)	*Arachis hypogaea*	Peanut (Hasselman, 1993)
	Cajanus cajan	Pigeon pea (Mali, et al., 1988)
	Canavalia ensiformis	Jackbean (Mali, et al, 1988)
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium murale	Nettleleaf goosefoot (Mali, et al., 1988)
	Chenopodium quinoa	Quinoa
	Crotalaria spectabilis	Showy crotalaria
	Desmodium spp.	Beggarweed
	Glycine max	Soybean (Fukomoto, et al., 1987)
	Gomphrena globosa	Globe amaranth
	Lathyrus odoratus	Sweet pea

Virus:	Host	
	Scientific Name:	**Common Name:**
(=Blackeye Cowpea Mosaic Virus)	*Nicotiana benthamiana*	
	Nicotiana clevelandii	
	Ocimum basilicum	Basil (Mali, et al., 1988)
	Petunia hybrida	Garden petunia
	Phaseolus lunatus	Lima bean (Mali, et al., 1988)
	Phaseolus vulgaris	Garden bean
	Senna obtusifolia	Sicklepod
	Sesamum indicum	Sesame
	Tetragonia tetragonioides	New Zealand spinach
	Trigonella foenum-graceum	Fenugreek (Mali, et al., 1988)
	Vicia faba	Broadbean
	Vigna mungo	Black gram
	Vigna radiata	Mung bean (Mali, et al., 1988)
	Vigna unquiculata	Cowpea (Mali, et al., 1988)
	Vigna unguiculata cylindrica	Catjang (Mali, et al., 1988)
	Vigna unguiculata sesquipedalis	Asparagus bean
NOTE: At least 36 species in 7 families are susceptible (CMI/AAB-305, 1985).		
(=Peanut Stripe Virus	*Arachis hypogaea*	Peanut
	Glycine max	Soybean
	Sesamum indicum	Sesame
	Trifolium incarnatum	Crimson clover
	Vigna unguiculata	Cowpea
NOTE: Hosts taken from NPAG Data Sheet in 1983 when this disease was discovered in the U.S.A. (NPAG, 1983).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Bean Yellow Mosaic Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Chenopodium spp.	Goosefoot
	Cladrastris spp.	
	Crotalaria spectabilis	Showy crotolaria
	Gladiolus sp.	Gladiolus (Becker, 1993)
	Gomphrena globosa	Globe amaranth
	Lupinus albus	White lupine (Jones, 1991)
	Lupinus angustifolius	Narrow-leafed lupine (Jones, 1991)
	Lupinus atlanticus	(Jones, 1991)
	Lupinus cosentinii	(Jones, 1991)
	Lupinus digitatus	(Jones, 1991)
	Lupinus mutabilis	(Jones, 1991)
	Lupinus pilosus	(Jones, 1991)
	Nicotiana clevelandii	
	Nicotiana tabacum	Tobacco
	Ornithopus sativus	Serradella
	Papaver somniferum	Opium poppy
	Petunia hybrida	Garden petunia
	Phaseolus vulgaris	French bean (CMI/AAB-40, 1970)
	Pisum sativum	Pea (CMI/AAB-40, 1970)
	Robinia pseudo-acacia	Black locust
	Robinia spp.	Locust
	Spinacia oleracea	Spinach

Virus:	Host	
	Scientific Name:	**Common Name:**
Bean Yellow Mosaic Virus	*Tetragonia tetragonioides*	New Zealand spinach
	Trifolium incarnatum	Red clover
	Trifolium subterraneum	Sub clover
	Trifolium spp.	Clover
	Trigonella foenum-graecum	Fenugreek
	Vica faba	Broadbean
		Broadbean (Skaf & Makkouk, 1988)
	Vicia sativa	Common vetch (Skaf & Makkouk, 1988)
		Vetch
	Vigna radiata radiata	Mung bean
NOTE: Causes diseases in many legumes and infects a number of non-legumes, especially Liliiflorae (CMI/AAB-40, 1970). As weeds, *Chenopodium* sp. and *Trifolium* sp. serve as reservoirs of BYMV. *Robinia* spp. and *Cladrastris* are two woody hosts that may also serve as reservoirs for BYMV (Cooper, 1988).		
Beet Mosaic Virus	*Beta vulgaris*	Beet
	Chenopodium quinoa	Quinoa
	Gomphrena globosa	Globe amaranth
	Spinacia oleracea	Spinach
NOTE: Moderately wide host range, mostly Chenopodiaceae, Solanaceae, and Leguminosae (CMI/AAB-53, 1971).		
Bidens Mottle Virus	*Chenopodium quinoa*	Quinoa
	Cichorium endiva	Endive (and escarole)
	Helianthus annuus	Sunflower
	Latuca sativa	Lettuce
	Nicotiana clevelandii	
	Nicotiana glutinosa	
	Zinnia violacea	Zinnia
NOTE: Known to infect 10 species of Compositae and 9 species in 5 other families (CMI/AAB-161, 1976).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Cardamom Mosaic Virus	*Amomum cannecarpum*	Cardamon, a (Rao & Naidu, 1973)
	Amomum involucratum	Cardamon, a (Rao & Naidu, 1973)
	Amomum microstephanum	Cardamon, a (Visiswanath, et al., 1973)
	Amomum sp.	Cardamom, a (Rao, 1977b)
	Elettaria cardamomum	Cardamom (Rao, 1977a) (Devi, et al., 1982)
	Zea mays	Maize (Rao & Naidu, 1973)
Carnation Vein Mottle Virus	*Amaranthus caudatus*	Love-lies-bleeding
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Dianthus barbatus	Sweet William
	Dianthus caryophyllus	Carnation
NOTE: Restricted to the Caryophyllaceae and allied families (CMI/AAB-78, 1971).		
Carrot Thin Leaf Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Coriandrum sativum	Coriander
	Daucus carota sativa	Carrot
	Nicotiana clevelandii	
NOTE: Plants from the Umbelliferae, Chenopodiaceae, and Solanaceae are susceptible (CMI/AAB-218, 1980).		
Celery Mosaic Virus	*Apium graveolens*	Celery
	Conium maculatum	Poison hemlock
	Daucus carota	Carrot
	Pastinaca sativa	Parsnip
	Petroselinum crispum	Parsley
NOTE: Only infects certain members of the Umbelliferae (CMI/AAB-50, 1971).		

Virus:	Host	
	Scientific Name:	Common Name:
Chili Veinal Mottle Virus	*Capsicum annuum*	Pepper
	Capsicum frutescens	Pepper, tabasco
NOTE: Hosts as given by Ong, et al., 1978).		
Clover Yellow Vein Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Coriandrum sativum	Coriander
	Nicotiana clevelandii	
	Nicotiana tabacum	Tobacco
	Phaseolus vulgaris	French bean
	Pisum sativum	Garden pea
	Tetragonia tetragonioides	New Zealand spinach
	Trifolium spp.	Clover
	Vicia faba	Broadbean
NOTE: Known hosts comprise 25 species in 6 plant families (CMI/AAB-131, 1974). The hosts of a recent synonym, Statice virus Y are listed below, owing to frequent usage in the literature.		
(=Statice Virus Y)	*Chenopodium quinoa*	Quinoa
	Limonium sinuatum	Statice
NOTE: Infects other Leguminous plants as well as the above, but not cucumber or pea (Lesemann, et al., 1979).		
Cocksfoot Streak Virus	*Anthoxanthum aristatus*	
	Avena strigosa	Bristle oat
	Bromus hordeaceus	Soft chess
	Dactylis glomerata	Cocksfoot (CMI/AAB-59, 1971)
	Dactylis spp.	Cocksfoot
	Festuca tenuifolia	Hair fescue
	Hordeum murinum	Wall barley
	Lagurus ovatus	Hare's-tail

Virus:	Host	
	Scientific Name:	**Common Name:**
Cocksfoot Streak Virus	*Lamarkia aurea*	
	Lolium multiflorum	Italian ryegrass
	Paspalum membranaceum	
	Phalaris paradoxa	Hood canarygrass
	Setaria macrostachia	
	Setaria viridis	Green foxtail
NOTE: Host range restricted to a few Gramineae (CMI/AAB-59, 1971).		
Colombian Datura Virus	*Datura candida*	
	Datura metel	Hindu datura
	Gomphrena globosa	Globe amaranth
	Nicotiana tabacum	Tobacco
	Solanum tuberosum x demissum	Potato
NOTE: Host range taken from Kahn and Bartels, 1968. There has been almost no work on this virus since the original description.		
Commelina Mosaic Virus	*Commelina diffusa*	Dayflower, a (Morales & Zettler, 1977)
Cowpea Aphid-Borne Mosaic Virus	*Canavalia ensiformis*	Jackbean (Mali, et al., 1988)
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium murale	Nettleleaf goosefoot (Mali, et al., 1988)
	Chenopodium quinoa	Quinoa (Mali, et al., 1988)
	Cicer arietinum	Chickpea (Mali, et al., 1988)
	Glycine max	Soybean
	Gomphrena globosa	Globe amaranth (Mali, et al., 1988)
	Lablab purpureus	Hyacinth bean (Mali, et al., 1988)
	Ocimum basilicum	Basil
	Petunia hybrida	Petunia

Virus:	Host	
	Scientific Name:	**Common Name:**
Cowpea Aphid-Borne Mosaic Virus	*Phaseolus angularis*	Adzuki bean
	Phaseolus lunatus	Lima bean
	Phaseolus vulgaris	French bean
	Pisum sativum	Pea
	Vigna radiata	Mung bean (Mali, et al., 1988)
	Vigna sesquipedalis	Asparagus bean
	Vigna unguiculata	Cowpea
NOTE: Infects many species in the Leguminosae and the Amaranthaceae, Chenopodiaceae, Cucurbitaceae, Labiatae, and Solanaceae (CMI/AAB-134, 1974).		
Cowpea Green Vein Banding Virus	*Vigna unguiculata unguiculata*	Cowpea (Lin, et al., 1981)
Dasheen Mosaic Virus	*Aglaonema* spp.	
	Caladium hortulanum	Caladium
	Colocasia spp.	Dasheen, Taro
	Diiffenbachia spp.	Dieffenbachia, dumbcane
	Philodendron selloum	Philodendron, a
	Philodendron verrucosum	
	Xanthosoma spp.	Cocoyam, Elephant's ear
	Zantedeschia spp.	Calla lily
NOTE: Infects species of 13 genera of Araceae: The above genera and the following *Alocasia, Amorphophallus, Anthurium, Ariusaema, Cryptocoryne,* and *Spathiphyllum* (CMI/AAB-191, 1978).		
Datura Shoestring Virus	*Datura metel*	Hindu datura (Weintraub, et al., 1973)
	Nicotiana debneyi	Tobacco, a (Weintraub, et al., 1973)
	Nicotiana glutinosa	
Dendrobium Mosaic Virus	*Dendrobium* spp.	Dendrobium (Inouye, 1973)

Virus:	Host	
	Scientific Name:	Common Name:
Gloriosa Stripe Mosaic	*Gloriosa rothschildiana*	Glory lily (Koenig & Lesemann, 1974)
Groundnut Eyespot Virus	*Arachis hypogaea*	Peanut (Dubern, 1979)
	Physalis floridana	Weed, a (Dubern, 1981)
Guinea Grass Mosaic Virus	*Brachiaria brizantha*	Palisade grass (Morales, et al., 1974)
	Panicum maximum	Guinea grass
	Setaria italica	Italian ryegrass
	Zea mays	Maize
NOTE: Host range limited tothe Paniceae, Maydeae, and Bromeae of the Gramineae (CMI/AAB-190, 1978).		
Helenium Virus Y	*Helenium amarum*	Bitter sneezeweed (Kuschki, et al., 1978)
Henbane Mosaic Virus	*Atropa bella-donna*	Belladonna
	Chenopodium quinoa	Quinoa (Horvath, et al., 1989)
	Datura stramonium	Jimson weed
	Datura spp.	Datura
	Hyoscyamus niger	Black henbane (Horvath, et al., 1988)
	Nicotiana glutinosa	Tobacco, a
	Nicotiana rustica	Aztec tobacco
	Nicotiana sylvestris	Tobacco, a
	Nicotiana tabacum	Tobacco
	Physalis alkekengi	Chinese lantern plant
	Solanum demissum x *S. tuberosum*	Potato, a
NOTE: Host range mainly Solanaceae. Does not naturally infect tobacco (CMI/AAB-95, 1972).		

