1979- 1984

Current Status of

POTATO LEAFROLL VIRUS DISEASE

in the San Luis Valley

Bulletin 536A

Colorado State University Cooperative Extension

CURRENT STATUS OF POTATO LEAFROLL

VIRUS DISEASE IN THE SAN LUIS VALLEY, COLORADO

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Overview - Epidemiology

Potato leafroll is a disease caused by a virus (potato leafroll virus, PLRV) introduced into its hosts, potato and related plants, by an insect vector, aphids. All three components of this "disease triangle" (virus, host, vector) must interact for the disease to occur, persist and spread.

Pathogen

PLRV occurs in the nutrient conducting elements (phloem) of the plant, including tubers. The virus multiplies rapidly in phloem cells and can be detected in cell sap. The development of the virus, at the expense of the host, causes a characteristic rolling of leaves for which the disease, leafroll, is named.

The virus can only survive within a living organism, either the host plant or the insect vector. Early work suggested that the virus was occasionally transmitted from mother to daughter aphids. Later work could not confirm this and such transmission is now considered doubtful. The virus is not found in the overwintering eggs of the aphid.

Several other plants related to potato can be hosts of PLRV. Certain plants, such as field bindweed, are perennial and can serve as overwintering sources of the virus in some potato growing areas. However, in the San Luis Valley (SLV), surveys by Dr. Robert Klein and Dr. Clark Livingston, Department of Plant Pathology and Weed Science, Colorado State University, rarely detected PLRV in perennial weeds (field bindweed). Thus, it appears that weeds play a minor roll in leafroll transmission.

It must be concluded that the principal overwintering source of the potato leafroll virus in the SLV is infected potato tubers planted in spring or volunteer plants arising from infected tubers remaining after harvest the previous fall.

In other areas, beet western yellows virus is implicated in the potato leafroll syndrome. It is still unclear whether beet western yellows is part of the leafroll complex in the SLV.

Vectors

Numerous studies have demonstrated that only a few species of aphids serve as vectors of PLRV. A wide variety of other insects and mites, including *Lygus* bugs and grasshoppers have been tested extensively for their ability to transmit the virus with negative results. Aphid feeding is relatively non-damaging to the plant and is often directed at the phloem. This allows the aphid to acquire PLRV from an infected plant and subsequently introduce it into the phloem of non-infected plants.

The green peach aphid (GPA) is regarded as the most efficient vector of the virus and has behavioral habits that make it important in leafroll spread. A few other aphids, most notably the potato aphid (PA), transmit PLRV less efficiently than the green peach aphid. Potato aphids collected from the SLV have been shown by Klein and Livingston to transmit potato leafroll.

Both GPA and PA overwinter as eggs on certain species of woody plants (see section on overwintering hosts). After the eggs hatch, a few generations are produced on the overwintering host before winged forms appear. The winged forms move to the various summer hosts in late spring in the SLV. The summer host range of the GPA is unusually broad--over 200 plant species; however, the summer hosts of the PA are limited primarily to plants in the Solanaceae or potato family. Summer populations of the GPA have been monitored in the SLV for years by using pan traps and observing populations on potato plants. GPA are not commonly found on plants until July. This coincides with increasing rate of aphid capture in pan traps. However, isolated captures of winged aphids have been reported as early as mid-June. Pan trap captures and aphid populations typically increase through August and peak in late August and early September.

Between flights from the overwintering host and appearance on potatoes (mid-June to early-July), GPA are found on certain weeds, including pigweed, lambsquarter, field bindweed and shepherdspurse. Failure to detect aphids on potatoes during this time may be due to limitations of trapping methods in detecting low numbers of aphids present early in the season.

PA flights have not been monitored routinely in the SLV. During 1985, flights occurred shortly before GPA and peaked in mid-August. Potato aphids are found commonly on potatoes in the SLV during early July, usually slightly prior to the GPA.

Virus-GPA Vector Relationships

A close relationship exists between the virus and the aphid vector. The virus is acquired by the aphids while ingesting sap from the phloem of infected plants. The virus then moves from the gut of the aphid into its body cavity and finally into the salivary glands. Once it reaches the salivary glands, it can be injected with saliva into a plant during subsequent feedings.

The time required to acquire PLRV from a diseased plant (acquisition period) is related to the time it takes for the aphid to reach the phloem with its stylet and begin feeding. In general, this takes a minimum of about 15 minutes with optimum acquisition requiring several hours.

