SOURCES, DISSEMINATION, AND CONTROL OF POTATO LEAFROLL DISEASE

by
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SUMMARY

Studies were conducted to determine the relationships between different sources of potato leafroll virus (PLRV) inoculum, the timing of aphid flights, and the development of leafroll disease in potato fields of the Columbia Basin. More than 99% of vector aphids found on potatoes and winter rapeseed were the green peach aphid (GPA) (Myzus persicae) and the remainder were the potato aphid (Macrosiphum euphorbiae). In 6 yrs of aphid trapping, three distinct, predictable GPA flights were determined: spring (April 20 - May 12), mid-summer (July 1 - Aug. 10), and fall (Sept. 20 - frost). The spread of PLRV in plots that contained seed sources of virus began during the spring aphid flight. Although these plots initially contained very low levels of seed infection, they became completely infected before the mid-summer flight began. In contrast, potato plots grown from virus free plantlets escaped infection until after the mid-summer flight began. These results indicate that the spring flight does not introduce PLRV from outside sources, but it is responsible for spread of virus from seed sources of virus that are already present within the field. There was a rapid increase in PLRV infection in the virus-free plots starting 3 to 4 wks after the beginning of the mid-summer aphid flight. This indicates that the mid-summer flight introduced much virus into virus-free potato plots which was probably acquired from volunteer potato plants and weeds. These results illustrate the importance of seed sources of virus. With potato seed that was truly free of virus, chemical control of aphids could be delayed until mid-July. By this time in the season, protection is only needed until the end of the summer flight in early August, and this protection could be provided with only one or two aphicide applications. However, with currently available seed, all of which contains some level of PLRV infection, aphicide control of the spring flight of aphids is essential. The fall aphid flight does not directly affect commercial potatoes in the Columbia Basin However, it could distribute PLRV to emerging winter annual weeds that may serve as overwintering inoculum sources.

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INTRODUCTION

Our research has shown that the loss of insecticides to control potato aphids results in a severe increase in aphid-borne virus diseases in the Columbia Basin. In 1974, the year in which Temik was introduced, incidence of leafroll virus averaged 38%, and leafroll-induced net necrosis of tubers was rampant. Average yield was 383 cwt/A. By 1982, use of Temik was common practice, leafroll incidence was less than 1%, and yields began to exceed 500 cwt/A. Without Temik, aphid-borne virus diseases are again on the rise. Clearly, we could return to very high levels of virus diseases if other key pesticides are removed from the market.

The chief objective of this work was to develop additional knowledge that will be needed to achieve good control of leafroll disease with minimum use of pesticides. This work deals with the relationships between different sources of potato leafroll virus (PLRV) inoculum, the timing of green peach aphid (GPA) flight, and the development of leafroll disease in potato fields of the Columbia Basin.

Biology of leafroll disease

Potato leafroll virus is transferred from one plant to another only by a few species of aphids. Aphids acquire the ability to transmit PLRV by feeding on infected plants and they retain the ability to transmit for life. Only two aphid species that transmit PLRV were found on potato, rapeseeds, forage brassicas, or weeds in the Columbia Basin of northwestern U.S.A. More than 99% of these were the GPA (green peach aphid) (Myzus persicae) and the remainder were the potato aphid (Macrosiphum euphorbiae).

The GPA may exist: 1) as eggs, the cold resistant, overwintering form found on peach trees, 2) as winged, flying aphids (alatae) that can fly and carry virus long, and 3) as wingless aphids (apterae) that crawl and carry viruses short distances from plant-to-plant. Winged and wingless aphids give birth to living young. Offspring from winged aphids are wingless. Wingless aphids produce wingless aphids while life is good on the host plant, but when the host plant enters a period of stress or when overcrowding occurs, the wingless aphids begin to bear winged aphids. Short daylength in the fall can also stimulate production of winged aphids. Aphid flights occur when large numbers of alatae accumulate. These flight are detected and quantified by various types of aphid traps.

The GPA routinely overwinters in the egg stage on peach trees in the Columbia Basin, spends the summer on a wide variety of weeds and crops, and returns to peach in the fall. It can overwinter as adult apterae or alatae in warmer climates, and it sometimes overwinters in isolate microclimates of the Columbia Basin that remain warm throughout the winter. However, we found no GPAs overwintering on winter annual Brassica crops or weed species in mild or severe winters over a 4-year period in the Columbia Basin.

