Vol. 6 (1997): 323–336.

Review

Viruses and their significance in agricultural and horticultural crops in Finland

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This paper reviews the plant viruses and virus vectors that have been detected in agricultural and horticultural crop plants and some weeds in Finland. The historical and current importance of virus diseases and the methods used for controlling them in cereals, potato, berry plants, fruit trees, ornamental plants and vegetables are discussed. Plant viruses have been intensely studied in Finland over 40 years. Up to date, 44 plant virus species have been detected, and many tentatively identified viruses are also reported. Control of many virus diseases has been significantly improved. This has been achieved mainly through changes in cropping systems, production of healthy seed potatoes and healthy stocks of berry plants, fruit trees and ornamental plants in the institutes set up for such production, and improved hygiene. At the present, barley yellow dwarf luteovirus, potato Y potyvirus and potato mop-top furovirus are considred to be economically the most harmful plant viruses in Finland.

Key words: berry plants, cereals, healthy plant production, onion, potato, vegetables, virus control, virus transmission, virus vector, yield losses

Introduction

Plant viruses cause huge economic losses in many crop species worldwide (Matthews 1991). In Finland, too, severe outbreaks of virus infections frequently affect many crops, but, fortunately, the climate restricts occurrence of insect species that can transmit viruses in the field (Roivainen 1947, Heikinheimo 1959, Vappula 1962, Raatikainen 1967, Kurppa and Rajala 1986). The very long days of summer reduce the time need-

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ed for the maturation of crops (Pohjakallio et al. 1961b) and thus also the duration of growth stages when plants are susceptible to virus infections. However, the climate restricts the number of agricultural and horticultural crops that can be cultivated outdoors (Broekhuizen 1969, Mukula and Rantanen 1987), and so many horticultural and ornamental crops are grown in the greenhouse in Finland (Laurila 1995).

Viruses can be transmitted to new crops via virus-infected seeds, tubers, seedlings and cuttings. Many viruses also persist in the agricultural environment in perennial crops and wild plants, from which they are transmitted to new crops by vectors (Thresh 1981). Efforts to prevent viruses from spreading by controlling virus vectors in the field tend to be ineffective and are useless against viruses transmitted mechanically, i.e., in the sap of virus-infected plants via wounds by contact. Thus, plant viruses are best controlled by using virus-free planting materials and by growing virus-resistant cultivars. Choice of the appropriate control method or virus-resistant cultivar requires knowledge of the locally prevalent viruses.

New forms of virus resistance have recently been developed in crop plants using genetic engineering. In Finland, these applications have mainly been used on the potato (Mehto 1991, Truve et al. 1993, Pehu et al. 1995, Seppänen et al. 1997). Assessing risks of the experimental and commercial release of transgenic crop species that express viral sequences has therefore become an important task for researchers and public authorities alike (OECD 1996, Robinson 1996). Further, the use of plant viruses as gene vectors in plants (Scholthof et al. 1996) will require risk assessment. The potential risks caused by each transgenic crop and gene vector must be assessed in the specific environment and cropping system in which they will be used. Such assessments require knowledge not only of the properties of the transgenic plant or gene vector but also of the plant viruses that naturally occur in the crop and the environment.

This review lists the viruses and their vectors detected in agricultural and horticultural crop plants in Finland. No complete list similar to that given here is available, and previous reviews are either no longer up to date (Jamalainen 1957) or cover only a limited range of crop plants (Bremer 1987) or groups of viruses (Lindsten and Tapio 1986). Furthermore, some of the data we provide have not been published in refereed journals and so are difficult to obtain. The Finnish names of the viruses have been given elsewhere (Valkonen 1993) as have those of the vectors (Vappula 1962, Markkula 1993). Viruses occurring in forest trees in Finland were recently reviewed by Bremer et al. (1991). The present data may be useful for the authorities responsible for assessing the risks associated with the release of transgenic crops expressing viral sequences and also for those involved in plant protection and quarantine. We also summarize a few important milestones in plant virus research in Finland, and examine the historical and current significance of viruses and their control in crops grown in this country.