Virus:	Host	
	Scientific Name:	Common Name:
Hippeastrum Mosaic Virus	*Chenopodium murale*	Nettleleaf goosefoot
	Chenopodium quinoa	Quinoa
	Crinum spp.	
	Gomphrena globosa	Globe amaranth
	Hippeastrum equestre	
	Hippeastrum hybridum	
	Hymenocallis spp.	
	Hyoscyamus niger	Black henbane
	Isomene spp.	
	Nicotiana clevelandii	Tobacco, a
	Phaedranassa spp.	
	Tetragonia tetragonioides	New Zealand spinach
	Urceolina spp.	
NOTE: Naturally only in the Amaryllidaceae, but will infect inoculated leaves of some species in 3 other families (CMI/AAB-117, 1973).		
Hordeum Mosaic Virus	*Triticum aestivum*	Wheat (Langenberg, 1991)
Iris Fulva Mosaic Virus	*Amaranthus caudatus*	Love-lies-bleeding
	Belamcanda chinensis	Blackberry lily
	Chenopodium quinoa	Quinoa
	Iris fulva	Iris
	Iris fulva x brevicaulis	Iris, an
	Iris sibirica	Iris, an
NOTE: Hosts as cited by Barnett and Alper, 1977 and CMI/AAB-310, 1986.		
Iris Mild Mosaic Virus	*Chenopodium quinoa*	Quinoa
	Ferraria undulata	
	Freesia refracta	
	Iris anglica	English iris

Virus:	Host	
	Scientific Name:	**Common Name:**
Iris Mild Mosaic Virus	*Iris danfordia*	
	Iris histrioides	
	Iris x hollandica	Dutch iris
	Iris reticulata	
	Iris susiana	
	Iris xiphium	Spanish iris
NOTE: Iridaceous species are the only known natural hosts, but it is reported to infect 16 species in 5 dicotylendonous families (CMI/AAB-324, 1986).		
Iris Severe Mosaic	*Belamcanda chinensis*	
	Crocus vernus	Crocus
	Iris angelica	English iris
	Iris aurea	
	Iris gatesii	
	Iris germanica	
	Iris x hollandica	Dutch iris
	Iris pumila	
	Iris ricardi	
	Iris spuria	
	Iris susiana	
	Iris tectorum	
NOTE: This host list follows CMI/AAB-338, 1988 and Barnett, pers comm.		
Johnsongrass Mosaic Virus	*Avena sativa*	Oats
	Saccharum officinarum	Sugarcane
	Sorghum halepense	Johnsongrass
	Zea mays	Maize
NOTE: Hosts as given in Shukla, et al., 1989.		

Virus:	Host	
	Scientific Name:	**Common Name:**
Konjac Mosaic Virus	*Amorphophallus konjac*	Konjac
	Amorphophallus oncophyllus	
	Amorphophallus sp.	
	Philodendron oxycardium	Philodendron, a
	Philodendron selloum	
	Pinellia ternata	
NOTE: Hosts as given in Shimoyama, et al., 1992).		
Leek Yellow Stripe Virus	*Allium ascalonicum*	Shallot
	Allium cepa	Onion
	Allium porrum	Leek
	Celosia argentea	
	Chenopodium album	Lambsquarters
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Chenopodium spp.	Goosefoot
NOTE: Only 9 of 32 *Allium* species are susceptible and most are infected without symptoms. Four unnamed *Chenopodium* spp. also product local lesions (CMI/AAB-240, 1981).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Lettuce Mosaic Virus	*Carthamus tinctorius*	Safflower
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Gomphrena globosa	Globe amaranth
	Lactuca sativa	Lettuce (CMI/AAB-9, 1970)
	Pisum sativum	Pea (Xinshun, 1990)
NOTE: Host range is wide over 20 genera in 10 plant families. Nine genera are Compositae (CMI/AAB-9, 1970).		
Lily Mottle Virus	*Chenopodium quinoa*	Quinoa
	Lilium formosanum	
	Lilium longiflorum	Lily
	Lilium spp.	
	Nicotiana benthamiana	
	Nicotiana clevelandii	
	Tetragonia tetragonioides	New Zealand spinach
	Tulipa spp.	
NOTE: Host list from Dekker, et al., 1993.		

Virus:	Host	
	Scientific Name:	**Common Name:**
Maclura Mosaic Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Maclura pomifera	Osage orange
	Nicotiana clevelandii	Tobacco, a
	Tetragonia tetragonioides	New Zealand spinach
NOTE: Narrow range of 17 species from 5 plant families, most in the Chenopodiacae and Solanaceae (CMI/AAB-239 1981).		
Maize Dwarf Mosaic Virus	*Hordeum vulgare*	Barley (Garrido & Trujullo, 1988)
	Leersia virginica	Cut grass (Boothroyd, 1979)
	Panicum clandestinum	Deer's tongue (Boothroyd, 1979)
	Saccharum officinarum	Sugarcane (Garrido & Trujillo, 1988)
	Sorghum arundinaceum (=verticilliflorum)	False Johnsongrass (Garrido & Trujillo, 1988)
	Sorghum bicolor	Sorghum (Toler, et al., 1989)
	Sorghum halepense	Johnsongrass (Toler, et al., 1989)
	Triticum aestivum	Wheat (Garrido & Trujillo, 1988)
	Zea mays	Maize (Garrido & Trujillo, 1988)
Narcissus Degeneration Virus	*Narcissus tazetta*	Polyanthus narcissus (Stone, 1973)
Narcissus Latent Virus	*Iris* spp.	Iris
	Narcissus spp.	Narcissus
	Nerine spp.	Nerine
	Nicotiana clevelandii	
	Tetragonia tetragonioides	New Zealand spinach
NOTE: Hosts from Mowat, et al., 1991.		

Virus:	Host	
	Scientific Name:	**Common Name:**
Narcissus Yellow Stripe Virus	*Narcissus jonquilla*	Jonquil
	Narcissus pseudonarcissus	Daffodil (CMI/AAB-76, 1971)
	Nerine bowdenii	Nerine
	Tetragonia tetragonioides	New Zealand spinach
NOTE: Restricted to a few members of the Amaryllidaceae, but can infect one member of the Azioaceae (CMI/AAB-76, 1971).		
Nothoscordum Mosaic Virus	*Nothoscordum inodorum*	Onion weed (Pares & Gillings, 1990)
Oat Mosaic Virus	*Avena sativa*	Oat
NOTE: Apparently confined to 8 hosts in the genus *Avena* (CMI/AAB-145, 1975).		
Oat Necrotic Mottle Virus	*Avena sativa*	Oat
	Bromus hordeaceus	Soft chess
	Bromus racemosus	Chess, a
	Bromus secalinus	Cheat
	Bromus tectorum	Downy brome
	Lolium multiflorum	Annual ryegrass
	Lolium temulentum	Darnel
	Poa annua	Annual bluegrass
	Poa compressa	Canada bluegrass
	Poa pratensis	Kentucky bluegrass
	Poa trivialis	Roughstalk bluegrass
NOTE: Infects many cultivars of oat, other species of *Avenua* and some wild and cultivated grasses (CMI/AAB-169, 1976).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Onion Yellow Dwarf Virus	*Allium ascalonicum*	Shallot
	Allium cepa	Onion
	Allium fistulosum	Welsh onion
	Allium porrum	Leek
	Allium sativum	Garlic
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Narcissus odorus regulosus	True jonquil
	Narcissus pseudonarcissus	Common daffodil
	Narcissus tazetta orientalis	Polyanthus narcissus
NOTE: *Allium* spp., especially onions, are the only hosts really susceptible (CMI/AAB-158, 1976).		
Ornithogalum Mosaic Virus	*Ornithogalum umbellatum*	Star-of-Bethlehem
Papaya Ringspot Virus	*Carica papaya*	Papaya
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Citrullus lanatus	Watermelon
	Cucumis dipsaceus	Wild cucumber (Ullman, et al., 1991)
	Cucumis melo	Cantaloupe
	Cucumis metuliferus	Horned cucumber
	Cucurbita pepo	Pumpkin (squashes)
	Lagenaria siceraria	Bottle gourd (Ullman, et al., 1991)
	Luffa acutangula	Angled luffa
	Mormordica charantia	Bittermelon (Ullman, et al., 1991)
	Nicotiana benthamiana	Tobacco, a
NOTE: Papaya and cucurbits are natural hosts (CMI/AAB-292, 1984).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Parsnip Mosaic Virus	*Anthriscus cerefolium*	Chervil
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Coriandrum sativum	Coriander
	Pastinaca sativa	Parsnip
NOTE: Infects several species in the Umbelliferae, Amaranthaceae, Chenopodiaceae, and Scrophulariaceae (CMI/AAB-91, 1972).		
Passionfruit Woodiness Virus	*Arachis hypogea*	Peanut
	Centrosema pubescens	Centro
	Crotalaria zanzibarica	Crotalaria, a
	Glycine max	Soybean
	Macroptilium atropurpureum	Sirato
	Macroptilium lathyroides	Bean, a
	Passiflora edulis	Passionfruit
	Passiflora suberosa	Granadilla, a
	Phaseolus vulgaris	French bean
NOTE: Hosts include 10 species of *Passiflora* and 18 others in the Leguminosae (CMI/AAB-122, 1973).		
Pea Seed-Borne Mosaic Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Lens culinaris	Lentil (Hampton, et al., 1993)
	Pisum sativum	Pea
	Vicia articulata	Single-flowered vetch
	Vicia faba	Broad bean
	Vicia narbonensis	Narbonne vetch
	Vicia pannonica	Hungarian vetch
NOTE: Peas are the main host, but this virus can infect 47 species in 12 families. Most nonleguminous hosts are infected without symptoms (CMI/AAB-146, 1975).		

Virus:	Host	
	Scientific Name:	**Common Name:**
Peanut Mottle Virus	*Arachis hypogaea*	Peanut
	Glycine max	Soybean
	Nicotiana clevelandii	Tobacco, a
	Phaseolus vulgaris	French bean
	Pisum sativum	Pea
	Senna occidentalis	Coffee senna
NOTE: Host range outside the Leguminosae extremely limited (CMI/AAB-141, 1975).		
Pepper Mottle Virus	*Capsicum annuum*	Pepper
	Capsicum frutescens	Pepper, tabasco
	Lycopersicon lycopersicum	Tomato
	Nicotiana tabacum	Tobacco
	Nicotiana spp.	Tobacco, hybrids
	Physalis floridiana	
	Solanum spp.	Nightshade
NOTE: Hosts taken from Purcifull, et al., 1975.		
Pepper Severe Mosaic Virus	*Capsicum annuum*	Bell pepper
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
NOTE: This virus is transmissible by sap inoculation to 23 species of Solanaceaous plants as well as the above (Feldman & Gracia, 1977).		
Pepper Veinal Mottle Virus	*Capsicum annum*	Sweet pepper
	Capsicum frutescens	Tabasco pepper
	Chenopodium album amaranticolor	Lamsbquarters biotype
	Nicotiana clevelandii	Tobacco, a
	Nicotiana megalosiphon	

Virus:	Host	
	Scientific Name:	**Common Name:**
Pepper Veinal Mottle Virus	*Nicotiana tabacum*	Tobacco
	Petunia hybrida	Garden petunia
	Solanum nigrum	Black nightshade (Alegbejo, 1987)
NOTE: Reported to have 16 hosts, 11 in the Solanaceae alone; 5 are in 3 other families (CMI/AAB-104, 1972).		
Peru Tomato Mosaic Virus	*Capsicum annuum*	Sweet pepper
	Capsicum chinense	Hot pepper
	Capsicum pendulum	Hot pepper
	Lycopersicon lycopersicum	Tomato
	Lycopersicon pimpinellifolium	Currant tomato
	Nicandra physalodes	Apple of Peru
	Nicotiana debneyi	Tobacco, a
	Nicotiana occidentalis	
	Physalis peruviana	Cape gooseberry
	Solanum demissum x *S. tuberosum*	Potato hybrid
	Solanum nigrum	Black nightshade
NOTE: Host range restricted to the family Solanaceae except for a few chenopodiaceous species (CMI/AAB-255, 1982).		
Plum Pox Virus	*Campunula rapunculoides*	Creeping bellflower (Chang, 1987)
	Chenopodium foetidum	Goosefoot, a
	Chenopodium spp.	(Chang, 1987)
	Dimorphotheca aurantiaca hybrida	(Chang, 1987)
	Lamium album	White deadnettle (Chang, 1987)
	Lamium amplexicanule	Henbit
	Lupinus albus	White lupine (Chang, 1987)
	Lupinus barbarum	Barbary matrimonyvine (Chang, 1987)

Virus:	Host	
	Scientific Name:	**Common Name:**
Plum Pox Virus	*Lycium* spp.	
	Medicago lupulina	Black medic (Chang, 1987)
	Melilotus officinalis	Yellow sweetclover (Chang, 1987)
	Nicotiana clevelandii	Tobacco, a
	Nicotiana megalosiphon	
	Pisum sativum	Garden pea (Chang, 1987)
	Prunus armeniaca	Apricot
	Prunus avium	Sweet cherry
	Prunus cerasifera	Myrobalan plum (Chang, 1987)
	Prunus cerasus	Sour cherry (Hadidi, Pers. Comm.)
	Prunus domestica	Plum
	Prunus domestica institita	Damson plum (Chang, 1987)
	Prunus dulcis	Almonds
	Prunus glandusosa	
	Prunus persica	Peach (Becker, 1993)
	Prunus salicina	Japanese plum (Chang, 1987)
	Prunus spinosa	Blackthorn (CMI/AAB-70, 1971)
	Prunus tomentosa	(Chang, 1987)
	Ranunculus acer	(Chang, 1987)
	Ranunculus arvensis	Corn buttercup
	Silene vulgaris	Bladder campion (Chang, 1987)
	Solanum dulcamara	Bittersweet nightshade (Chang, 1987)
	Solanum nigrum	Black nightshade
	Trifolium incarnatum	Crimson clover (Chang, 1987)