Since the virus must move from the aphid gut to the salivary glands before the aphid can transmit, there is a latent period during which the insect cannot transmit the virus. The latent period for PLRV in the GPA is generally longer than the acquisition period, and may require a few days. The feeding period required for an infective aphid to transmit the virus to a healthy plant (inoculation period) is similar to the acquisition period.

An aphid may transmit PLRV for a long time after acquisition and the latent period has passed. Occasionally, an aphid transmits PLRV for its entire lifetime, following a single acquisition feeding. However, aphids transmit with somewhat less efficiency as they age.

Spread of PLRV in the SLV accelerates in mid-July and early August, in approximate relationship with increasing aphid flights. However, recent research indicates spread may occur early in July, before GPA are detected in fields. This very early season PLRV spread may involve PA as well as GPA.

Aphid Population Dynamics - Trapping Data

The biological activity of a wide range of insects and plant pathogens is related to accumulated ambient temperatures over a period of days. These are expressed as day-degree or heat unit accumulation (HUA). HUA data collected through the IPM program in the SLV were used to predict the onset of early blight. Published HUA data combined with data on GPA flights collected in the SLV IPM program were used by Klein to develop a workable model to predict the appearance of GPA in pan traps. The model accurately predicted the appearance of GPA in the SLV in all years for which data were available. The incidence of leafroll in RB seed stocks for 1969, 1971-75 and 1977-82 was analyzed. A correlation with HUA was found prior to the initiation of GPA control in the IPM program but not subsequent to that time. This finding suggests that the GPA is controlled by the IPM program. The continued increase in leafroll incidence suggests that a vector or vectors other than the GPA, which are not controlled through the IPM program, are transmitting PLRV in the SLV.

In 1984 aphid traps were placed at 13 sites throughout the central portion of the SLV by Klein and Livingston to detect interfield movement of viruliferous aphids. A water pan, a sticky trap and indicator trap plants were placed at each site weekly from early June to mid-August. Trap plants were returned to the greenhouse at CSU for incubation and tested serologically for PLRV. Viruliferous aphids were detected in flight as early as mid-July. None of the trapped vectors were the GPA which again supports the position that the GPA is not the only vector involved. The only other vector aphid observed in the trap program was the PA. To establish the role of the PA as a potential PLRV vector, both GPA and PA were collected from leafroll infected plants in the SLV and transferred to indicator host plants. Serological tests of indicator plant tissues showed that both aphids (GPA and PA) were viruliferous. Aphids were also trapped by a scoop net mounted on the cab of a low moving truck. One PA which proved to be viruliferous was trapped. More research is needed to establish the role of the PA and its overwintering hosts in the epidemiology of PLRV in the SLV.

Interaction of PLRV with the Potato Host

Potatoes can be infected with PLRV whenever acceptable leaf tissue is available for the viruliferous aphid vector to feed upon. However, transmission is frequently less successful after flowering. Apparently, older potato plants are less desirable hosts for PLRV infection.

There is an interval between inoculation of leaves with PLRV and movement of the virus into the tuber. This interval appears to be at least eight days. Not all tubers may be infected. In plants which become infected during the season (current season spread), older tubers are most often infected.

In most areas, current season infection of Russet Burbank (RB) plants by PLRV results in discoloration of the phloem of the tuber. This symptom is called "net necrosis." This results in a grade defect of particular concern to table stock and processing potato producers as well as seed potato growers. For unknown reasons, PLRV infections rarely produce net necrosis in RB potatoes grown in SLV.

Overwintering Hosts

GPA overwinter in the egg stage in the SLV. Only a very few, closely related woody plants in the genus Prunus (plum, apricot, cherry and peach) can support the overwintering stage. Other Prunus species (sandcherry, chokecherry, etc.) are reported as GPA overwintering hosts, however, surveys in the SLV have not demonstrated the presence of overwintering GPA on these species. GPA migrants can be found on these plants later in the season.

Egg hatch of GPA may occur as early as April in the SLV. First winged forms have not been detected in sleeve traps prior to late May.

Aside from overwintering GPA eggs, aphids overwinter on bedding plants or other plants grown in greenhouses in the SLV. In these protected environments the GPA maintains its summer form and produces multiple generations during the cold season. The repeated presence of the GPA on these sources is an ongoing concern.