All young GPAs, whether they arise by hatching from eggs or by live birth, are initially free of PLRV. Thus, to transmit PLRV, young aphids must first acquire virus by feeding on an infected plant. Young aphids that are born on a virus-infected plant usually acquire virus in their first feeding shortly after birth. However, peach trees are immune to PLRV. Therefore, aphids that hatch from eggs on peaches do not acquire the virus until they fly from peach to infected hosts.

The minimum time required for an aphid to acquire and transmit PLRV is 24 hrs. The minimum time required for an infective aphid (one that already has acquired the virus) to transmit is 1-2 hrs. Thus, winged aphids from outside sources can and do introduce PLRV into fields that are treated with systemic pesticides, but they usually die before they can transmit virus from plant-to-plant in such fields.

Over a 6-year period of trapping winged aphids at four locations in Washington (Paterson, Prosser, Ephrata, Walla Walla), three distinct GPA flights were identified. One small flight from the overwintering peach tree host in early spring distributes aphids to the emerging potato crops, to volunteers, and to weeds. Aphids from this flight multiply in the wingless form for several weeks and give rise to a large mid-summer flight in July. A massive fall flight in October returns aphids to peach and infests winter annual weeds and crops. A typical seasonal pattern of aphid flights for the Columbia Basin is given in Fig. 1. Timing of the spring flight is variable and may extend from mid April to mid May. The mid-summer flight is very consistent, however, and the first aphids were almost always taken in the first week of July, rarely the last week of June. Size of the fall flight was variable.

Relationships between virus sources, aphid flights, and field spread

In the typical PLRV epidemic observed in the Columbia Basin, relatively few infection foci are established in the field. Then, virus is spread from the infection foci from plant-to-plant by crawling aphids. This gives rise to the characteristic, circular infection centers that are easily observed in potato fields when a leafroll epidemic is in progress. The virus spreads rapidly until the entire field is infected when aphids are not controlled.

The initial infection foci may arise either as chronically infected plants derived from infected seed, or as current season infections carried into the field from an outside source by flying aphids. In the past, it has been assumed that the spring flight of aphids acquired PLRV from weeds in route to the emerging potato fields. However, we find that very few weeds are actually infected with PLRV in the spring, and those that are infected often contain so little virus that they are not good sources of virus for aphid dissemination to other plants. This fact introduced the possibility that the spring flight of aphids may be a source of virus for potato fields. If this were true, then spring dissemination of the virus in potatoes would depend entirely on seed infection within the crop.

We tested this hypothesis by comparing the incidence and spread of PLRV in potatoes grown from virus-free plantlets produced in tissue culture with that in potatoes with very low levels of seed infection.

The seasonal spread of PLRV observed in virus free and low seed infection potatoes is presented in Fig. 2. The seasonal pattern of aphid flights in the Columbia Basin is also shown in Fig. 2 to illustrate the relationship between aphid flights and virus dissemination. Spread of PLRV was visually detected in plots containing very low levels of seed infection soon after aphids arrived in the spring flight. The spread proceeded slowly at first, probably because few aphids were present at first. However, rate of spread accelerated and nearly all potatoes in the low seed infection plots had symptoms before the mid-summer flight began. In contrast, no virus infection was detected in the virus-free plantings until 3 wks after the mid-summer flight began - a full 12 wks after the spring flight began. Although many aphids were found in both lots of potatoes, there apparently was no source of virus for dissemination in the virus-free potatoes until aphids introduced it in the mid-summer flight. Once infection of the virus-free plots got underway in late July, the rate of increase in incidence of infection was much sharper in the virus-free plots than in the plots with a low initial levels of seed infection. This probably reflects both a much larger number of aphids entering the plots in the mid-summer flight and a larger number of infection foci created by the summer flight than was available from seed infection in the spring.

Interpretation of results

These results clearly show that the spring flight of aphids carries little or no PLRV into potato fields in the Columbia Basin, but the mid-summer flight introduces a massive inoculation. Thus, we could probably avoid the use of pesticides for control of PLRV in potatoes until the second or third wk of July if seed potatoes could be obtained that were truly free of PLRV. Only one or two pesticide applications would be needed to protect the crop until the end of the mid-summer flight when further protection would no longer be required to finish the crop.

In practice, however, virus-free seed potatoes are not available, and the spring flight does supply aphids for dissemination of virus from seed infected plants. Therefore, it is essential that we control the spring flight of aphids. Our studies performed in the mid 1970's showed that most growers effectively controlled the spring flight, primarily by the use of Temik. A soil applied, systemic pesticide is preferred rather than a foliar pesticide because soil applied pesticides generally do not kill beneficial insects, but foliar pesticides not only kill aphids but also kill beneficial insects that help to control aphids.