Virus:	Host	
	Scientific Name:	**Common Name:**
Plum Pox Virus	*Trifolium pratense*	Red clover (Chang, 1987)
	Trifolium repens	White clover (Chang, 1987)
	Zinnia violacea	Zinnia
NOTE: Host range includes various stone fruit trees (Becker, 1993). Only found naturally in the genus *Prunus*, in which 15 species are susceptible. Blackthorn is the most important source of reservoir infection, but this plant usually shows no symptoms. *Lycium* spp. and *Prunus glandusosa* are 2 other reservoir hosts (Cooper, 1988). Sixty other host plant species in 8 plant families were identified (CMI/AAB-70, 1971).		
Pokeweed Mosaic Virus	*Chenopodium quinoa*	Quinoa
	Gomphrena globosa	Globe amaranth
	Phytolacca americana	Pokeweed (CMI/AAB-97, 1972)
NOTE: Host range restricted to the 3 hosts listed here (CMI/AAB-97, 1972).		
Potato Virus A	*Lycopersicon pimpinellifolium*	Currant tomato
	Nicandra physalodes	Apple-of-Peru
	Nicotiana tabacum	Tobacco
	Solanum demissum	Nightshade, a
	Solanum tuberosum	Potato (CMI/AAB-54, 1971)
NOTE: Host range is limited to the Solanaceae (CMI/AAB-54, 1971).		
Potato Virus V	*Datura metel*	Hindu datura
	Lycopersicon lycopersicum	Tomato
	Nicandra physaloides	Apple-of-Peru
	Nicotiana bigelovii	
	Nicotiana clevelandii	
	Nicotiana debneyi	
	Nicotiana glutinosa	
	Nicotiana occidentalis	
	Nicotiana tabacum	Tobacco
	Physalis floridana	
	Solanum berthaultii	

Virus:	Host	
	Scientific Name:	Common Name:
Ryegrass Mosaic Virus	*Bromus sterilis*	Poverty brome
	Cynosurus cristatus	
	Dactylis glomerata	Orchardgrass
	Festuca pratensis	Meadow fescue
	Lolium multiflorum	Italian ryegrass
	Lolium perenne	Perennial ryegrass
	Oryza sativa	Rice
	Poa annua	Annual bluegrass
	Poa pratensis	Kentucky bluegrass
	Poa trivialis	Roughstalk bluegrass
NOTE: Limited to the Gramineae. Other hosts within the Gramineae reported, but not confirmed (CMI/AAB-86, 1972).		
Sorghum Mosaic Virus	*Saccharum* spp.	Sugarcane
	Sorghum bicolor	Sorghum
NOTE: Described in 1989. Only 2 hosts mentioned (Shukla, 1989).		
Soybean Mosaic Virus	*Chenopodium album*	Lambsquarters
	Chenopodium quinoa	Quinoa
	Cyamopsis tetragonoloba	Guar
	Glycine max	Soybean
	Lablab purpureus	Hyacinth bean
	Lupinus albus	White lupine (Tamada, 1977)
	Macroptilium lathyroides	Bean, a
	Phaseolus lunatus	Lima bean (Tamada, 1977)
	Phaseolus vulgaris	French bean
	Vigna unguiculata	Southern pea
NOTE: Transmissable to about 30 plant species. All but 2 hosts are legumes. Some necrotic strains are not in the U.S.A. (CMI/AAB-93, 1972).		

Virus:	Host	
	Scientific Name:	Common Name:
Sugarcane Mosaic Virus	*Hordeum vulgare*	Barley
	Musa textilis	Abaca
	Oryza sativa	Rice
	Panicum miliaceum	Millet
	Saccharum spp.	Sugarcane
	Secale cereale	Rye
	Sorghum bicolor	Sorghum
	Sorghum halepense	Johnsongrass
	Triticum eastivum	Wheat
	Zea mays	Maize
NOTE: Host range (except AMV strain) limited to Gramineae, including numerous cultivated and wild grasses. The AMV strain host range includes monocotyledons outside the Gramineae (CMI/AAB-88, 1972).		
Sweet Potato Feathery Mottle Virus	*Ipomoea alba*	Moonflower
	Ipomoea batatas	Sweet potato
	Ipomoea carnea	
	Ipomoea fistulosa	
	Ipomoea hederacea	Ivyleaf morning-glory
	Ipomoea nil	
	Ipomoea purpurea	Tall morning-glory
	Ipomoea setosa	
	Ipomoea tiliacea	Choisy
	Ipomoea tricolor	
	Ipomoea wrightii	
	Merremia spp.	
	Quamoclit hederifolia	
NOTE: Taken in a review of alternate hosts from Venezuela (Olivero, 1989).		

Virus:	Host	
	Scientific Name:	Common Name:
Sweet Potato Mild Mottle Virus	*Ipomoea batatas*	Sweet potato
	Ipomoea nil	
	Ipomoea setosa	
	Lycopersicon lycopersicum	Tomato
	Nicotiana clevelandii	Tobacco, a
	Nicotiana glutinosa	
	Nicotiana tabacum	Tobacco
NOTE: Not naturally found in tomato or tobacco. Can infect 45 hosts from 14 plant families (CMI/AAB-162, 1976).		
Sweet Potato Yellow Dwarf Virus	*Chenopodium* spp.	
	Datura stramonium	Jimson weed
	Gomphrena globosa	Globe amaranth
	Ipomoea batatas	Sweet potato
	Ipomoea setosa	(Green & Lo, 1989)
	Nicotiana glutinosa	(Green & Lo, 1989)
	Senna occidentalis	Coffee senna
	Sesamum indicum	Sesame
	Sesamum orientale	
NOTE: Hosts as given in Brunt, et al., 1990.		
Tamarillo Mosaic Virus	*Cyphomandra betacea*	Tree tomato (Mossop, 1977)
	Nicotiana clevelandii	Tobacco, a (Mossop, 1977)
Telfairia Mosaic Virus	*Amaranthus caudatus*	Love-lies-bleeding
	Canavalia ensiformis	Jackbean
	Canavalia rosea	Beach bean
	Celosia argentea	Cockscomb
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium capitatum	
	Chenopodium murale	Nettleleaf goosefoot

Virus:	Host	
	Scientific Name:	**Common Name:**
Telfairia Mosaic Virus	*Chenopodium quinoa*	Quinoa
	Citrullus lanatus	Watermelon
	Cucumis melo	Melon
	Cucurbita pepo	Pumpkin
	Cucumis sativus	Cucumber
	Datura stramonium	Jimson weed
	Datura tatula	
	Gomphrena globosa	Globe amaranth
	Macroptilium lathyroides	Bean, a
	Nicotiana benthamiana	Tobacco, a
	Nicotiana clevelandii	
	Nicotiana megalosiphon	
	Nicotiana plumbaginifolia	
	Nicotiana sylvestris	
	Nicotiana tabacum	Tobacco
	Phaseolus vulgaris	Garden bean
	Physalis angulata	
	Physalis floridana	
	Telfairia occidentalis	Fluted pumpkin
	Tetragonia tetragonioides	New Zealand spinach
	Trifolium incarnatum	Crimson clover
	Vicia faba	Broadbean
	Vigna radiata	Mung bean
NOTE: The above hosts are in 6 plant families (Shoyinka, et al., 1987).		
Tobacco Etch Virus	*Capsicum annuum*	Sweet pepper
	Capsicum frutescens	Tabasco pepper
	Chenopodium album	Lambsquarters
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa

Virus:	Host	
	Scientific Name:	**Common Name:**
Tobacco Etch Virus	*Cirsium vulgare*	Bull thistle
	Datura stramonium	Jimson weed
	Linaria canadensis	Oilfield toadflax
	Nicotiana tabacum	Tobacco
	Physalis spp.	
	Senna obtusifolia	Sicklepod
	Solanum spp.	
NOTE: Other 120 species in 19 families are susceptible (CMI/AAB-258, 1982).		
Tobacco Vein Mottling Virus	*Lycopersicon lycopersicum*	Tomato
	Nicotiana tabacum	Tobacco
NOTE: From Pirone, et al., 1988 and CMI/AAB-325, 1988.		
Tulip Band Breaking Virus	*Tulipa* spp.	Tulip
NOTE: Host as given by Dekker, et al., 1993.		
Tulip Breaking Virus	*Lilium* spp.	Lily
	Tulipa spp.	Tulip (CMI/AAB-71, 1971)
NOTE: Over these 2 plant genera, both in the Liliaceae, are hosts (CMI/AAB-71, 1971).		
Tulip Chlorotic Blotch Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Gomphrena globosa	Globe amaranth
	Lycopersicon lycopersicum	Tomato
	Nicotiana benthamiana	Tobacco, a
	Nicotiana clevelandii	
	Nicotiana debneyi	
	Nicotiana glutinosa	
	Nicotiana rustica	Azetic tobacco
	Petunia hybrida	Garden petunia

Virus:	Host	
	Scientific Name:	Common Name:
Tulip Chlorotic Blotch Virus	*Spinacia oleracea*	Spinach
	Tetragonia tetragonioides	New Zealand spinach
	Tulipa spp.	Tulip (Mowat, 1985)
NOTE: This host list follows Mowat, 1985.		
Turnip Mosaic Virus	*Anemone* spp.	
	Arenaria serphllifolia	Thyme-leaved sandwort (Stobbs & Stir., 1990)
	Armoracia rusticana	Horseradish
	Brassica napa	Rape
	Brassica napa var. *napobrassica*	Swede
	Brassica napus	Winter rapeseed (Stobbs & Stir., 1990)
	Brassica oleracea var. *botrytis*	Cauliflower
	Brassica oleracea var. *capitata*	Cabbage (CMI/AAB-8, 1970)
	Brassica oleracea var. *gemmifera*	Brussels sprout
	Brassica pekinensis	Chinese cabbage
	Brassica perviridis	Tendergreen mustard
	Brassica rapa	Turnip
	Brassica spp.	Mustard
	Capsella bursa-pastoris	Shepherd's-purse (Stobbs & Stir., 1990)
	Cardaria draba	Heart-podded hoary cress (Stobbs & Stir., 1990)
	Cheiranthus cheiri	Wallflower
	Chenopodium album	Lambsquarters (Stobbs & Stir., 1990)
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium murale	Nettleleaf goosefoot (Stobbs & Stir., 1990)
	Chenopodium quinoa	Quinoa

Virus:	Host	
	Scientific Name:	**Common Name:**
Potato Virus Y	*Nicotiana plumbaginifolia*	Tobacco, a (Fletcher, 1989)
	Nicotiana rustica	Azetic tobacco (Fletcher, 1989)
	Nicotiana tabacum	Tobacco
	Physalis floridana	Groundberry, a
	Ranunculus spp.	Buttercup (Lisa, et al., 1990)
	Solanum chacoense	Bitter forma chacoense
	Solanum demissum	Nightshade, a
	Solanum luteum	Nightshade, a (Raccah & Gal-On, 1984)
	Solanum tuberosum	Potato
	Tinantia erecta	
NOTE: Has been transmitted to 120 plant species. Host range is mainly limited to the Solanaceae, although species in 4 other families are susceptible (CMI/AAB-242, 1981).		
Prunus-Latent Virus	*Nicotiana occidentalis*	Tobacco (Hadidi, Pers. Comm.)
	Prunus mume	Japanese apricot (Hadidi, Pers. Comm.)
	Prunus persica	Peach
NOTE: Becker (1993) mentioned this as a new potyvirus by Hadidi.		
Rembrandt Tulip Breaking	*Lilium formosanum*	Lily, a
	Tulipa spp.	Tulip
NOTE: Hosts from Dekker, et al., 1993.		
Rice Necrosis Mosaic Virus	*Oryza sativa*	Rice
NOTE: Rice is the only known host (CMI/AAB-172, 1977).		
Ryegrass Mosaic Virus	*Agrostis scabra*	Rough bentgrass
	Alopecurus agrestis	Foxtail, a
	Avena fatua	Wild oat
	Avena sativa	Common oat
	Bromus arvensis	Field brome