The possibility that the initial source of GPA in May is windborne migrants from outside the SLV is apparently discounted by trapping data. Studies have demonstrated negligible GPA flights in the southern part of the valley. This area would be expected to be in the primary path of a southern originating flight, if it existed.

It is concluded that each year GPA populations originate solely within the SLV either from eggs on certain Prunus species or from both juveniles and adults on greenhouse materials grown in or imported into the SLV.

Levels of Leafroll Detected Through the Certification Program

Field inspection data compiled by the Colorado Potato Certification Service provide a useful tool to evaluate the severity of the leafroll virus problem. Field inspections are conducted at least twice each season on each seed field to determine disease levels and detect other problems. These data are collected on approximately 10,000 acres per year. Inspectors count at least 100 plants per acre (overall field basis) to determine disease levels. The information in Tables 1 and 2 present data from the second field inspection for 1979-84. Data, presented in Tables 3 and 4, summarize five years of winter test observations for 1979-83. Each seedlot inspected during the growing season is represented in the winter test plot by a sample of 400-1200 tubers, depending on field size. Data from the winter test plot are intended to detect late season leafroll virus spread--as well as other problems.

The cultivars, CR, RB and Sangre were included since they represent an average of 91 percent of the acreage entered for certification for the six year reporting period.

Varying levels of PLRV can be noted readily for the 1979-84 period. The percentage of seedlots in the "0 percent" leafroll category for the Centennial and RB cultivars (Tables 1 and 2) clearly indicates reduced PLRV for 1980 and 1981 followed by three years of increasing leafroll. The increase of seedlots in the "0 percent" category for RB from 1983 to 1984 (19.2 percent to 46.6 percent) can be explained by improved roguing and introduction of selected seedlots from out of state sources. Data also suggest that prior to 1980, leafroll incidence was similar to that occurring in 1983 and 1984.

Table 1: 1979-84 Potato Leafroll Virus Summary Second Inspection Field Readings Centennial, Russet Burbank and Sangre.

Cultivar	Leafroll Virus Percent	Percent Seedlots					
		1979	1980	1981	1982	1983	1984
Centennial	0	25.5	47.1	52.8	33.3	25.1	22.4
	.01-.1	56.4	47.1	38.4	55.6	55.8	50.5
	.11-.4	24.5	5.8	8.8	11.1	17.9	25.5
	.41-.8	2.1	----	----	----	1.1	1.5
	+.80	----	----	----	----	----	----
Russet Burbank	0	11.7	28.9	28.6	19.5	19.2	46.6
	.01-.1	55.8	52.2	50.0	43.9	29.4	24.1
	.11-.4	26.7	15.6	21.4	35.4	47.0	25.9
	.41-.8	4.2	3.3	----	1.2	2.0	3.4
	+.80	1.7	----	----	----	----	----
Sangre	0	90.0	82.4	83.3	63.6	75.0	73.3
	.01-.1	10.0	17.6	16.7	31.8	25.0	24.4
	.11-.4	----	----	----	4,6	----	2.2
	.41-.8	----	----	----	----	----	----
	+.80	----	----	----	----	----	----

Table 2: 1979-84 Potato Leafroll Virus Summary Comparison of Three Cultivars: Centennial, Russet Burbank and Sangre Grouped According to Five Levels of Leafroll Virus Second Inspection Field Readings (rounded to whole numbers).

Cultivar	Leafroll Virus Percent	Percent Seedlots					
		1979	1980	1981	1982	1983	1984
Centennial	0	26	47	53	33	25	22
Russet Burbank	0	12	29	29	20	19	47
Sangre	0	90	82	83	64	75	73
Centennial	.01-1.0	56	47	38	56	56	51
Russet Burbank	.01-1.0	56	52	50	44	29	24
Sangre	.01-1.0	10	18	17	32	25	24
Centennial	.11-0.4	25	6	9	11	18	26
Russet Burbank	.11-0.4	27	16	21	35	47	26
Sangre	.11-0.4	0	0	0	5	0	2
Centennial	.41-0.8	2	0	0	0	1	2
Russet Burbank	.41-0.8	4	3	0	2	2	3
Sangre	.41-0.8	0	0	0	0	0	0
Centennial	+.80	0	0	0	0	0	0
Russet Burbank	+.80	2	0	0	0	0	0
Sangre	+.80	0	0	0	0	0	0

Winter test data presented in Tables 3 and 4 indicate the same cyclic PLRV pattern noted in the second inspection reports (Tables 1 and 2). Winter test readings provide a more accurate confirmation of the summer field inspections for RB cultivar than for either CR or Sangre cultivars.