Viruses detected in crop plants in Finland

The viruses listed in Table 1 have been identified on the basis of the symptoms they cause in experimentally inoculated test plant species. The majority have also been identified by serological tests and the morphology of particles observed under the electron microscope. Many, but not all, of the viruses in Table 1 have been tested for transmission by specific vector species. However, it is possible that many of the viruses for which no vector has been identified in Finland are transmitted here by a vector related to those identified elsewhere (Table 1). At this point, it is appropriate to note that *Myzus persicae*, one of the most efficient and important aphid vectors of viruses elsewhere, is not known to overwinter in the wild in Finland. It does, however, in the greenhouses and can spread to near-

Vol. 6 (1997): 323–336.

Table 1. Viruses identified in agricultural and horticultural crops in Finland, and their vectors.

		Transmission			
		By vectors[a]		Through	
Virus	Host species	Finland	Elsewhere	seeds[b]	Reference[c]
Agropyron mosaic virus	*Agropyron repens*, wheat	nr	eriophyid mites		Bremer 1964, 1974a, [118]
Alfalfa mosaic virus	luzerne	nr	aphids	E	E. Tapio (unpublished)[d], [46, 229]
Apple chlorotic leaf spot virus	*Malus sylvestris*	nr	unknown		Lemmetty 1988, [30]
Aronia ring spot virus	*Aronia melanocarpa*	nr	unknown	.	Bremer 1984
Arabis mosaic virus	rhubarb	nr	*Xiphinema* sp.		Heinonen 1978, [16]
Barley yellow dwarf virus	cereals and grasses	*Rhopalosiphum padi*, *Sitobion avenae*, *Metapolophium dirhodum*			Bremer 1965, Korhonen 1981, [32]
Bean common mosaic virus	french bean	nr	aphids	F, E	Jamalainen 1957, Tapio 1970, [73, 337]
Bean yellow mosaic virus	red and alsike clover, pea, fababean	*Acyrthosiphon pisum*, *Aphis fabae*	aphids		Jamalainen 1957, Raininko 1964, Tapio 1964, 1970, [40]
Beet soilborne virus	sugarbeet	nr	*Polymyxa betae*		Bremer et al. 1990
Black currant reversion associated virus	*Ribes* spp.	*Cecidophyopsis ribis*			Bremer and Heikinheimo 1980, Lemmetty et al. 1997
Brome mosaic virus	cereals, timothy grass, wheat, *Agrostis tenuis*, *Agropyron repens*	nr	no vector		Bremer 1973, 1974a, [3, 180]
Carnation etched ring virus	carnation	*Myzus persicae*			Bremer and Lahdenperä 1981, [182]
Carnation mottle virus	carnation	nr	unknown		Bremer 1978, [7]
Carnation necrotic fleck virus	carnation	*M. persicae*			Bremer and Lahdenperä 1981, [136]
Carnation ringspot virus	carnation	nr	nematodes		Bremer and Lahdenperä 1981, [21]
Carnation vein mottle virus	carnation	nr	aphids		Bremer and Lahdenperä 1981, [78]
Cherry leaf roll virus	*Sambucus* spp.	nr	*Xiphinema* sp.	E	Cooper and Edwards 1980, [80]
Chrysanthemum aspermy virus	chrysanthemum, tomato	*M. persicae*			Tapio 1963b, Bremer and Lahdenperä 1981
Chrysanthemum virus B	chrysanthemum	nr	aphids		Tapio 1963b, Bremer and Lahdenperä 1981, [110]
Cucumber green mottle mosaic virus	cucumber	nr	unknown	F, E	Linnasalmi 1966, [154]
Cucumber mosaic virus	cucumber, tomato, black currant, *Stellaria media*, *Mentha gentilis*, *Phlox paniculata*	aphids		F(?)[b], E	Rainio 1941, Linnasalmi 1966, Linnasalmi ja Murtomaa 1966, Bremer 1983, Lemmetty 1985, Tegel 1987, [1, 213]
Garlic latent virus	garlic	nr	aphids		Kokkola 1992
Leek yellow stripe virus	shallot, garlic	nr	aphids		Bremer 1990, Kokkola 1992, [240]
Lettuce mosaic virus	lettuce	nr	aphids	F, E	Lahdenperä 1981, [9]
Oat sterile dwarf virus	oat	*Javesella pellucida*, *J. obscurella*, *Dicranotropsis hamata*			Kanervo et al. 1957, Ikäheimo 1961, Ikäheimo and Raatikainen 1961, 1963, [217]