Virus:	Host	
	Scientific Name:	Common Name:
Potato Virus V	*Solanum brachycarpum*	
	Solanum chacoense	
	Solanum chancayense	
	Solanum curtilobum	
	Solanum demissum	
	Solanum demissum x tuberosum	
	Solanum mochicense	
	Solanum raphanifolium	
	Solanum tuberosum	Potato
NOTE: Hosts as originally given in the description of PVV (Fribourg & Nakashima, 1984). See also CMI/AAB-316, 1986.		
Potato Virus Y	*Capsicum annuum*	Bell pepper (Fletcher, 1989)
	Capsicum spp.	Pepper
	Chenopodium album amaranticolor	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Cyphomandra betacea	Tree tomato (Fletcher, 1989)
	Hyoscyamus aureus	Henbane, a (Raccah & Gal-On, 1984)
	Hyoscyamus desertorum	Henbane, a (Raccah & Gal-On, 1984)
	Lycium spp.	
	Lycopersicon lycopersicum	Tomato
	Nicandra physalodes	Apple-of-Peru (Fletcher, 1989)
	Nicotiana benthamiana	Tobacco, a (Fletcher, 1989)
	Nicotiana debneyii	
	Nicotiana glutinosa	Tobacco, a
	Nicotiana occidentalis	Tobacco, a (Fletcher, 1989)

Virus:	Host	
	Scientific Name:	**Common Name:**
Turnip Mosaic Virus	*Diplotaxis tenuifolia*	Narrow-leaved wall rocket (Stobbs & Stir., 1990)
	Erucastum gallicum	Dog mustard (Stobbs & Stir., 1990)
	Erysimum cheiranthoides	Wormseed mustard (Stobbs & Stir., 1990)
	Gomphrena globosa	Globe amaranth (Stobbs & Stir., 1990)
	Matthiola incana	Stock
	Nasturtium officinale	Watercress
	Nicotiana glutinosa	Tobacco, a
	Nicotiana tabacum	Tobacco
	Petunia spp.	
	Phytolacca americana	Pokeweed (Stobbs & Stir., 1990)
	Raphanus sativus	Radish
	Rheum rhabarbarum	Rhubarb
	Senecio vulgaris	Common groundsel (Stobbs & Stir., 1990)
	Sinapsis arvensis	Wild mustard (Stobbs & Stir., 1990)
	Sonchus asper	Spiny annual sow-thistle (Stobbs & Stir., 1990)
	Spergula arvensis	Corn spurry (Stobbs & Stir., 1990)
	Stellaria media	Chickweed (Stobbs & Stirling, 1990)
	Tropaeolum spp.	
	Zinnia spp.	
NOTE: Wide host range in 20 plant families (CMI/AAB-8, 1970). Those hosts listed by Stobbs & Stirling are weeds. Winter rapeseed serves as an excellent overwintering host for TuMV and is especially attractive to aphids (Stobbs & Stirling, 1990).		
Watermelon Mosaic Virus 2	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Citrullus lanatus	Watermelon

Virus:	Host	
	Scientific Name:	**Common Name:**
Watermelon Mosaic Virus 2	*Cucumis melo*	Cantaloupe
	Cucumis sativus	Cucumber
	Cucurbita pepo	Pumpkin
		Squash
	Luffa acutangula	Angled luffa
	Nicotiana benthamiana	Tobacco, a
	Pisum sativum	Pea
NOTE: Over 160 species in 23 families are susceptible (CMI/AAB-293, 1984).		
Wheat Streak Mosaic Virus	*Aegilops* spp.	Wild grasses
	Agropyron spp.	
	Avena sativa	Oats
	Bouteloua spp.	
	Bromus spp.	
	Cenchrus spp.	
	Digitaria spp.	
	Echinochloa spp.	
	Elymus spp.	
	Eragrostis spp.	
	Haynaldia spp.	
	Hordeum vulgare	Barley
	Hordeum spp.	
	Lolium spp.	
	Oryzopsis spp.	
	Panicum spp.	Millets
	Phalaris spp.	
	Poa spp.	
	Secale cereale	Rye
	Setaria spp.	Millets
	Sorghum bicolor	Sorghum (Harvey & Seifers, 1991)

Virus:	Host	
	Scientific Name:	**Common Name:**
Wheat Streak Mosaic Virus	*Stipa* spp.	
	Triticum aestivum	Wheat (CMF/AAB-48, 1971)
	Zea mays	Maize
NOTE: No dicotyledons have been infected (CMI/AAB-48, 1971).		
Wheat Spindle Streak Mosaic Virus	*Triticum aestivum*	Winter wheat (Zagula, et al., 1990)
Wisteria Vein Mosaic Virus	*Nicotiana megalosiphon*	(Brcak, 1980)
	Pisum sativum	Pea (Brcak, 1980)
	Wisteria sinensis	Wisteria (Brcak & Kralik, 1983)
Yam Mosaic Virus	*Dioscorea alata*	Greater yam
	Dioscorea cayenensis	Yellow guinea yam (Thou, & Fau., 1979)
	Dioscorea esculenta	Lesser yam (CMI/AAB-314, 1986)
	Dioscorea liebrechtsiana	Yam, a
	Dioscorea praehensilis	Bush yam
	Dioscorea preussii	Yam, a
	Dioscorea rotundata	White yam (Reckhaus, 1979)
	Nicotiana benthamiana	Tobacco, a
NOTE: *Nicotiana benthamiana* was the only host found in families other than the Dioscoreaceae; also only the *Dioscorea* spp. listed above could be infected; other *Dioscorea* spp. are not infected, even by mechanical means (Thouvenel & Fauquet, 1979).		
Zucchini Yellow Fleck Virus	*Cucumis sativus*	Cucumber (Avgelis, 1985)
	Cucurbita pepo	Zucchini squash (Vovlas, et al., 1981)
	Cucurbita spp.	Cucurbits (Katul & Makkouk, 1987)
	Ecballium elaterium	Cucumber, squirting (Rana & Mondelli, 1985)

Virus:	Host	
	Scientific Name:	**Common Name:**
Zucchini Yellow Mosaic Virus	*Chenopodium album amaranticolor*	Lambsquarters biotype
	Chenopodium quinoa	Quinoa
	Citrullus lanatus	Watermelon
	Cucumis dipsaceus	Wild cucumber (Ullman, et al., 1991)
	Cucumis melo	Muskmelon
	Cucumis metuliferus	(Yang, et al., 1987)
	Cucumis sativus	Cucumber
	Cucurbita moschata	Pumpkin (Yang, et al., 1987)
	Cucurbita okeechobeensis	Squash, a
	Cucurbita pepo	Zucchini squash
	Gomphrena globosa	Globe amaranth
	Lagenaria siceraria	Bottle gourd (Ullman, et al., 1991)
	Lavatera trimestris	
	Luffa acutangula	Angled luffa
	Luffa aegyptiaca	Luffa (Yang, et al., 1987)
	Melothria pendula	
	Mormordica charantia	Bittermelon (Ullman, et al., 1991)
	Phaseolus vulgaris	Garden bean (Greber, et al., 1989)
	Ranunculus sardous	Buttercup, a
	Trichosanthes anguina	Snakegourd (Greber, et al., 1989)
NOTE: Experimental hosts come from 11 families of plants (CMI/AAB-282, 1984).		

ADDENDUM 4

Technical Survey Information

Cross Transit Survey:

Draw two straight lines on a map that will intersect each other and run through:

- High Risk suburban/urban areas whose residents are likely to travel to PotyV-infected areas of the species of concern
- Host production areas
- Areas where hosts are in abundance (backyards, etc.)
- Coastal areas where hosts are available

The lines should both bisect the area under survey. They do not need to be perpendicular to each other, but should both run through the most suitable local sites that have been identified.

Survey Procedures:

1. If host(s) are in new flush:

   a. Examine all hosts along the transit. If there are many hosts along the transit (as in a field or grove), select 1 out of every 10 most likely localities. A minimum sample along any one transit should be 10 host localities.

   Each host locality may be sampled, depending on the type of host.

   Woody hosts generally may be sampled on the basis often trees or bushes per locality.

   Herbaceous hosts are best sampled if aggregated in wild stands or in cultivated fields. These fields or stands should be sampled at a minimum of 5 different sites, following a predetermined pattern agreed to beforehand by program staff or a technical advisory committee.

2. Restrict examination to host(s), especially host with new growth. In particular, pay attention to new growth that appears stunted, retarded, or with narrowed to shoestring leaves, or has spots or streaks on the leaves, is distorted, or is otherwise abnormal in appearance and seems to show any one of the visual symptoms of the PotyV or of an attack of any of its local vector(s); and in general check host(s) which appear to be unhealthy. Samples of plant tissue, especially leaves, should be taken immediately from different parts of the plant, unless it is known that the virus is concentrated in a particular area (leaves, fruit, stems, or roots) of the host. In this case, samples will be concentrated from such area(s).

Leaf sampling may be modeled along the lines of the leaf sample collection procedure for PVY^n under the Canada/U.S.A. Management Plan (see page 11.6). Modifications may be necessary owing to factors such as virus type, vector(s) involved and other plant part(s) which may be collected.

3. Knock insect vectors, if any, into a wide mouth jar with a gauzed or screened top; or onto a light-colored cloth sheet such as a beating (insect) umbrella from which insects (if any), can be put quickly into a vial or bottle with a gauzed or screened top.

Mite vectors are to be collected by removing that part of the plant they are on and putting this into the jar.

Soil borne fungal vectors are collected by digging out root samples (since such vectors are obligate root parasites), air-drying these, and placing them into a clean, empty jar (Adams, et al., 1988). Air borne fungi, however, should be collected through leaf or stem samples.

Precautions should be taken to ensure that no insects, mites, whiteflies, or fungal cystosori or urospores are accidently spread through collection methods or procedures.

Special precautions must be carried out for fungal vectors, since there is a constant danger of the inadvertent spread of the fungus and thus any virus it contains, by survey personnel. To minimize this possibility, disposable gloves will be used or hands will be thoroughly washed with soap and water before exiting each field or garden. Hands must be washed on site in order not to contaminate other areas. Rubber boots will be worn and disinfected with quaternary ammonium upon exiting each field or garden visited. In addition, all tools and equipment that come in contact with plants or soil will be disinfected with quaternary ammonium before their removal from the field (Dufresne, 1990).

4. Label each sample with the collector's name, the date, and the exact location in enough detail so that someone else can find the spot.

5. Send vials (bottles) to a designated center for identification/processing. Insect or mite samples may be sent in live if suitable, or otherwise in 50 percent ethanol, if they are to be frozen for blot tissue analysis. Otherwise they can be sent in jars of alcohol if the intent is identification of the insect only.

When host(s) are not in new flush:

1. Examine the undersides of mature foliage for dead, parasitized insect vectors or mummies. As these adhere to the leaves, they can be used for identification in the absence of living specimens (EPPO, 1992).

2. Examine all suspect secondary or reservoir hosts, such as herbaceous weeds and shrubs which show typical visual symptoms of the PotyV and are found in or near infected properties along the transit. This includes backyard and field locations that are relatively easy to examine (Vicchi & Bellardi, 1988).

3. Follow the procedures as given above.

The survey should be run weekly or biweekly until it is determined, through negative finds, that PotyV is not present in a given area. Transit lines may be moved in the judgement of the survey officer responsible for that area, in an attempt to cover more favorable hosts or new locations.

Inspection Procedures:

During periods of low insect vector populations and mobility, visual surveys and aids are better employed. Traps may be deployed when vector populations are high or flight times (of insect vectors) are estimated to peak at a given time.

1. Survey of new flush on hosts. Look for symptoms of the targeted PotyV, evidence of the vector(s) presence, and colonies (especially) of the vector(s). This technique is best in the spring.

2. Generally, look for certain signs, such as spots, rings, stripes, wilted leaves, and other year round evidence characteristic for the PotyV. These signs may be checked throughout the year.

3. Fruit survey. During fruiting periods, survey for visual signs characteristic of the PotyV on fruit such as plums, apricot, or peach, when applicable to such hosts.

4. Beating sheet. Use a beating sheet under suspect hosts to detect light infestations of any insect vector (CDFA Detection Manual- D.T. 3:29).

5. Traps. Traps may be used for the purpose of determining the populational numbers of vectors, for identifing the vectors present or for determining flight times or flight periods or releases of given vectors. They are not suitable for collecting the live insects or mites needed to determine if a virus is being carried by them, although this may be done with fungal spores.

   a. Green or yellow pan traps (Halbert et al., 1986). These traps are for use among hosts with a low canopy such as soybean or grass fields. They may be used for the purpose of determining the populations of insect vectors or identifying the vectors present.

Traps are of clear plastic sandwich boxes, each with a 11 cm x 11 cm green or yellow tile ceramic within, and filled with water containing 2 percent nicotine sulfate (Black Leaf Co., Elgin, Illinois; 40 percent ai) (Irwin & Goodman, 1981; Raccah, et al., 1985). The actual color would depend on the preferences of the local vector(s). Traps are mounted at canopy level with double ended clamps and support stands. Traps are to be serviced every day and water is to be changed at least once a week.

An alternate pan trap is the mosaic green pan trap. This trap consists of a 12 cm x 12 cm mosaic green ceramic tile in a plastic sandwich box. The box is filled with a 50 percent aqueous solution of ethylene glycol. This box is mounted at canopy level by means of a metal pole and a double chemistry clamp (Irwin & Kampmeier, 1989).

