THE VECTORS OF PLANT VIRUSES

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Summary

Insect-transmitted plant viruses are either stylet-borne or circulative. The carriers or vectors can be either aphids, mites, leaf-hoppers, mealy bugs or thrips. For viruses to spread, there must be a source of virus, the vector must be present, and it must move from crop to crop and within crops. Aphid-borne viruses of the circulative type are of most importance in crops in New Zealand. Control of some has been achieved by using soil-applied granular organophosphorus insecticides, while with others altering the planting or sowing date has enabled the crop to miss the aphid flights and virus infection.

THE VECTORS OF PLANT VIRUSES

As with animal viruses which are spread by contact between diseased and healthy animals (such as colds, influenza, measles), so too are plant viruses spread by contact between diseased and healthy plants. However, many of the important animal and plant viruses are spread by arthropods and other organisms. These carrier agents are known as vectors. Table 1 illustrates the range of viruses which are transmitted in this manner.

TABLE 1: PLANT VIRUSES TRANSMITTED BY ARTHROPODS AND OTHER ORGANISMS FROM DISEASED TO HEALTHY HOSTS

Virus	*Manner of Transmission*	*N.Z. Examples, Hosts and Symptoms*
NON-PERSISTENT OR STYLET-BORNE VIRUSES		
Virus carried on surface of mouth-parts, insect acts as a "flying needle", a probe in a diseased, then a probe in a healthy host being sufficient to transmit; rapid transfer (1 to 5 min). In some cases, the insect can transmit the virus even after 24 hr.		
Potato virus Y	Potato aphids	Potatoes—stunting and severe mosaic of plants, in some varieties only.
Cucumber mosaic virus	Various aphids	Lettuce and many ornamental plants—mosaic disease.
Cocoa swollen-shoot virus	Mealy-bugs	Important in cocoa-producing areas.
Turnip yellow mosaic virus	Biting insects (flea beetles). Contaminated mouth parts and regurgitation from stomach is source of virus.	Not yet in New Zealand.

TABLE 1—*Contd.*

PERSISTENT OR CIRCULATIVE VIRUSES

These pass into the body of the carrier in which they may or may not multiply. There is usually a latent period of a few hours to several days between "pick-up" of the virus and infection of a new host.

Cereal yellow dwarf virus	Cereal grass aphid	Reduces yield in wheat, barley and oats. Causes stunting plus yellow and red leaves.
Potato leaf roll virus	Potato aphids (3 species)	Potatoes—causes stunting and rolling to bottom leaves, and degeneration of seed-potato crops.
Carrot motley dwarf virus	Carrot-willow aphid	Red and yellow leaves and stunting—prevents growing of early carrots.
Pea leaf roll virus	Pea aphids (4 species)	Yellowing and stunting of peas, beans, and subterranean clover.
Tomato spotted wilt virus	Thrips. Larval thrips can acquire this virus but not adults	Tomatoes, dahlias, nasturtiums, and other hosts.
Cotton leaf curl virus, Abutilon variegation and 5 others	White-flies	Abutilon variegation in New Zealand.
Various viruses overseas	Leaf-hoppers, numerous species. Virus multiplies within the insect, also transmitted through the eggs to the progeny	Only one example known in New Zealand, yellow-leaf disease of flax.
Currant reversion virus and 5 others overseas	"Big-bud mite" *Phytoptus ribis.* Virus may be retained in and circulate through body of its vector.	Black currant reversion disease probably present.

SOIL-BORNE VIRUSES

These are present in the soil in association with either nematodes or fungi, which can attack plants and in so doing transmit virus.

Many strawberry, raspberry, potato and grape viruses.	Nematodes of the genera *Longidorus, Trichodorus* and *Xiphinema.*	Grape fan leaf disease.
Lettuce big vein virus	*Olpidium* fungus which infects roots.	Common in lettuce crops, causes crinkling of leaves and veins to be prominent.

Specificity of Virus in Relation to its Vector or Carrier

Circulative viruses show greater vector specificity than stylet-borne viruses. In general, the latter are more readily transmitted than the circulative groups, as they are transmitted by a wider range of insect species. Group specificity is usual — *i.e.,* a virus can be transmitted by one group (say aphids) but not by members of another group (say leaf hoppers). Species specificity is common (*i.e.,* one virus will be transmitted by only one or a few species of insect), but there are some viruses which are transmitted by a number of species (*e.g.,* onion yellow dwarf can be transmitted by 50 different aphid species). On the other hand, some aphid species can transmit many plant viruses — *e.g.,* the green peach-aphid *Myzus persicae* has been recorded as transmitting 108 plant viruses. There are thirteen aphid species which have been recorded as transmitting more than 10 plant viruses; of these thirteen, eight can transmit more than 20 viruses. There is an estimated total of 2,690 aphids in the world. Of these, 242 species have been tested as vectors of plant viruses, and 192 or 80% of them have been shown to be vectors of at least one virus.