Cultivar differences regarding the amount of leafroll detected by field inspectors are shown in Tables 2 and 4. RB consistently had the greatest amount of leafroll. The extreme susceptibility of RB is well known wherever it is grown. However, the reduced rate of leafroll spread occurring in CR and Sangre was not observed prior to their introduction. The practical significance of relatively low PLRV levels in the CR and Sangre cultivars under SLV conditions should not be overlooked. One could easily hypothesize that the certified seed potato industry in the SLV would have had difficulty surviving at its present level if these two cultivars did not possess some type of resistance to PLRV.

The reasons for reduced leafroll in CR and Sangre are unknown. It should be remembered that insect pests and virus pathogens often undergo genetic changes which allow them to attack hitherto resistant plant hosts. Although data are limited, there may already be indications in Table 1 (1980-84) that a steady, but consistent increase in leafroll is occurring in CR. If this is true, the overall PLRV problem in the SLV seed potato industry might accelerate.

Certified seed potato fields in the SLV are often located adjacent to non-certified potato fields having unknown, although sometimes high, leafroll levels. This presents a threat regarding PLRV spread to seed fields, especially late in the growing season when winged aphids are numerous. Experience in other parts of North America and Europe indicate that, under such conditions, even the most rigid requirements of early vine kill and extensive chemical control measures may not protect seed fields adequately. Unless the entire SLV potato industry is willing to address this important aspect of the PLRV problem in a meaningful way, it is unlikely that even significant research advances regarding the biology and life cycle patterns of aphid vectors will solve the problem totally.

Table 3: 1979-83 Potato Leafroll Virus Summary; Winter Test Data - Centennial, Russet Burbank and Sangre.

Cultivar	Leafroll Virus Percent	Percent Seedlots 1979	1980	1981	1982	1983
Centennial	0	59.1	85.6	82.9	87.2	73.9
	.01-0.5	39.2	12.2	14.6	11.6	22.6
	.51-1.0	----	2.2	2.4	1.2	3.5
	1.10-1.5	1.5	----	----	----	----
	+1.50	----	----	----	----	----
Russet Burbank	0	41.5	27.1	44.3	24.1	15.5
	.01-0.5	43.9	55.7	30.4	20.7	31.1
	.51-1.0	6.1	15.7	17.7	27.6	17.8
	1.10-1.5	6.1	1.4	2.5	10.3	11.1
	+1.50	2.4	1.4	5.1	17.2	24.4
Sangre	0	75.0	71.4	100.0	87.5	92.3
	.01-0.5	25.0	28.6	----	12.5	7.7
	.51-1.0	-----	----	----	----	----
	1.10-1.5	----	----	----	----	----
	+1.50	----	----	----	----	----

Table 4: 1979-83 Potato Leafroll Virus Summary Comparison of Three Cultivars (Centennial, Russet Burbank and Sangre) Grouped According to Five Levels of Leafroll Virus Winter Test Data.

Cultivar	Level of Leafroll Virus (%)	Percent Seedlots 1979	1980	1981	1982	1983
Centennial	0	59	86	83	87	74
Russet Burbank	0	42	27	44	24	16
Sangre	0	75	71	100	88	92
Centennial	.01-0.5	39	12	15	12	23
Russet Burbank	.01-0.5	44	56	30	21	31
Sangre	.01-0.5	25	29	0	13	8
Centennial	.51-1.0	0	2	2	1	4
Russet Burbank	.51-1.0	6	16	18	28	18
Sangre	.51-1.0	0	0	0	0	0
Centennial	1.10-1.50	2	0	0	0	0
Russet Burbank	1.10-1.50	6	2	3	10	11
Sangre	1.10-1.50	0	0	0	0	0
Centennial	+1.5	0	0	0	0	0
Russet Burbank	+1.5	2.4	1.4	5	17	24
Sangre	+1.5	0	0	0	0	0

Varietal Response/Yield Effects

Clonal responses to PLRV are varied and manifested in three ways: 1) plant symptom expression; 2) variable PLRV transmission to the host from some type of host resistance; and 3) yield response. While a clone may exhibit only one of these responses, most exhibit a combination of several responses. The following sections summarize the ways that clones can differ in their response to PLRV infection.