Another alternate pan trap is one of aluminum, 23 cm diameter, and painted yellow inside. These may be filled with water and placed on the ground under low canopy hosts (Adlerz, 1987).

b. Sticky traps. These traps may be used among hosts with a high canopy, such as *Prunus*. The color selected should reflect the preference of the target vector(s). If the preference is not known, choose yellow or white traps. Such traps may be used for aphids and whiteflies and leafminers (Berlinger, et al., 1988). Certain types may also be suitable for mites.

A variety of commercial traps of this type is available and may be suitable for aphid, leafminer or whitefly vector(s) of concern to a given program. Examples are the Chroma® line card traps from Phero Tech Inc. (Bright Yellow No. 611), the Trappit Yellow Sticky Trap® from Agrisense (primarily for whitefies), and the AM Trap® from Trece Inc. The Trece Tent Trap® may be more suitable for mites. Instructions enclosed with these traps should, in general be followed, unless program management or a technical advisory committee determines otherwise.

c. Moericke trays (Carver, 1978; Seif & Islam, 1988). These traps may be used in hosts with a high canopy, such as *Prunus*.

Traps are of 25 cm diameter plastic bowls, painted yellow or green inside and black outside. They are filled with water up to two small outlets below the rim. A few drops of formaldehyde are added to preserve the catch. The outlets are covered with plastic gauze

to prevent the trapped insects from being washed out during heavy rains. The traps need to be serviced as frequently as necessary to maintain the water level, but should be serviced at least weekly.

Each trap is suspended 6 1/2 feet (2 m) above the ground or as necessary to be in line with the host canopy. In general, they should not be hung from a host, but near it, on a post or pole in the open. Approximately 4 traps per 1/4 acre have been used to track Brown citrus aphids, for example.

d. Suction traps (Carver, 1978). Suction traps may or may not be recommended for a given arthropod vector, owing to their comparatively great cost per trap. A trap design described as an "inexpensive suction trap" cost $300 in 1987 and required 20 man-hours of labor for construction and erection (Allison and Pike, 1988). It is possible that a suction trap design incorporating color as part of its attraction could be developed and deployed in such a way that a few traps could cover a large area, but this is not now available. However, if a given vector is flying at that time of year and suction traps have collected adequate numbers of that vector in the past, then this method may well prove worthwhile.

NOTE: If color is incorporated into the design, it may greatly affect both the size of the sample and its species composition. Deciding which color to use may be complicated, because manufacturers use different bases and pigments to produce colors which appear the same to humans, but not to insects. For that reason, different species of insects may react differently to two different preparations. This may be of concern in a survey for one specific insect (Taylor, et al., 1972).

e. Whitefly trap (Berlinger, 1980). This trap is best suited for low canopy hosts or inside greenhouses.

The trap is constructed out of 9.0 cm diameter plastic petri dishes. The cover of a dish is glued horizontally, upside down, onto a rod (or placed directly on the ground). This inverted cover is painted yellow or a yellow plastic sheet is placed into it. Since whiteflies respond to yellow in the 520-620 nm range, a color in that range should be utilized. On the Munsell color file, a color with 5Y 8.5/12 (500 to 700 nm) would be appropriate.

The inverted cover with color is the base and stationary part of the trap. The portable part also consists of a plastic petri dish. The bottom is smeared with a thin layer of tanglefoot or similiar sticky material. Benzene may be used to dilute the sticky material if necessary. This bottom is placed on the yellow trap base and exposed by removing the top of the dish. When it is time to service the trap, the top is put over this bottom and the whole removed. A fresh bottom may be put in place and the catch transported to the lab with appropriate collection data (written on the top) with a grease pen.

Generally, the trap is placed at a level which depends primarily on the height of the flight activities of the whitefly species in question. This can range from ground level up to above host height.

No figures have been given for trap spacing. From 5 to 20 traps were deployed in a greenhouse of unknown size for populational studies (Berlinger, 1980).

f. Mite slide trap (Jeppson, et al., 1975).

Standard 1" x 3" glass slides coated with silicone grease are placed in a one foot square frame (one slide on each side). The trap is placed at just above canopy level. The traps may be left in place during the trapping period and serviced daily. No figures are available for optimum trap spacing.

Canadian/U.S.A. Leaf Sample Collection Procedures:

The Canadian/U.S.A. Leaf Sample Collection procedures for PVY^n are given here as a general guide. As stated in Survey Procedures (page 11.2), modifications may be necessary for a specific program on some other PotyV.

Leaf Sample Collection
PVY^n Management Plan
(In hectares & meters)

1. The objective of sampling is to provide the laboratory with high quality leaf samples that are representative of the crop being examined.

2. In all potato leaf sampling for PVY^n the normal sample collected per plant is the terminal three leaflets from the upper portion of the plant. For more detail, see the PVY^n Management Plan.

3. Care must be taken to complete all sample submission forms and label all containers appropriately, so that a positive laboratory result can be traced back to the field of origin, and negative results may be credited to the appropriate field of origin.

4. The mathematical probability theory used to estimate sample numbers assumes that each plant in a given field, has an equal probability of being sampled. This can be achieved in grid sampling by randomly selecting the starting point (corner) of the grid. After randomly selecting the starting point, sample collection follows a systematic grid pattern which ensures samples are collected from all sectors of the field (i.e., a systematic random sampling).

5. As an example, if it is determined that a field should be sampled at a rate of 100 plants per hectare (ha), then collecting terminal leaf triplets from plants located every 20 m X 5 meters (m) across the field, will provide 100 samples per ha.

To achieve this in a systematic random "grid" pattern, stand at one corner of the field, beside the first plant at the end of the first row. Select a random number between 1 and 20 (e.g., Y=12) and walk Y m across the head-land (i.e., across the ends of rows). Turn to face into the field, looking between the two rows of potatoes nearest to you. Select a random number between 1 and 5 (e.g., Z=2). Walk Z m in from the head-land between the rows. This is the random starting point of your 20 m by 5 m grid pattern. Collect a terminal leaf triplet from the nearest plant from the row to your left. Walk another 5 m into the field between the same two rows, and collect a sample from the nearest plant from the row to you right. Continue along between the rows in this manner, to the end of the field collecting a sample every 5 m, alternating from the row on your left to the row on your right. When you get to the end of the field, walk a further 20 m across the headland and start back down the field Z m, collecting a sample every 5 m alternating left and right. In this manner, work your way across the field at 20 m intervals across the head-land, collecting a sample every 5 m along rows alternating left and right (see Fig. 11 on page 11.10).

Regardless of the size or shape of the field this 20 m X 5 m grid pattern will lead to a sampling rate of 100/ha. Similarly a 15 m X 5 m grid would provide 133.3 samples per ha, or a 20 X 8 = 62.5/ha, a 30 X 10 = 33/ha, a 10 X 5 = 200/ha.

6. As a general rule the ratio of head-land interval to row interval (HL:R), should not exceed 4:1.

For example: a) 5 m (HL) X 20 m (R); b) 100 m HL X 10 m R; and c) 20 m HL X 5 m R, grid patterns each provide sampling rates of 100/ha. But, their HL:R ratios are 0.25:1, 1:1, and 4:1 respectively. In a 100 m X 100 m square, 1 ha field, the a) 5 HL X 20 R grid pattern would require walking the length of the field 20 times (i.e., 2000 m) to collect the 100 samples; b) would mean walking the field 10 times (1000 m); and c) 5 times (500 m), to collect the 100 samples (plus head-land walking). Obviously, c) is preferable because it means less walking, but still provides samples from all sectors of the field.

However, the head-land to row interval ratio, cannot be too great. Clearly, walking the length of a 100 m X 100 m field once, collecting one sample every 1 m is unacceptable, because it would not provide samples from all sectors of the field (i.e., equal to a 100 m HL X 1 m R grid or HL:R ratio of 100:1). A square grid pattern (e.g.,10 X 10, HL:R=1:1), provides the most uniform coverage possible; however it means walking 1000 m (plus head-land) for every 100 samples. A 20 m HL X 5 m R interval grid pattern (HL:R ratio 4:1) is a reasonable compromise. However, as a general rule the HL:R ratio should not exceed 4:1.

7. The Canada/U.S.A. PVY^{n} Management Plan for the control of PVY^{n} requires sampling at 400 plants per field. This provides a 95 percent confidence of sampling at least one positive plant if the prevalence of infection within the field is 0.75 percent, regardless of the size of the field.

8. The next step is to calculate the sampling rate per ha, that is required to provide the 400 samples per field. Learn the size of the field in hectares from: records, the owner or measurement estimates. Then divide 400/field size in ha, to calculate the number of samples required per ha to obtain the require 400 samples for the field.

For example: a) a 1 ha field will be sampled at 400/1 = 400 plants (i.e., 400 terminal leaf triplet samples) per ha; b) a 10 ha field at 400/10 = 40 samples per ha; and c) a 0.1 ha field at 400/0.1 = 4000 samples per ha.

9. Once the sampling rate per ha has been calculated, find that rate in the body of the table on page 11.11. Then read the appropriate head-land and row intervals from the top and side of the table respectively, that will achieve the appropriate sampling rate per ha, and yet do not exceed a HL:R ratio of 4:1.

a. Example 1:

If a sampling rate of 100/ha is required, find the number 100 in the body of the table on page 11.11 (example *), read the headland interval from the top of the table (e.g., 20 m) and the "along the row" interval from the side of the table (e.g., 5 m). This means that pacing off a 20 m HL X 5 m R grid pattern as per 5. on page 11.7, will provide the appropriate sampling rate of 100/ha. To achieve this, find the randomized starting point (in from the corner of the field), by picking a random number between 1 and 20 and between 1 and 5 m. Proceed at the appropriate HL and R intervals, in a manner similar to the instructions in 5. on page 11.7.

b. Example 2:

Suppose that an irregularly shaped 6 ha field is to be sampled. It must be sampled at rate of 400/6=67 plants/ha. Find the number nearest to 67 in the body of the table on page 11.11 (example ** = 63). This indicates that a head-land interval of approximately 22.5 m, with sampling every 7 m along the rows, will provide the appropriate total sample (377 approx. = 400). Pick a random number between 1 and 22 and between 1 and 7 to select the randomized starting point (in from the corner of the field). Proceed using the appropriate "along the row" interval of 7 m between samples and head-land interval of 22.5 m, in manner similar to the instructions in 5. on page 11.7. This will result in a sampling rate of approximately 67/ha, for a 6/ha field (in this case 63/ha for a total of 377 samples, if all paced measurements are exact). Obviously, paced measurements will rarely all be exact. Therefore, keep track of the total number of samples collected for the field, and "top-up" randomly (in this case with approximately 23 samples) or randomly skip samples as required, to meet the desired sample size of 400 for the field.

10. If leaf sampling is being done during the winter grow outs it is necessary to randomly select 400 tubers, at harvest, from the field, using the sample pattern as if leaves were being collected. Extra tubers should be collected to ensure that a minimum of 400 grow out samples (one from each tuber) is available for testing. During winter grow out, one leaflet from each plant is taken from the plot.

11. Always remember that the objective of sampling is to provide the laboratory with high quality leaf samples that are truly representative of the crop being examined. It is the responsibility of the person collecting the samples to ensure that this objective is achieved.

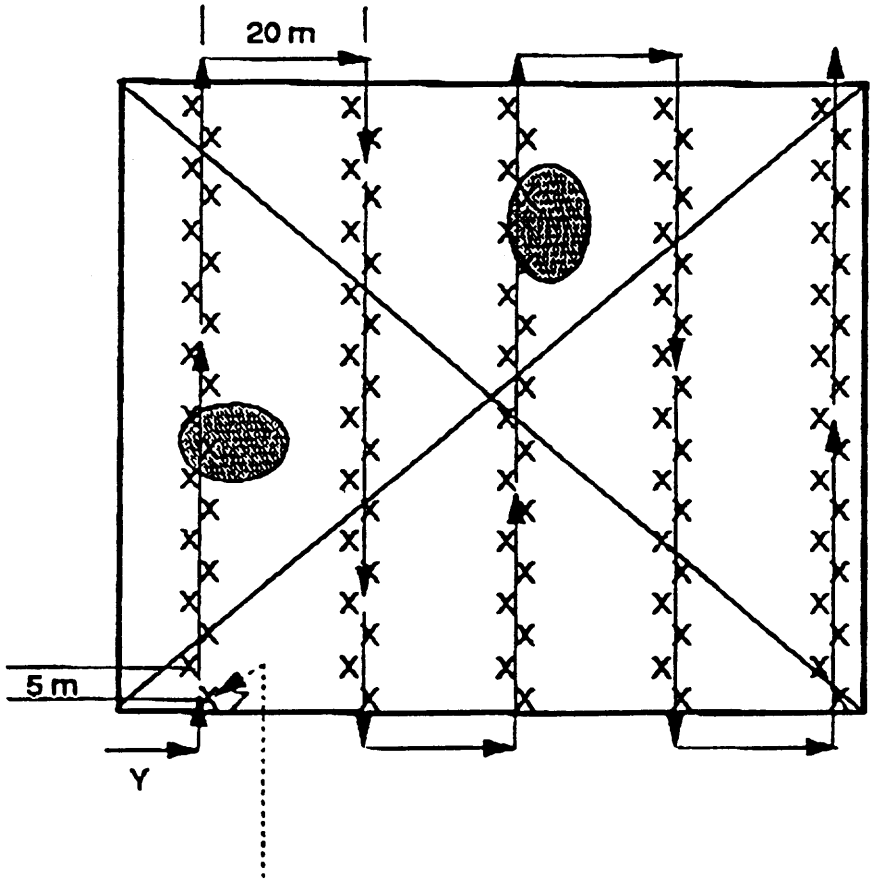


Figure 11: Example of 20mHL x 5mR "grid" sampling pattern. Arrows illustrate path walked through field. Random start of grid in from corner Y m across head-land, Z m into field. Shaded areas are schematic representations of pockets of infection. Note lines of sampling if "X" pattern had been used.