It has been found (Kennedy, *et. al.,* 1962) that polyphagous aphids (living on many hosts) are better vectors of plant viruses than oligophagous (living on a few hosts) and monophagous (living on one host) aphids. Vector performance is always better when the virus source is also a host of the aphid than when it is not — *i.e.,* viruses and vectors tend to share host plants. However, a vector relationship between an aphid and a virus sharing the same host plant is least likely when the aphid is closely adapted to the plant as its host.

SPREAD OF PLANT VIRUSES

There are three requirements for an insect-transmitted plant virus disease to spread, and these are as follows:

(1) There must be a source of virus. This can be either within the crop or more usually is in biennial and perennial weeds or other crops in the vicinity.

(2) The insect vector must be present at the time the crop is grown. Good control of a virus disease has often been obtained by growing a crop in areas where the vector is absent or at times of the year when it is not present.

(3) The insect vector must move about and spread the virus from diseased to healthy plants, either (a) by bringing viruses into a crop from outside sources (primary spread) or (b) by spreading virus from infected to healthy plants within a crop (secondary spread). The amounts of primary and secondary spread that occur will depend on the particular virus-vector-crop combination.

In addition to these three points, the relative importance of winged and wingless aphids in spreading viruses also must be assessed. The following examples will illustrate the above points.

(A) The virus is spread into the crops by winged aphids, and the spread within the crop is by both winged and wingless aphids — *e.g.,* barley yellow dwarf virus. Many virus-vector-host combinations occur in this category. It cannot be assumed that all winged aphids arriving in a crop necessarily are infected with virus. In some cases only a small proportion may be infected, whereas in others almost 100% are infected. It also cannot be

assumed that the most abundant aphid in the crops is the vector, as in many cases it has been shown that the virus has been spread mainly by a species that never becomes numerous enough to warrant control measures. Also, a few specimens of an active and mobile species will transmit more disease than large populations of a more sedentary species.

(B) Virus spread occurs mainly within the crop and can be by both forms of aphids — *e.g.*, potato leaf roll virus. The winged aphids arriving in the crop need to acquire the virus before transmitting the disease. Some spread along rows is undoubtedly due to wingless aphids, but most spread will be by winged forms.

(C) All virus spread is into the crop by winged forms; there is little or no spread by wingless aphids — *e.g.*, lettuce necrotic yellows virus. In this case the virus is spread from sowthistle to lettuce by winged aphids of a species which does not colonize lettuce.

Winged aphids are most important in introducing virus into a crop, and at times this may be the only or major method of spread. Within-crop spread can be by both winged and wingless forms. In some crops and with some viruses, winged aphids are more important in this role than wingless (potato leaf roll virus), whereas the reverse is true in other situations (barley yellow dwarf virus). There is usually more virus present in small areas of crops than in large; at the edge of fields than in the centre; and in crops which were young at the time of aphid flights as compared with crops which were older.

CONTROL OF VIRUSES WITH INSECTICIDES

Obviously the chances of an insecticide being useful against virus diseases will depend on whether the virus is of the circulative or stylet-borne type, and whether the spread is mainly from infected to healthy plants within a crop, or whether spread is mainly by virus being brought into a crop by already infected aphids. It has been found that insecticides are most useful against circulative viruses, since the delay in acquisition provides a chance of the aphids being killed before transmission can take place. With stylet-borne viruses, insecticides can increase the amount of spread, since the vectors are disturbed, become more restless and more spread occurs.

SPREAD OF VIRUS INTO AND WITHIN CROPS

The general principles of virus-vector relationships will now be looked at in relation to particular virus-host combinations in New Zealand.

WHEAT

(a) *Autumn-sown*

There is a relationship between the time of emergence of the crop, the aphid flights, and the subsequent amount of barley yellow dwarf (BYDV) infection. Crops sown in April emerge well before the flights have ceased, and are infested by many winged aphids. There seems to be a considerable amount of primary and secondary spread. Protection of the crops at this early stage is necessary to prevent the early secondary spread. As the emergence date of the wheat moves from early May to mid-June, there will be a gradual reduction in the number of winged aphids infesting the crops,

and a corresponding decrease in the amount of primary virus infection. The amount of secondary spread which is likely to occur in the spring through the activities of winged and wingless aphids is related to the emergence date of the crop and the amount of infection. Thus, insecticide sprays or granules should be applied after the aphid flights have ceased and before the cereal aphid multiplication within the crop commences in August.

(b) *Spring-sown*

In general, the crop emerges in October and the developing wheat plant is infested by winged aphids over the October-November period. Hence primary (by winged aphids) and secondary spread (by winged and wingless aphids developing within the crop) are taking place simultaneously. Favourable weather conditions are needed for the development of aphids in the crop and for virus spread to occur. Rain seems to be an important factor which can affect aphid establishment and multiplication. To some extent this may explain the lack of aphids and virus in some North Island crops, even though there have been quite large aphid flights during the spring.