continues

		Transmission			
		By vectors[a]		Through	
Virus	Host species	Finland	Elsewhere	seeds[b]	Reference[c]
Onion yellow dwarf virus	shallot, garlic	nr	aphids		Jamalainen 1957, Bremer 1990, Kokkola 1992, [158]
Potato leaf roll virus	potato	*M. persicae, Aphis frangulae-nasturtii, Aulacorthum solani, Macrosiphum euphorbiae*			Kurppa 1983, Uusitalo 1985, [36, 291]
Potato mop-top virus	potato	*Spongospora subterranea*			Kurppa A. 1989, [138]
Potato virus A	potato	nr	aphids		Kurtto 1969, Kurppa 1983, [54]
Potato virus M	potato	*Myzus persicae, A. frangulae-nasturtii*			Tapio 1980, Kurppa 1983, [87]
Potato virus S	potato	*M. persicae*			Aura 1957, Kurppa 1983, [60]
Potato virus X	potato, tomato	nr	no vector		Aura 1957, Linnasalmi 1964, [4, 354]
Potato virus Y	potato	*Myzus persicae, A. solani, A. frangulae-nasturtii*			Pohjakallio et al. 1961a, Tapio 1980, Kurppa 1983, [37, 242]
Raspberry bushy dwarf virus	*Rubus arcticus*	nr	unknown	E	Kokko et al. 1996, [165]
Raspberry ringspot virus	*Ribes* spp, plants and soil in plant nurseries[f]	*Longidorus elongatus*	E		Bremer 1983, Tapio 1985, [6, 198]
Raspberry vein chlorosis virus	*Rubus* spp.	*Aphis idaeus*			Tapio 1961, [174]
Shallot latent virus	shallot, garlic	nr	aphids		Bremer 1990, Kokkola 1992, [250]
Strawberry latent ringspot virus	*Astible* x *arendsii, Peonia officinalis, Phlox spp.*	nr	nematodes		Bremer 1985, [126]
Tobacco mosaic virus[e]	tomato, rhubarb, plants and soil in plant nurseries[f]	nr	no vector		Linnasalmi 1964, Heinonen 1978, Tapio 1985, [151]
Tobacco necrosis virus	cucumber, tulip, plants and soil in plant nurseries[f]	*Olpidium brassicae*			Tapio 1972b, Bremer and Lahdenperä 1980, Lemmetty 1991a, [14]
Tobacco rattle virus	potato, plants and soil in plant nurseries[f] *Paeonia Lactiflora* hybrids	*Trichodorus* sp.			Tapio 1972b, Kurppa 1983, Keskinen 1991, [12, 346]
Tomato black ring virus	black currant, plants and soil in plant nurseries[f]	*Longidorus* sp.			Bremer 1983, Tapio 1985, [38]
Tomato spotted wilt virus	tomato, *Dahlia*, cineraria, chrysanthemum	*Thrips tabaci, Frankliniella occidentalis*			Lemmetty 1991b, Lemmetty and Lindqvist 1993, [39]
Turnip mosaic virus	rhubarb	nr	aphids		Heinonen 1978, [8]
Wheat striate mosaic virus	oat	*Javesella pellucida, J. obscurella*			Ikäheimo 1960, Ikäheimo and Raatikainen 1961, [99]

[a]Vectors of Finnish origin experimentally shown to transmit Finnish virus isolates are indicated. The group of vectors known to transmit the virus elsewhere is mentioned if the vector in Finland is not identified. "No vector" means that the virus is mechanically transmitted only. "Unknown" means that the virus probably has a vector but it has not been identified. nr, not reported.
[b]Seed-transmissibility is indicated only if it is considered to be important for dispersal of the virus in the field. F, in Finland; E, elsewhere; (?), transmission of cucumber mosaic virus probably occurs via seeds of *Stellaria media* (Lemmetty 1985).
[c]References to reports in which isolation, host range and vectors of Finnish isolates of the virus were described first. Numbers in parentheses correspond to the numbers of viruses in the series of C.M.I./A.A.B. Descriptions of Plant Viruses (Kew, UK).
[d]The Finnish isolates of alfalfa mosaic virus were identified in 1971 as previously described for isolates from other Scandinavian countries (Tapio 1970).
[e]A few strains isolated from tomato plants and originally identified as tobacco mosaic virus are currently considered to be strains of tomato mosaic virus (Linnasalmi 1972).
[f]Many plant species were infected (Tapio 1972b, 1985), but for brevity they are not listed here.