Sample numbers per ha that are provided by various head-land by row (HL X row) grid patterns.

meters along rows	meters accross headland rows																				
	1.0	1.5	2.0	2.5	3.0	3.5	4.0	4.5	5.0	6.0	7.0	8.0	9.0	10.0	12.5	15.0	17.5	20.0	22.5	25.0	27.5	30.0
1.0	10000	6667	5000	4000	3333	2857	2500															
1.5		4444	3333	2667	2222	1905	1667	1481	1333	1111												
2.0				2000	1667	1429	1250	1111	1000	833	714	625										
2.5						1143	1000	889	800	667	571	500	444	400								
3.0									667	556	476	417	370	333	267							
3.5											408	357	317	286	229	190						
4.0												313	278	250	200	167						
4.5													247	222	178	148	127					
5.0														200	160	133	114	100*				
6.0														167	133	111	95	83	74			
7.0																95	82	71	63**	57	52	
8.0																83	71	63	56	50	45	42
9.0																	63	56	49	44	40	37
10.0																			44	40	36	33
12.5																				32	29	27
15.0																					24	22
17.5																						19
20.0																						17

ADDENDUM 5

Technical Control Information

Polymer Webs:

Upon the declaration of a regulatory zone or when domesticated or commercial plantings are visible above the soil surface:

1. Completely cover susceptible herbaceous hosts with polypropylene fleece as soon as possible. The fleece of choice is Lutrasil LS10® or equivalent for aphids and Agril® or equivalent for whiteflies.

2. Sheets should be inspected for damage on a regular basis to ensure that the fleece remains intact over the host.

3. Control of other pests may be achieved by spraying the appropriate pesticide over the sheets.

Methyl Bromide:

1. As a soil or field fumigant for fungi, a 98:2 or 70:30 mixture of methyl bromide and chloropicrin is injected into the soil by inserting shanks that penetrate to a depth of at least 6" (15 cm). The methyl bromide is applied at a rate of 600 lbs per acre (675 kg per ha). The injection is immediately covered with a plastic sheet for a minimum of 48-hours to retard loss of the fumigant. There is currently no EPA approval for this rate or use, so an emergency exemption is required. Successful treatment required a soil moisture content of approximately 70 percent of field capacity, and temperatures of at least 50° F (10° C) at a depth of 8" (20 cm). Avoid excessively wet or dry conditions. Soil must be worked to a seedbed condition. Weeds, debris, large rocks and other objects which may be prevent penetration of the chemical into the soil must be removed. Sampling of plots should be conducted 14 or more days after treatment for devitalization determinations.

2. When used to fumigate contaminated storage buildings, cellars, or infected material, apply methyl bromide at a rate of 15 lbs per 1,000 cubic feet, (240 gms/m^3), for 24 hours at 60° F (15.5° C) or above. In order to assure effective treatment, buildings to be fumigated are to be sealed and/or tarped.

Quaternary Ammonium Compounds:

The recommended formulations are for Coverage 256®. If a different quaternary ammonium compound is used, it must be approved, because different mixtures of quaternary ammoniums have different effects. For safety and comfort, applicators are required to wear rainwear such as hats, coats, rubber boots, and face shields. Soil should not be removed from equipment before treatment if there is a possibility that the soil will contaminate the site. Once soil is saturated with quaternary ammonium, it is no longer considered cause for contamination.

1. To disinfect storage areas, drench area thoroughly with a 0.15 percent active ingredient (a.i.) quaternary ammonium solution. Do not rinse. In household situations, a 0.06 percent a.i. solution may be used instead.

Prepare a 0.15 percent a.i. solution by diluting a 15.34 percent a.i. formulation 1:100 with water, or 1.3 oz/gal. Prepare a 0.06 percent a.i. solution by mixing 1/2 oz of a 15.34 percent a.i. formulation in 1 gallon of water.

2. To disinfect vehicles, portions of vehicles where soil is likely to adhere, such as tires, wheel wells, and under the chassis, should be thoroughly washed with a 0.15 percent a.i. solution of quaternary ammonium. Do not rinse for at least 1 hour. After 1 hour, equipment should be rinsed only if specifically required by owners or operators. Because quaternary ammonium will kill grass on contact, it should be used to wash equipment in nonplanted areas. Equipment should be dry at the time of treatment to facilitate uptake of the liquid. For large pieces of equipment, a high pressure delivery system is recommended to penetrate the soil and debris, which still may adhere to various surfaces. Equipment must be wet to saturation with the quaternary ammonium compound.

3. When used to disinfect tools and boots, remove adhering soil and thoroughly wet the tools and boots with a 0.15 percent a.i. quaternary ammonium solution. Do not rinse. An emergency exemption will be required for the above rates and uses.

Glyphosate (Roundup•):

Use to kill infected or infested hosts when a PTV is detected during the growing season, and to destroy susceptible hosts after field bioassays. The herbicide may be boom-applied at the rate of 4 quarts (3 lb a.i.) per acre (3.4 kilos a.i. per ha) overall. For spot treatment, using a hand or knapsack sprayer, apply a solution containing 2 ounces of Roundup• per gallon of water.

Phenolic Compounds:

Used in household situations to disinfect storage areas. A 0.4 percent solution should be used. Contact with skin should be avoided. Gloves and a face shield should be worn where necessary. An emergency exemption will be required for this.

ADDENDUM 6

Special Considerations for Home Gardens

Factors in Regulatory Decisions:

Home gardens and similar situations may present a lower risk of viral spread, because their produce may not be commercially distributed and they may (or may not) be well tended to and treated for pests, including possible vectors. Because they occur in diverse situations, survey techniques, regulatory actions, and control, suppressive or eradicative procedures will be decided on a case-by-case basis. Procedures mutually will be approved by cooperating State and local regulatory officials. Factors in regulatory decisions include:

- Proximity of site to areas of commercial production
- Size of garden
- Movement of hosts, vector(s) or soil (if applicable)
- Proximity of site to streams
- Concentration of spores in the soil
- Changes in size or location of garden on a property over the years
- Proximity of site to dwellings
- Suitability of the PotyV to such regulatory measures (i.e., Plum pox virus is not suitable, owing to risks of its spread on numerous hosts with serious economic consequences; but Aparagus virus 1 may be so regulated, owing to a singular host which may not be prevalent in the area.)

Some of these factors may also apply to the choice of survey, control, suppressive, or eradicative techniques at commerical sites.

Regulatory Options:

These include:

- Control, suppression, or eradication measures
- Prohibition of host crops at the infected site

Alternative options may be developed if deemed necessary. A quarantine or compliance agreement may or may not be required.

Regulatory Treatments:

Storage areas in or near houses may be disinfected with a 0.06 percent a.i. quaternary ammonium compound such as Coverage 256® or a phenolic compound such as Amphyl® (0.4 percent). These may be preferable to a 0.15 percent a.i. quaternary ammonium compound because they are milder solutions.

ADDENDUM 7

Life History

Systematic Position:

Potyviruses

Superkingdom:	Prokaryotae
Kingdom:	Virus
*Class:	Plant Viruses
*Order:	Picorna-like Viruses (Picornavirales)
Family:	Potyviridae

*Class and Order are not recognized terms for the plant viruses at this time. They are used here to give continuity to the viruses covered by this document.

Potyviruses are the largest and most important of the 35 groups of plant viruses currently recognized (Brunt, in Barnett, 1992). They are transmitted by aphids (most species), mites, whiteflies, and certain fungi. Some species are also borne by the seed of hosts or in one case, by rust spores.

At present, the Potyviridae have a total of 88 identifiable viruses in 3 genera (ICTV-VI, in press), including Lily mottle virus, as resurrected by Dekker, et al., 1993. There are another 91 possible viruses which may belong here. All but 6 would be in the genus *Potyvirus*, if confirmed. Another possible undescribed genus with two viruses inclusive may belong in the Potyviridae too, as indicated below (Barnett, 1992).

The inexact state of our knowledge is reflected by the fact that recently, rod-shaped virus particles of 50 to 250 nm length were found in two aquatic plants, *Hygrophila difformis* and *H. polysperma* (Proeseler, et al., 1990). These are shorter than any known Potyviridae, but the pathogen was not isolated, nor was it possible to transmit a number of well known potyviruses to these hosts. However, the authors did succeed in identifying the unrelated Cucumber mosaic virus (CMV) in these plants. The vector was the aphid, *Rhopalosiphum nymphaeae*, which is a known vector of CMV. It was found on immersed shoots of the hosts. The question still remains whether or not the short rod-shaped particles are potyviruses.

Acronym:	Virus:	Geographical Distribution:
Genus *Potyvirus*		
AlMV	Alstroemeria mosaic	Canada (SRPQS, 1984), Netherlands (Hakkaart, 1988), UK (Phillips, et al., 1981)
AmLMV	Amaranthus leaf mottle	Morocco, Italy, Spain, Africa, Europe (Lovisolo & Lisa, 1979)
ArjMV	Araujia mosaic	Argentina (Charudattan, et al., 1980)

Acronym:	Virus:	Geographical Distribution:
ALV	Artichoke latent	California (Smith, 1972)
AVI	Asparagus 1	Michigan (Evans & Stephans, 1989); Washington (Howell & Mink, 1985); U.S.A., UK, Germany, Japan (Foster, 1993)
BCMV	Bean common mosaic (=BlCMV Blackeye cowpea mosaic) (=AZMV Azuki bean mosaic) (=PStV Peanut stripe) (=peanut chlorotic ring mottle) (=Sesame yellow mosaic)	World wide (CMI/AAB-337, 1988) Kenya, Nigeria, Brazil, India, Japan Taiwan, Thailand, Malaysia, U.S.A., Widespread (CMI/AAB-305, 1985) (Mali, et al., 1988); Indonesia, Netherlands, Morocco, Lebanon (Foster, 1993) China, Georgia, North Carolina, Texas, Virginia, Florida, Oklahoma (NPAG, 1983); Asia (Foster, 1993)
BCMNV	Bean common mosaic necrosis	Serotype A of BCMV, above
BYMV	Bean yellow mosaic (=*Crocus tomasinianus*) (=white lupin mosaic) (=pea mosaic)	Florida (Becker, 1993); World wide (CMI/AAB-40, 1970)
BtMV	Beet mosaic	World wide, esp. temp. beet regions (CMI/AAB-53, 1971)
BiMoV	Bidens mottle	Florida (CMI/AAB-161, 1976)
CdMV	Cardamon mosaic	India (Devi, et al., 1982), Guatemala (Gonsalves, 1986)
CVMV	Carnation vein mottle	U.S.A., Europe, where carnations are grown (CMI/AAB-78, 1971); Australia, New Zealand, Japan (Foster, 1993)
CTLV	Carrot thin leaf	NW U.S.A. (CMI/AAB-218, 1980)
CeMV	Celery mosaic	Western States, Florida of U.S.A., Germany, France, UK (CMI/AAB-50, 1971)
CVMV	Chili veinal mottle	Malaysia, China (Fujisawa, et al., 1990)