1) Variation in plant symptom expression involves several factors as illustrated in the following section by comparing CR to RB.
   a) Color change. This can range from little or no color change to yellowing or bronzing of a plant. CR tends to show little or no color change in the upper plant, but shows a distinct bronzing of the lower leaves. RB, in contrast, routinely displays a color change of the entire plant from light yellow to bronze.
   b) Leaf curling. This can be a simple curl of the bottom leaf or every leaflet of the plant may curl. CR usually shows a distinct leaf curl on lower leaves only. RB tends to show involvement of the entire plant.
   c) Individual leaf or leaflet changes. These changes include marginal burning, purpling, and a leathery feel to the tissue. RB usually has thickened leaves with slight marginal burning, or shows only thickened lower leaves with intensive marginal burning.
   d) Onset of symptoms. CR appears to express leafroll symptoms later than RB.
2) Clonal responses to PLRV infection can vary widely due to host resistance or host-vector interactions. In the SLV, more infection is shown by RB than by either CR or Sangre, even in fields where these cultivars are planted side by side.

   Symptoms from current season spread of PLRV are seldom observed in RB and have never been observed in CR and Sangre. This suggests that aphids may colonize RB to a greater extent during the season than CR, but further work is necessary to verify this. If this is true, it may provide part of the explanation of why CR shows less season to season PLRV increase than RB.

3) Yield responses to PLRV infection usually range from 50 to 65 percent for CR and RB on a per plant basis. However, there are indications that PLRV infected CR may develop a larger percentage of tubers over 3 to 4 oz than infected RB. Also, there is evidence to suggest that CR plants infected with PLRV may set fewer tubers than RB plants. If PLRV is a problem there may be a greater chance for a productive crop if CR is grown instead of RB because of the larger tuber size produced by PLRV infected CR.

Whatever the basic cause of clonal differences in their response to PLRV, it is evident that more information is needed under SLV conditions. Answering any of the preceding questions may give quick payoffs, in terms of potential PLRV reduction, increased yields and better disease management strategies.

Insecticide Effectiveness

PLRV is thought to be spread primarily by infective, winged aphids which move from outside sources into a field (primary spread). Aphids colonizing plants and moving from an infected plant to a healthy plant within a field (secondary spread) are usually much less important in PLRV transmission in seed potatoes, particularly in fields planted with PLRV-free seed.

Minimally, an effective insecticide program should have the following characteristics:

1) The insecticide should be fast-acting enough to incapacitate the vector before transmission of the virus occurs.
2) The insecticide should be on the plant in an effective dose at the correct time (i.e., when PLRV spread occurs).
3) Coverage of the plant with the insecticide should be thorough enough that all vector aphids landing on the plant are contacted by the insecticide.

Not all insecticide applications are equivalent in their ability to control aphid spread of PLRV. Indeed, many treatments have little impact in PLRV spread although aphid populations on potatoes may be controlled. Also, control of the GPA is often more difficult than PA since the former is considerably more resistant to insecticides.

In general, research from other potato growing areas indicate that certain soil-applied systemic insecticides often perform better than sprays for preventing PLRV spread; however, this is not documented in the SLV. Among sprayed insecticides, certain synthetic pyrethroids appear to be fast acting. However, certain organophosphorous compounds, such as methamidophos (Monitor), are also highly effective against the GPA. Regardless, conditions in the SLV are unique from other potato areas in ways which can affect insecticide performance.

Casual use of insecticides may also be detrimental to PLRV control. Aside from wasting money, some insecticides provide poor aphid, particularly GPA, control and their use may actually result in an increase in aphid populations through destruction of natural enemies. Insecticides may also irritate aphids causing more interplant movement, or leave colored residues on the plants which make them more attractive to the aphids. Finally, some insecticides may act directly on the physiology of the potato plant and affect its growth.

Limited work in the SLV demonstrated that a considerable range exists among insecticides in their ability to control aphids on plants. Comparisons of insecticides for control of PLRV have not been made. Proper timing of applications and choice of insecticides also require better information on how and when PLRV is spread in the SLV.