Vol. 6 (1997): 323–336.

Table 2. Tentatively identified viruses and virus-like diseases observed in crops grown in Finland.

Virus or disease	Crop	Reference
Apple flat limb disease	apple	Jamalainen 1964
Apple green crinckle disease	apple	Jamalainen 1964
Apple rubbery wood disease	apple	Jamalainen 1964
Apple star crack disease	apple	Jamalainen 1964
Apple stem grooving disease	apple	Jamalainen 1964
Beet mild yellowing virus	sugarbeet	E. Tapio, unpublished
Beet mosaic virus	sugarbeet, *Chenopodium* spp.	E. Tapio, unpublished
Beet yellows virus	sugarbeet	E. Tapio, unpublished
Fuchsia latent virus	*Fuchsia* spp.	K. Bremer, unpublished
Garlic mosaic virus	garlic	Kokkola 1992
Infectious variegation disease	*Ribes* spp.	Bremer 1983
Pelargonium leaf curl virus	*Pelargonium* spp.	E. Tapio, unpublished
Phleum green stripe disease	timothy grass	Nuorteva 1962, Heikinheimo and Raatikainen 1976
Potato aucuba mosaic virus	potato	Kurtto 1969
Raspberry vein banding disease	*Rubus* spp.	Tapio 1961
Raspberry yellows/yellow mosaic disease	*Rubus* spp.	Tapio 1961
Red raspberry mosaic/raspberry leaf mottle disease	raspberry	Tapio 1961
Red clover mottle virus	red clover	E. Tapio, unpublished
Soil-borne wheat mosaic virus	rye	Bremer and Vestberg 1986
Strawberry crinkle virus	strawberry	E. Tapio and K. Bremer, unpublished
Strawberry mild yellow edge virus	strawberry	E. Tapio, unpublished
Tomato ringspot virus	*Phlox paniculata*	Tegel 1987
Vein banding disease	*Ribes* spp.	K. Bremer, unpublished

by fields during the summer (Heikinheimo 1959). Aphids of the genus *Chaetosiphon* (Bremer and Pethman 1978) and nematodes of the genus *Xiphinema* (Tapio 1972b, 1985, Kari Tiilikkala, pers. comm.) are important virus vectors elsewhere but have not been found in Finland. Seed-transmitted viruses (Table 1) may also be transmitted by pollen (Matthews 1991), but adequate tests are not always carried out.

Table 2 lists viruses that have been only tentatively identified, mainly on the basis of symptoms observed in crop plants. In some cases, test plant responses or a positive reaction in serological tests with virus-specific antisera have been reported. Some of the viruses could probably be included in either Table 2 or Table 1. Inclusion in Table 2, however, is usually based on the original author's suspicions concerning the identity of the virus; identity of the viruses and even confirmation of the viral nature of some of the diseases listed in Table 2 awaits more definite determination. Nevertheless, we felt that we should include these data in this review, because in so doing we could point to crops and viruses that may deserve more detailed investigation by virologists in Finland.

Significance of plant virus diseases in Finland

The occurrence of plant virus diseases in Finland has been known for over 60 years (Liro

1930, Rainio 1941, Brummer 1946, Jamalainen 1943, 1946). However, it was only 40 years ago that the economic damage caused by viruses in crop plants was more fully recognized and efforts to identify and control plant viruses were launched on a broader front, first at the Agricultural Research Centre of Finland, Tikkurila (Jamalainen 1952, 1957), and then at the University of Helsinki, Viikki. For the next 30 years, plant virologists were mainly concerned with virus identification and the development of control methods. This work involved tight collaboration with the entomologists. During that time, a few foreign scientists spent a few months in Finland participating in the identification of viruses in potato (A.B.R. Beemster, The Netherlands, 1955), cereals and grasses (E. Banttari, USA, 1966-67) and woody plants (J.I. Cooper, UK, in the 1970s and 1980s). During this decade, M. Saarma (Estonia) and his research group have contributed to research mainly of a theoretical nature on plant viruses in Finland.