Acronym:	Virus:	Geographical Distribution:
ClYVV	Clover yellow vein (=pea necrosis) (=SVY Statice Y)	Britain, Canada, U.S.A. (CMI/AAB-131, 1974), Northern Europe (Foster, 1993); Australia (Barnett, et al., 1987) Germany (Lesemann, et al., 1979)
CSV	Cocksfoot streak	Widespread, UK & Europe (CMI/AAB-59, 1971)
CDV	Colombian datura	Columbia (Kahn & Bartels, 1968)
ComMV	Commelina mosaic	Florida (Morales & Zettler, 1977)
CABMV	Cowpea aphid-borne mosaic (=South African Passifora)	Cyprus, India, Iran, Italy, Morocco, Florida ?? (Mali, et al., 1988), Barnett, (pers. comm.) not naturally (CMI/AAB-134, 1974; Uganda, Rumania, Indonesia, China, Japan (Foster, 1993)
CGVBV	Cowpea green vein banding	Brasil (Lin, et al., 1981)
DsMV	Dasheen mosaic	World wide, Florida (CMI/AAB-191, 1978)
DSTV	Datura shoestring	Canada (Weintraub, et al., 1973)
DEMV	Dendrobium mosaic	Japan (Inouye, 1973), Italy (Bellardi, 1983)
GSMV	Gloriosa stripe mosaic	Germany (Koenig & Lesemann, 1974), Japan (Aruki, et al., 1985)
GEV	Groundnut eyespot	Ivory Coast (Dubern, 1979)
GGMV	Guinea grass mosaic	Ivory Coast (CMI/AAB-190, 1978); Columbia, Brazil (Morales, et al., 1994)
HVY	Helenium virus Y	Iran (Kuschki, et al., 1978)
HMV	Henbane mosaic	England, Germany, Italy (CMI/AAB-95, 1972), Hungary (Horvath, et al., 1988)
HiMV	Hippeastrum mosaic	World wide (CMI/AAB-117, 1973)
IFMV	Iris fulva mosaic	Massachusetts (Barnett & Alper, 1977); Western U.S.A. (CMI/AAB-310, 1986)
IMMV	Iris mild mosaic	World wide (CMI/AAB-116, 1973); 324, 1986)
ISMV	Iris severe mosaic (=bearded iris mosaic)	U.S.A., Japan, Europe (CMI/AAB-147, 1975); World wide (Foster, 1993; CMI/AAB-338, 1988)

Acronym:	Virus:	Geographical Distribution:
JGMV	Johnsongrass mosaic	Australia, U.S.A. (Shukla, et al., 1989), Yugoslavia (Tosic, et al., 1990)
KMV	Konjac mosaic	Japan (Shimoyama, et al., 1992)
LYSV	Leek yellow stripe	Europe (CMI/AAB-240, 1981)
LMV	Lettuce mosaic	World wide; widespread in U.S.A., esp. California and in Europe (CMI/AAB-9, 1970), China (Xinshun, 1990)
LiMV	Lily mottle virus	Netherlands (Dekker, 1993), World wide, esp. temp. regions (following TBV distribution - same author)
MDMV	Maize dwarf mosaic	Zambia (Toler, et al., 1989); Yugoslavia (Tosic, et al., 1990), Venezuela (Garrido & Trujillo, 1988), U.S.A., (New York, Wisconsin, Ohio, Vermont) (Boothroyd, 1979), Minnesota, Southern States (Heppner, 1977); World wide (Foster, 1993)
NDV	Narcissus degeneration	Isles of Scilly (Stone, 1973)
NYSV	Narcissus yellow stripe	World wide, esp. temp. (CMI/AAB-76, 1971)
NoMV	Nothoscordum mosaic	Australie (Pares & Gillings, 1990); Louisiana (Foster, 1993)
OYDV	Onion yellow dwarf	World wide, except New Zealand (CMI/AAB-158, 1976)
OrMV	Ornithogalum mosaic	South Africa (Burger, et al., 1990)
PRSV	Papaya ringspot (=watermelon mosaic I)	N. & S. America, Asia, Australia, Africa, Europe (CMI/AAB-292, 1984), Hawaii (Ullman, et al., 1991)
ParMV	Parsnip mosaic	UK only (CMI/AAB-91, 1972)
PWV	Passionfruit woodiness	Australia, Surinam only (CMI/AAB-122, 1973)
PSbMV	Pea seed-borne mosaic	U.S.A., Europe, Japan (CMI/AAB-146, 1975); India (Hampton, et al., 1993)
PeMoV	Peanut mottle	S.E. U.S.A., Africa, N.E. Australie, Japan, Malaysia, S. America, Europe (CMI/AAB-141, 1975); World wide (Foster, 1993)

Acronym:	Virus:	Geographical Distribution:
PepMoV	Pepper mottle	Arizona, California, Florida, North Carolina (Vance, et al., 1992)
PeSMV	Pepper severe mosaic	Argentina (Feldman & Gracia, 1977)
PVMV	Pepper veinal mottle	Ghana, Africa (CMI/AAB-104, 1972); Nigeria, Kenya, Ivory Coast, S. Africa (Foster, 1993)
PTV	Peru tomato mosaic	Peru (CMI/AAB-255, 1982)
PPV	Plum pox	Europe, Egypt (EPPO, 1992); Turkey, Chile (Acuna, 1993); India (Thakur, 1992)
PkMV	Pokeweed mosaic	North America East of Rocky Mts. (CMI/AAB-97, 1972)
PVA	Potato A	Widespread in most potato-growing countries (CMI/AAB-54, 1971)
PVV	Potato V	Ireland, Netherlands, Peru (Fribourg & Nakashima, 1984); Great Britain (Foster, 1993; CMI/AAB-316, 1986)
PVY	Potato Y	Y^o is world wide, Y^n is in Europe and parts of Africa & South America, Y^c is in Australia, India, parts of the UK and Europe (CMI/AAB-242, 1981), New Zealand (Fletcher, 1989)
PLPV	Prunus-latent	China, Japan (Hadidi, pers. comm., 1993)
ReTBV	Rembrandt tulip breaking	Netherlands (Dekker, et al., 1993)
SrMV	Sorghum mosaic	U.S.A., Deep South only (Jensen, 1992; Shukla, et al., 1989)
SbMV	Soybean mosaic	Most areas with soybeans, Japan (Tamada, 1977)
SCMV	Sugarcane mosaic	Occurs in many areas of the world where hosts are grown (CMI/AAB-88, 1972)
SPFMV	Sweet potato feathery mottle (=sweet potato russet crack) (=sweet potato A) (=sweet potato chlorotic leafspot) (=sweet potato internal cork)	Israel (Salomon, 1989), U.S.A. (Wolters, et al., 1990), Venezuela (Olivero, et al., 1989), Canada (Stobbs, et al., 1991); World wide (Foster, 1993)

Acronym:	Virus:	Geographical Distribution:
TamMV	Tamarillo mosaic	New Zealand (Mossop, 1982)
TeMV	Telfairia mosaic	Nigeria, Africa (Shoyinka, et al., 1987)
TEV	Tobacco etch	Common in N. & S. America, Hawaii, Puerto Rico, Venezuela (CMI/AAB-258, 1982)
TVMV	Tobacco vein mottling	Kentucky (Pirone, et al., 1988); North Carolina, Tennessee, Virginia (CMI/AAB-325, 1988; Foster, 1993)
TBBV	Tulip band braking	Netherlands (Dekker, et al., 1993)
TBV	Tulip breaking	World wide, esp. temp. regions (CMI/AAB-71, 1971)
TCBV	Tulip chlorotic blotch	Australia (Mowat, 1985)
TuMV	Turnip mosaic (=tulip top breaking)	World wide, esp. temp. regions (CMI/AAB-8, 1970)
WMV2	Watermelon mosaic 2 (=vanilla necrosis)	Australia, New Zealand, Europe, Japan, Middle East, S. America, Mexico, Florida ? (CMI/AAB-293, 1984), Hawaii (Ullman, et al., 1991)
WVMV	Wisteria vein mosaic	Czechoslovakia (Brcak, 1981), Italy, Netherlands (Brcak, 1980)
YMV	Yam mosaic (=dioscorea green banding)	Ivory Coast (Thouvenel & Fauquet, 1979), Nigeria, Caribbean ? (CMI/AAB-314, 1966)
ZYFV	Zucchini yellow fleck	Lebanon, Syria (Katul & Makkouk, 1987), Crete (Avgelis, 1985), Italy (Volvas, et al., 1981; Rana & Mondelli, 1985), Greece (Vovlas, et al., 1983)
ZYMV	Zucchini yellow mosaic	Europe, N. Africa, Middle East, Australia, Mauritius, UK, and Florida (CMI/AAB-282, 1984), Venezuela (Hernandez, et al., 1989), Hawaii (Ullman, et al., 1991), China (Yang, 1987); U.S.A., Taiwan, Mexico, Malaysia, Canada, Japan, Guam (Foster, 1993)

Possible *Potyvirus* Viruses:

Alstroemeria streak
Amazon lily mosaic
Aneilema**
Anthroxanthum mosaic
Aquilegia**
Arracacha Y
Asystasia gangetica mottle
Bidens mosaic
Bramble yellow mosaic
Brandle yellow mosaic
Bryonia mottle
Canary reed mosaic
Canavalia maritima mosaic
Carrot mosaic
Cassava brown streak-associated
Cassia yellow spot
(= cassia yellow blotch)
Celery yellow mosaic
Chickpea bushy dwarf
Chickpea filiform
Clitoria yellow mosaic
Cowpea rugose mosaic
Crinum mosaic
Crotian clover**
Cypripedium calceolus
Daphne Y
Datura 437
Datura distortion mosaic
Datura mosaic
Datura necrosis
Desmodium mosaic
Dioscorea alata ring mottle
Dioscorea trifida**
Dipladenia mosaic
Dock mottling mosaic
Eggplant green mosiac
Eggplant severe mottle
Euphorbia ringspot
Ficus carica**
Freesia mosaic
Garlic mosaic
Malva vein clearing
Marigold mottle
Melilotus mosaic
Melon vein-banding
Moroccan watermelon mosaic
Mungbean mosaic
Mungbean mottle
Narcicus late season yellows
(=jonquil mild mosaic)
Nerine**
Palm mosaic
Papaya leaf distortion
Passionfruit mottle
Passionfruit ringspot
Patchouli mottle
Peanut green mosaic
Peanut mosaic
Pecteilis mosaic
Pepper mild mosaic
Perilla mottle
Plantin 7
Pleioblastus mosaic
Populus**
Primula mosiac
Primula mottle
Ranunculus mottle
Sri Lankan passionfruit mottle
Sesame isolate***
Sunflower mosaic
Sweet potato latent
Sweet potato vein mosaic
Sword bean distortion mosaic
Teasel mosaic
Telfairia mosaic
Tobacco vein banding mosaic
Tobacco wilt
Tongan vanilla
Tradescantia/Zebrina**
Trichosanthes mottle
Tropaeolum 1
Tropaeolum 2

**Name inadequate, but denotes a host in which a potyvirus has been reported.
***See Sreenivasulu, et al., 1994.

Possible *Potyvirus* Viruses (continued):

Garlic yellow streak
Guar symptomless
Habenaria mosaic
Holcus streak
Hungarian datura innoxia
Hyacinth mosaic
Indian pepper mottle
Isachne mosaic
Kennedya Y
Lily mild mottle
Ullicus mosaic
Vallota mosaic
Vanilla mosaic
White bryony mosaic
Wild potato mosaic
Zoysia mosaic

Acronym:	Virus:	Geographical Distribution:
Genus *Rymovirus*		
AgMV	Agropyron mosaic	S. Dakota, Virginia, Ontario, Quebec, Prince Edward Island, Saskatchewan, Finland (Smith, 1972); Northern Europe (Foster, 1993)
HoMV	Hordeum mosaic	U.S.A., Canada (Langenberg, 1989); Alberta (Foster, 1993)
ONMV	Oat necrotic mottle	Manitoba (CMI/AAB-169, 1976),
RGMV	Ryegrass mosaic	U.S.A., Canada, UK (CMI/AAB-86, 1972); Northern Europe (Foster, 1993)
WSMV	Wheat streak mosaic	U.S.A., Canada, Jordan, Rumania, Yugoslavia, Russia (CMI/AAB-48, 1971); Bulgaria, Turkey (Foster, 1993)

Possible *Rymovirus* viruses

- Brome streak mosaic Yugoslavia (Foster, 1993).
- Spartina mottle Great Britain (Foster, 1993)

Acronym:	Virus:	Geographical Distribution:
	Genus *Bymovirus*	
BaMMV	Barley mild mosaic	Germany (Proeseler, 1991), Japan (Schlichter, et al., 1993), UK (Adams, 1991), China (Chen, et al., 1993), France (Signoret & Huth, 1993)
BaYMMV	Barley yellow mosaic	Japan (CMI/AAB-143, 1975), Germany (Proeseler, 1991), Europe, China (Foster, 1993)
OMV	Oat mosaic	S.E. U.S.A., N.W. U.S.A., UK, New Zealand ? (CMI/AAB-145, 1975)
RNMV	Rice necrosis mosaic	Japan (CMI/AAB-172, 1977), India (Foster, 1993)
WSSMV WYMV	Wheat spindle streak mosaic or Wheat yellow mosaic	World wide (Zagula, et al., 1990); U.S.A., India, France, Canada, Japan (Foster, 1993)

List of unassigned viruses in the Family (ICTV-VI, in press):

1 - Whitefly transmitted

SPMMV	Sweet potato mild mottle	Kenya, Tanzania, Uganda (CMI/AAB-162, 1976)
SPYDV	Sweet potato yellow dwarf	Taiwan (Foster, 1993; Green & Lo, 1989)

2 - Aphid transmitted

MacMV	Maclura mosaic	Yugoslavia (CMI/AAB-239, 1981)
NaLV	Narcissus latent	Europe (CMI/AAB-170, 1976); China (Xie, et al., 1990)

Epidemiology:

The dynamics of most plant disease epidemics in the ecosystem are strongly governed by meterological parameters.