Extension IPM Potato Leafroll Management in the San Luis Valley

Based on information and research data available from other areas where PLRV is a problem and on an increase in PLRV in SLV seedlots, a GPA suppression program was initiated in 1978. This pilot project was funded by the USDA/CES for a five-year period.

The main objective of the PLRV management program was to limit the numbers of GPA reaching virus infected host plants. This would limit the initial acquisition of virus by aphids and subsequent spread. The three possible sources of aphids were considered.

1) Winter carryover on Prunus hosts.
2) Introduction on bedding plants grown locally or imported from outside the SLV.
3) Flights of aphids into the valley.

The main thrust of the project was suppression of aphids on overwintering Prunus species commonly grown as ornamentals around SLV houses and treatment of bedding plants offered for sale by local retailers. This program began in 1978 and was carried out by IPM supervised personnel until 1983. In 1983, the project was transferred to the SLV potato growers and the Area II Potato Administrative Committee who now fund and supervise it. To monitor aphid populations, aphid collections were obtained from yellow pan traps throughout the growing season during the project years. Colorado State Potato Certification Service data from second inspections clearly show the effectiveness of the program (Tables 1 and 3). The aphid suppression program successfully contributes along with better roguing and inspection to increased leafroll control. This is reflected in both the number of potato fields entered for certification that show 0 or trace PLRV in summer field inspections and seedlots that show 0 or trace levels of PLRV in the Oceanside, CA tests (Tables 3 and 4).

Grower interest and cooperation in the program has been outstanding. The fact that management and support of the aphid suppression component of the program is entirely in the hands of the growers is an outward sign that the program is important and justified the pilot IPM project and the funding committed to the project in the SLV (Table 5).

Table 5: IPM Funding History of the San Luis Valley

Year	Federal IPM[1]	County/Extension[3]	Growers
FY78	$ 21,515.85	$ 0.00	$ 0.00
FY79	46,105.52	5,000.00	0.00
FY80	38,500.00	5,000.00	0.00
FY81	25,303.00[2]	5,000.00	5,000.00
FY82	28,581.29[2]	5,000.00	17,050.00
TOTAL	$160,005.66	$ 20,000.00	$ 22,000.00

[1] Salaries and operations.
[2] Salaries only.
[3] In-kind services, office, phone, secretarial, etc.

Recommendations for Aphid Suppression Program

Future aphid suppression programs in the SLV must take into consideration the history of success demonstrated by the pilot IPM project. This should not be interpreted as precluding a need for further research and development to fill in the numerous missing parts of the complete PLRV puzzle.

Recommendations for continued PLRV suppression in the SLV:

1) Plum and apricot trees should be sprayed:
All trees should be sprayed with a dormant oil plus either Diazinon or Thiodan during the dormant or delayed dormant period (April and early May). If GPA stem mothers and offspring are still present after the oil treatments--follow-up sprays with systemic insecticides must be applied before winged stages escape in late May or early June. Normally, all spraying activity should be completed before May 25.

   a) Priority Spray Areas (A highest - D lowest):
   High Priority
      o All *Prunus* trees in Monte Vista, Del Norte, Center and rural Rio Grande County.
      o Trees in the Capulin and Waverly area and the rest of Conejos County directly south of Monte Vista.

   Low Priority
      o Trees in Alamosa and Alamosa County.
      o Trees in LaJara, Sanford and Manassa.

2) Greenhouse-grown bedding plants:

   a) All plants shipped into the SLV each spring should be sprayed upon arrival.

   b) Greenhouses in the SLV should be managed using chemicals, biological control, or a low temperature period to eliminate GPA carryover.

3) Field monitoring:

   a) Trapping programs should continue in the SLV:
      o Detect long range trends and facilitate measuring program effectiveness.
      o Detect "hot spots" that may need localized treatment. If yellow pan traps are to be used, they should be on site by June 15.

4) Dissemination of information on aphid movement:

Pest status reports to growers should be continued via use of newsletters and the CSU coda-a-phone system.

5) Education programs emphasizing the following should be implemented:

   a) The need to eliminate leafroll infected planting stock currently used to plant many commercial potato fields in the SLV.

   b) The need for thorough and timely roguing of certified seed fields.

   c) The unique opportunity of the SLV potato industry to control PLRV and reduce its threat to a negligible level if a comprehensive effort is pursued.