Assuming that control of the spring aphid flight has been achieved with pesticides, it is important to understand that seed sources of virus are still present in the crop when the mid-summer flight begins about July 1. Flying aphids in the large mid-summer flight recognize and preferentially settle on these chronically infected plants and begin dissemination of virus immediately.

Therefore, aphid control must begin immediately when the summer flight begins with currently available seed sources. In contrast, using virus-free seed, there still are no infected plants when the summer flight begins (This is illustrated in Fig. 2). Since 3 to 6 wks are required after inoculation before an inoculated plant itself becomes a source of virus for further dissemination, aphid control could be delayed for 3 wks in potatoes grown from virus-free seed. An earlier application of pesticide probably would not reduce the number of plants initially infected by incoming aphids because aphids are able to transmit PLRV before they are killed by sytemic pesticides. In fact, an earlier pesticidal treatment may actually increase the number of initial infections by stimulating aphids to move about more actively in the treated cropbefore they die.

These results show clearly that infection foci derived from infected seed (chronic infection) are much more important than those derived from current season infection. Chronically infected plants begin serving as sources of virus in early spring when the first non infective aphids arrive from peach trees, but current season infections are not established until infective aphids arrive in the mid season flight. Thus, seed sources of virus result in high rates of field infection at least 6 wks earlier than current season sources and exert a much larger influence on plant growth and yield. In addition, chronically infected plants begin to serve as sources of virus immediately when the aphids arrive in the potato fields, but current season infections cannot serve as a sources of virus until at least 3 wk later, after inoculated plants become systemically infected. Furthermore, we find that chronic infections are better sources of virus than current season infections. This is true because aphids are found largely on older leaves of potato plants. Since virus occurs at high concentrations throughout chronically infected plants but is restricted largely to the young, upper leaves of current season infected plants, aphids are much more likely to transmit virus from chronic than from current season infections. Furthermore, flying aphids preferentially settle on chronically infected plants. The relative importance of infection foci derived from infected seed will increase if additional pesticides are removed from the market, since aphids will be present in fields season long. Under current practice, the spring flight of aphids can be killed in May and the next flight does not occur until July.

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Fig. 1. Seasonal flight pattern for green peach aphid in the Columbia Basin.

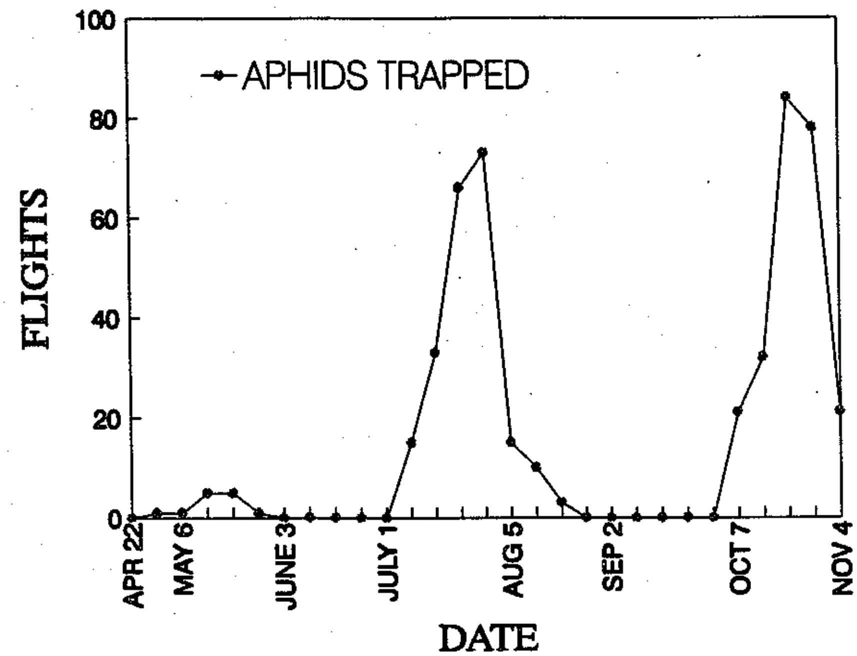

Fig. 2. Spread of potato leafroll disease in plots free of virus and in plots with a low level of seed infection in relationship to the seasonal pattern of aphid flights in the Columbia Basin. No pesticides applied.