Barley

In Canterbury, the barley crop is subjected to aphid flights over a long period (October to November). There appears to be ample opportunity for primary and secondary spread to occur simultaneously, but, in general, barley crops do not seem to suffer from BYDV. There have been no responses in trials following treatment with insecticides. However, more data are needed on the level of infection in various barley crops and the effects of virus on yield and quality.

Oats

Autumn-sown oats for greenfeed are infected in most years with much BYDV. This is from both primary and secondary spread which occurs in autumn. The crop shows varying amounts of stunting and leaf reddening. Further data are needed on nitrate levels in these crops and the possible toxic effects on grazing animals.

Oats for grain are spring-sown, often in areas where BYDV does not seem a problem, such as North Otago and Southland. However, in Canterbury, oats, when infected, show red leaves and sterility or "blasting" of the head does occur and there is much less grain. The pattern of virus introduction is similar to that for spring-sown wheat or barley.

For cereals in general, there is an urgent need to know what proportion of aphids entering a crop is infected with virus and in what way this is related to the final amount of virus infection in the crop. The proportion of winged aphids carrying virus will differ between autumn and spring, between one site and another, and also from season to season, since the proportion will depend to some extent on the crops in the vicinity. Breeding of cereals tolerant to virus infection is the final answer to BYDV.

Potatoes

Potato crops are usually infested with aphids as soon as they emerge. Winged aphids which arrive in the crop, in general, are not infected with

virus, and have to acquire virus from an infected plant before spread can occur. Thus, in the act of acquiring virus, the winged aphid can be killed by a systemic insecticide within the plant and virus spread prevented. Most spread, particularly between rows, is by winged aphids, but spread within rows is by both forms of aphids. Soil-applied granular organophosphorus insecticides have given good control of aphids and leaf roll virus.

Peas

Crops emerging in October are infested with four species of aphids. Transmission tests have indicated that only one of these species is carrying the pea leaf roll virus, and that most of these individuals arrive infected with virus. The pattern of spread indicates that winged aphids are most important, and there is little or no secondary spread by wingless or winged aphids developing on the plants. In general, peas are not a preferred host for aphids and only low populations have been recorded on this plant. Winged aphids arrive continuously in the crop over the period October to mid-December. Symptoms of the virus disease will vary depending upon the age of the plants when infected.

One of the important problems here is to determine the source of the virus-carrying aphids. Is this source lucerne, subterranean clover, or red or white clover?

Soil-applied granular insecticides have given good control of aphids, but although there have been fewer virus-infected plants in the treated plots there have not been any corresponding yield increases.

Carrots

In this case a proportion of the carrot aphids arriving in the crops is infected with carrot motley dwarf virus. The willow is the main overwintering host of these aphids and aphids from this source do not seem to be infected with virus. It is aphids which have over-wintered on wild carrots and related plants which carry the virus and introduce it into crops. There is some primary and some secondary spread. Insecticides have given a useful amount of control, but better control has been obtained by delaying sowing until the aphid flights are almost completed.

The main virus diseases of the crops already examined are, in relation to the aphid carriers, all of the persistent or circulative type. It is worth considering briefly the situation with respect to a crop such as turnips in which the main viruses are non-persistent or stylet-borne.

Turnips

In Canterbury, turnip crops are often severely infected by cauliflower mosaic virus and by turnip mosaic. These viruses cause crinkling, distortion of leaves and stunting of plants, and eventually death and rotting of bulbs. Both species of aphids which occur on turnips (*Myzus persicae* and *Brevicoryne brassicae*) are capable of transmitting these diseases. Large flights of *B. brassicae* occur in March, and they seem to come from rape crops which are acting as a source of virus. Almost all spread seems to be by infected winged aphids which enter a crop, probe several times on a healthy plant and then transmission has taken place. The relative importance of the two aphid species has not been determined, but flights of *B. brassicae* are always much greater than those of *M. persicae*. In addition,

B. brassicae colonizes young leaves which are very susceptible to virus, whereas *M. persicae* prefers more mature leaves which resist infection. Control of these diseases has not been achieved by using insecticides. However, the plant breeder has overcome this problem, since the recently-released variety Kapai is tolerant to infection — *i.e.,* turnips of this variety can grow well and produce excellent bulbs in spite of being infected with virus.

CONCLUSIONS

With respect to the virus diseases of any crop, the important questions which must be answered are:

(1) What is the method of spread?

(2) What is and where is the source of virus?

(3) If spread is by insects, then what is the most efficient vector?

(4) Is the vector present?

(5) Does the vector move about and when is it active?

(6) Is the virus being introduced into the crop by insects or is the spread mainly within the crop?

(7) What is the relative importance of the winged and wingless stages during within crop spread?

Only by knowing the answers to all of these questions is it possible to plan realistic and economic control measures which aim at checking the problem at its weakest link.

REFERENCE

Kennedy, J. S.; Day, M. F.; Eastop, V. F., 1962: *A Conspectus of Aphids as Vectors of Plant Viruses.* Comm. Agric. Bureaux. 114 pp.