The significance of virus diseases has declined in many crops in Finland during the past 40 years due to the development of schemes for producing virus-free planting materials, the better standards of hygiene in the greenhouse production, changes in cropping systems to reduce vector populations, introduction of procedures to predict and control the outbreak of virus epidemics, and improvements in cultivar resistance to viruses. Inspection of imported plants for viruses by the plant quarantine authorities has significantly decreased the occurrence of viruses in many horticultural and ornamental plants, the natural transmission of plant viruses to Finland being largely limited due to the country's isolation from other agricultural areas in Europe by the Baltic Sea. Only a few persistently transmitted viruses are known to be occasionally carried to Finland over the sea by wind-borne aphids (Kurppa 1983, Kurppa S. 1989a). Virus transmission from the east is probably limited because the land there is mainly occupied by forests and the prevailing winds during the growing season are from the south and west.

Viruses in cereals and grasses

The severe disease that affected oats growing at the coast of the Gulf of Bothnia in the 1950s (Jamalainen 1957) was shown to be caused by oat sterile dwarf virus (OSDV) transmitted by leafhoppers in a persistent manner. Wheat striate mosaic virus, also detected in the diseased oat crops, was transmitted by the same vectors as OSDV but occurred in fewer plants and was less damaging (Ikäheimo 1960, 1961, Ikäheimo and Raatikainen 1961, 1963). The epidemic in oats drew the attention of agriculturalists to viruses in cereals and grasses in Finland. Although the disease caused by OSDV was reported in many parts of Finland (Jamalainen 1957), the epidemic was most severe at the western coast, possibly due to the higher vectoring capacity of local leafhopper populations (Bremer 1974b). At the same time, epidemics caused by OSDV were reported on the other side of the Gulf of Bothnia in Sweden (Lindsten 1961), and also in the Soviet Union and the US (Slykhuis 1967). In Finland, OSDV was brought under control by changing the cropping system. Grass was abandoned as an undercrop of oat, which reduced the numbers of leafhopper nymphs that could overwinter and transmit OSDV to new oat crops during the next growing season (Ikäheimo 1962, Jamalainen and Murtomaa 1966, Raatikainen 1967). Since then, OSDV has not caused any significant problems in Finland.

Other viruses have also been detected in cereals and grasses (Table 1), of which a few await more definite identification (Table 2). Barley yellow dwarf virus (BYDV) causes economic losses in oats, barley and wheat (Bremer 1965, Korhonen 1981, Peltonen 1988). Epidemics in cereals thought to be caused by BYDV occurred in 1926, 1947 and 1954 (Jamalainen 1957), and epidemics known to be caused by BYDV in 1959 (Ikäheimo 1960), 1973, 1975 and 1988 (Kurppa S. 1989b). Many perennial grasses are natural hosts of BYDV (Korhonen 1981, Kurppa A. et al. 1989) and the aphids (Heikinheimo 1959, Rautapää 1970) that persistently transmit BYDV

Vol. 6 (1997): 323–336.

(Ikäheimo 1960, Bremer 1965). Epidemics of BYDV therefore coincide with outbreaks of aphids, notably *Rhopalosiphum padi* (Kurppa S. 1989a, 1989b). Long-distance wind-borne migration of viruliferuous *R. padi* from the south and southeast was a significant factor in the build-up of the epidemic caused by BYDV in 1988 (Kurppa S. 1989a).

Epidemics caused by BYDV can be forecast. The numbers of living eggs of *R. padi* are recorded in the winter host *Prunus padus* in the spring, and the development of aphid populations in grasses is monitored following migration from the winter host early in the summer. To prevent economic losses due to BYDV infection, migration of *R. padi* from grasses to cereals is monitored and chemical sprays are applied to kill the aphids in the cereal crop when a threshold value (one aphid found in one seedling out of five) is reached (Kurppa S. 1989a, 1989b). Long-distance migration of aphids can be observed with radar (Puhakka et al. 1986).