Fungal epidemics such as occur with *Puccinia sorghi* (common rust) spores, and any associated dust borne viral disease, usually rely rather directly on wind speed and direction for dust borne dispersal. However, the fungus *Polymyxa graminis* is soil borne and does not produce airborne spores.

Epidemics of plant viruses transmitted by arthropods result from recurring movement of infective vectors through the ecosystem, with subsequent infections of plants through the introduction of the pathogen by vectors. In these systems, an epidemic requires the interaction of four components: the host plant, the arthropod vector, the virus, and their interactions with the environment.

Potyvirus transmission by arthropods may be dependent on the presence within infected plants of a virus-coded helper component protein of M_r53-58k and the composition of the capsid protein. In many cases, an arthropod vector cannot transmit the virus without first acquiring this helper component or isolate, and if it is not present, will not transmit the virus (Govier & Kassanis, 1973, 1974). It is not known if fungal vectors have this mechanism, but Adams, et al., 1988, presents evidence that Barley yellow mosaic virus is transmitted by the vector only from plants where it had been introduced by the vector and not from mechanically inoculated plants.

In aphids, viruses are nonpersistent, but can be retained for a while during long-distance dispersal and migration, especially if the virus will survive for some time in the aphid after acquisition and the aphid does not feed enroute. Thus, epidemics of infection can be initiated at great distances from the primary infected area. In Israel, most aphid flight activity occurs between 7 a.m. and 9 a.m. and of the vectors, more than 80 percent are caught in the morning hours (Raccah & Gal-On, 1984).

Transmission over long distances of non-persistent viruses, of course, depends on the retention times of a non-persistent virus in the vector and the transmission rate. For Potato Virus Y (PVY), the retention time is better than 12 hours, but less than 16 hours, and the transmission rate decreases only in the first hour of a post-acquisition fasting period (PFP) and is constant thereafter. This allows for greater dispersal of PVY viruses over a period of time, than, say, the unrelated cucumber mosaic virus (CMV), which has a retention time of only 2-3 hours and a steadily decreasing transmission rate as the PFP increases. A third factor is the number of hosts a given infected vector can inoculate during the retention period. For PVY, an aphid can infect up to seven plants in succession; for CMV, only two (Conti, 1984).

Factors influencing viral transmission may include the location of the virus in the aphid. For the lentil strain of pea seed-borne mosaic virus (PSbMV), this appears to be defined areas on the internal mandibles, 50 nm from the stylet tips. For the Madison pea strain of PSbMV, the area involved is on the maxillary stylet tips near the food and salivary canals (Jellison, 1986).

Environmental factors influencing aphid transmission are relative humidity and temperature. A high relative humidity of about 80-90 percent and temperatures around 25-30° C, when combined, increases virus transmission by 30 to 35 percent. However, transmission rates are reduced by nearly 50 percent if the relative humidity drops to 50 percent while the temperature stays the same (M.N. Singh, 1988).

Since vector specificity among the potyviruses (of the genus *Potyvirus*) appear to be the exception, many aphid species may be capable of transmitting these viruses. For that reason, noncolonizing aphids are often implicated in the spread of a potyvirus in a given host. These noncolonizing aphids, indeed, may be the primary reason for spread of a given potyvirus, since causal, probing contact during the wanderings of migrant or transient alate aphids through a field or grove of a given crop or other susceptible plant species are all that may be necessary (Klein & Wyatt, 1989).

Viruses borne by the plasmodiophoraceous, root-infecting fungus *Polymyxa graminis* are persistent and are transmitted by the zoosphores and cystosori. Thus, the potential for wind and dust or water borne dispersal is high. However, only a small proportion of the spores may be viruliferous, and the average number of particles per zoospore (about 55-72) is low, so that in the majority of cases insufficient virus is transmitted to initiate systemic infections.

Only recently, it was confirmed that uredospores of *Puccinia sorghi* will transmit Maize dwarf mosaic virus (MDMV)(Wechmar, et al., 1993) when the spore comes to rest on a MDMV host. It is not necessary for the spore to germinate for MDMV to infect a susceptible host. There is no effect on aphid transmissibility of the virus. The very curious distribution and transmission patterns of MDMV may perhaps be explained by this mechanism.

Viruses borne by mites may be either persistent or nonpersistent. The egg stage is free of any plant virus. In the persistent type, the first nymphal stage can become viruliferous during a 10 to 30 minute or greater feeding period, depending on mite species, host and virus, if on a diseased plant. The virus can survive in the body of a mite through the nymphal stages into the adult. Older adults may gradually lose their ability as vectors. Adults which have never been exposed to the virus or have lost it, may acquire it, but are unable to transmit it unless they were viruliferous as nymphs (Jeppson, et al., 1975; Ahmed & Benigno, 1985).

Nonpersistent viruses such as Ryegrass mosaic virus may be retained for less than 24 hours and considerations applicable to aphid-borne viruses may be made.

Mites cannot travel any distance under their own power and rely on wind, insects, and birds to carry the adult females and (at least) a few males. These are the dispersal stages, although nymphs can surely be carried if circumstances dictate. Wind is probably the

principal dispersal mechanism. The adults rear up on their hind lobes and caudal setae and paw the air. If they are facing the wind, they will easily become airborne in slight air currents (Jeppson, et al., 1975).

When a virus is present, it usually is detected almost immediately when its vector(s) appears each season. This is usually about late spring to the end of summer, at which time the infection pressure drops off rapidly, owing to changes in vector availability and possible mature-host resistance. During the course of the growing season, fluctuations in vector pressure may reflect changes in host availability, vector numbers, and vector species involved (Ryden, K., et al., 1983).

Some insects and mites can survive in storage and spread the infection to other stores not previously infected. Some aphids, in fact, will feed on stored host when little or no light is available, but not when lighting is good. The infection is then spread further the following year when plantings are made from infected stores (Bell, 1988).

Many aphid-borne viruses have a narrow host range, but some have a wide host range. The mite and fungal-transmitted viruses are chiefly confined to the Graminae.

A few aphid-borne viruses may also be transmitted by leafminers of the genus *Liriomyza* (Zitter & Tsai, 1977). These are Celery mosaic virus and Watermelon mosaic virus. Transmission may be effected by the virus carried as a contaminant on the ovipsitor or on the mouthparts of flies that feed on the ovipositional wounds created by the female fly. However, this vector relationship has not been reported elsewhere and may represent an isolated incident.

At least one aphid-borne virus is also transmitted by a mite. This is Garlic mosaic virus (GarMV), which in the Philippines is carried by the eriophyid mite, *Aceria tulipae*. Actual feeding by this mite causes tangled and twisted leaves and large yellow blotches; which is distinguished from the pale yellow streaks caused by the virus itself (Ahmed & Benigno, 1984). It is not known if this situation occurs elsewhere.

While the impression given above is that a virus may spread very rapidly, local spread, in fact, may be very slow. For example, Plum pox virus in the Soviet Union averaged an estimated 10-15 m rate of spread per year (Chang, 1987).

The rate of infection may also drop off very rapidly from the source. In Yugoslavia, Plum pox virus infection rates dropped off very rapidly from a source of heavily infected trees to 49-100 percent at 100 m or less and to less than 2 percent at 500 m or more away (Chang, 1987).

A long-term epidermiological goal is to provide a set of principles or guidelines upon which to base virus epidemiological models and control strategies that take into account the total ecology of a virus and its vector(s) in agricultural systems (Irwin & Kampmeier, 1989). As more information becomes available about the biology and spatial components of plant disease epidemics, it will be possible to more accurately forcast their origins and spread and thus be well enough informed to take the steps needed to control, supress or even eradicate a virus from a given area. The following is a short summary of key factors.

Seed and Clonal Transmission:

Seed transmission is probably the most important single factor in the dispersal of a virus. There are two types of transmission. One is natural dispersal of the seed. Some seeds may be wind- or water-borne, others are dispersed by animals, such as birds, mammals, including man, and even insects. The second type is deliberate collection, transport, storage, and planting of the seed or of the whole or part of an infected host by man through clonal propagation. Seed transmission and other means of propagation also account for the carryover of a virus from one season to the next.

Vector Movement:

As plant viruses cannot exist outside the host, vectors must be present to carry them during the growing season. Potyvirus vectors are aphids, whiteflies, mites, and fungi. These are small to minute life forms greatly influenced by climatological factors in their movement. Factors in their movement include atmospheric conditions and wind direction. Subtle changes in the character of the environment can elicit abrupt changes in vector behavior, and in turn, the pattern of virus epidemics in time and space (Irwin & Kampmeier, 1989).

1. Vertical Displacement--Vertical displacement may be illustrated by dividing the troposphere into four layers. The lowest is the vector pool population on the hosts. Immediately above the crop canopy are the vectors within the surface boundary layer (lower 10 to 20 m). Above this is the 1 km planetary boundary layer where turbulence and surface effects such as inversions dominate. The uppermost layer is the area where the vectors have become involuntarily uplifted by convection into the free atmosphere.

Vectors in the surface boundary are involved in local or short-duration movement. This directly accounts for most local virus spread in a field. Vectors in the planetary boundary are true migrants. In the case of arthropods, movement from this layer to the host canopy is determined by an individual's physiological state, dictated by the depletion of fuel reserves through flight. Changes in the environment also play an important part in vector movement from the upper layers.

2. Horizontal Translocation--Arthropod vectors of Potyviruses are generally assumed to have low flight speed capabilities; thus, it is assumed that they are controlled by air movement. This makes it possible to measure long distance movement. Preliminary data indicate that aphids, at least, prefer prefrontal conditions of moderate to strong southwesterly air flows.

3. Flight Patterns--Alate flight requires the right combination of physiological and meteorological factors. Wind is the most obvious stimuli for the spatial component of arthropod flight. Wind speed controls takeoff thresholds and distance between landings. Wind direction influences direction of flight and thus direction of spread. Different species may react in very different ways to the same stimuli. Time of day is also a factor in flight as different species may have different activity cycles.

4. Barriers--Barriers, both living and artificial, can alter the pattern or timing of a plant virus epidemic. Barriers work by physically excluding (or including) the vector(s), by altering the flight path, or both.

5. Environmental Stimuli--Environmental stimuli that alter arthropod vector activity and the subsequent inoculation potential of host plants can dramatically change rates of viral epidemics in the ecosystem. These stimuli can be physical or chemical. Some examples include:

a. Canopy Cover

Canopy cover is the ratio of the amount of ground covered by plants to total ground area. A dense canopy may attract some vectors and deter others, depending on the species.

b. Foliage Color

The exact green or green/yellow color perceived by a vector may be or may not be attractive in eliciting alighting responses, depending on the species.

c. Leaf Pubescence

Increased leaf trichome density apparently retards virus epidemics by reducing probing frequency and total time spent probing by aphids.

d. Host Genotypes

Different cultivars may not alter probing behaviour, but depending on the pattern of susceptable host to resistant hosts and nonhosts, the dilution of infections may delay an epidemic long enough to reduce the effects of early infection and diminish the threat of seed transmission.

e. Insecticides

Many insecticides may not prevent the spread of a virus as they do not act quickly enough on the arthropod vector and may in fact increase the spread of a virus, as vector activity is increased. However, use of a quick-acting synthetic pyrethroid may overcome this problem.

Biology:

Once within the host, viruses characteristically induce the intracellular formation of cytoplasmic inclusions, which appear within 48 hours of infection, at first within the plasmalemma and with tubules apparently aligned with plasmodesmata, and then later found scattered throughout the cytoplasm.

Inclusion proteins demonstate ATPase and helicase activities and therefore are probably involved in viral replication. The monopartite genomes encode for eight proteins. Each monopartite genome has a single long open reading frame which is translated as one or more polyproteins. These undergo post-translational cleavage to produce functional virus proteins. The properties and functions of the component proteins and genomic RNA's are active topics of research.

Predators:

There are no direct predators of a plant virus, which, after all, exist within the host or vector. Resistance within the host is the result of the interaction of a multitude of chemical processes initiated by both the host and the pathogen while in contact in a favorable environment. The genes of the host plant that control disease resistance do so by changing or adapting the physiological processes of the plant, so that infection or disease development is neutralized or prevented from operating (Lucas, et al., 1985).

However, predators of vectors are another matter. They may affect viral spread by vectors in different ways. For example, if the vector population is low, predators may reduce vector numbers enough to lower the rate of infection. If the vector population is high, predators may increase vector activity and thus increase viral spread (Barnett, pers comm).

Natural Protection:

Protection from a viral epidemic is best in Northern regions, where vector activity is limited, both in species present and in total numbers, in cold climates. For this reason, some potato certification programs are located in such colder areas, even though these areas are not as well suited for potato production.

ADDENDUM 8

Forms Forms, as developed by the State, may be listed in this section.

ADDENDUM 9

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Thanks to the following individuals for their assistance in the development of these Guidelines. Drs. Barnett and Hadidi supplied the photographs given in the identification.

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ADDENDUM 10

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