Viruses in potato

The occurrence of viruses in potato was recognized in the 1940s, and viruses were tentatively identified based on symptoms (Brummer 1946). The first viruses to be detected using serological tests were the potato viruses X and S (Aura 1957). Since then, several viruses have been detected and studied in the potato in Finland (Table 1). As potatoes are vegetatively propagated, many cultivars were found to be 100% infected by viruses (Aura 1957, Seppänen 1972). The yields of some cultivars declined faster than those of others following virus infection (Pohjakallio et al. 1961a, Kurtto 1969, Seppänen 1972) and a few susceptible cultivars were abandoned from use. The deleterious effects of viruses on potato quality were also recognized, and breeding for virus resistance was emphasized (Varis 1970).

Professional farmers control potato viruses mainly by using virus-free seed potatoes (Tapio 1972a), of which the highest quality classes are produced by the Seed Potato Center established in Tyrnävä in 1976 (Pietarinen and Seppänen 1981) and by contract farmers in the protected seed potato production zone in the same area. Many potato cultivars currently grown in Finland are susceptible to aphid-transmissible viruses such as potato virus Y (PVY) (Valkonen and Palohuhta 1996) and potatoes grown in home gardens are often heavily infected with viruses. Potato crops are therefore frequently affected in the field with viruses non-persistently transmitted by aphids, particularly in southern Finland. In field experiments carried out on a farm in Renko (southern Finland), 26% and 38% of the initially healthy crop of potato cv. Rekord was infected with PVY after the first and second year, respectively (Tiilikkala 1987). The yield losses per hectare were equivalent to 48 000 Fmk (current value) at the second year (Tiilikkala 1987). The capacity of different aphid species to transmit potato viruses in the field has not been studied in Finland, but the abundance of *R. padi* and *Aphis frangulae-nasturtii* in potato fields (Kurppa and Rajala 1986) and their ability to transmit the potato viruses Y and M under experimental conditions (Tapio 1980) suggest that they may be important vector species. Large numbers of *Aphis fabae* and *Cavariella theobaldi* have also been reproted in potato fields (Kurppa and Rajala 1986, Tiilikkala 1987) but their capacity to transmit potato viruses in Finland is not yet known. Sprays with mineral oils can diminish the transmission of PVY by aphids in potato crops, whereas sprays with insecticides reduce the number of aphids but not the transmission of PVY (Tiilikkala 1987).

Potato leaf roll virus (PLRV) is the most important potato virus in many countries, but it has been detected only intermittently in Finland and is not economically damaging (Kurppa 1983). It is probably transmitted over the Baltic sea by wind-borne aphids (Kurppa 1983). Although a few aphid species that occur in potato fields in Finland can transmit PLRV (Uusitalo 1985), the most efficient vector species, *M. persicae*, is not known to overwinter outdoors here (Heikinheimo 1959). This may explain why no significant dispersal of PLRV from initially infected potato plants has been observed in the field in Finland. Unlike other potato viruses that occur in this country, PLRV is not transmitted mechanically (Kurppa 1983, Uusitalo 1985).

Potato mop-top virus (PMTV) was first detected in Finland only 10 years ago (Kurppa A. 1989) but it has become increasingly prevalent and is now considered a serious problem (Aarne Kurppa, pers. comm.). Control of PMTV is difficult because it can persist in the resting spores of its fungal vector, *Spongospora subterranea*, in the soil for many years, and only a few potato cultivars currently grown in Finland are resistant to PMTV in the field (Hassi 1991).

Viruses in berry plants, fruit trees and ornamental plants

The viruses detected in berry plants in Finland are listed in Table 1 and have been reviewed elsewhere (Tapio 1963a, Bremer 1987). Recently, raspberry bushy dwarf virus was shown to be prevalent in arctic bramble (*Rubus arcticus*) in eastern and southeastern Finland (Kokko et al. 1996). A virus resembling nepoviruses has been isolated from the reversion-diseased black currants (Lemmetty et al. 1997). Back-inoculation tests to healthy plants (Anne Lemmetty, pers. comm.) suggest that this virus may be the primary causal agent of the reversion disease (Bremer and Heikinheimo 1980).

Apple is the only fruit tree that is widely grown and therefore economically significant in Finland. Virus disease-like symptoms have been reported in apple trees and may be attributable to infection by several different viruses (Table 2; Jamalainen 1964); only apple chlorotic leaf spot virus has, however, been identified (Lemmetty 1988).

In the past, virus infections were common in imported chrysanthemum (Tapio 1963b) and carnation (Bremer 1978, Bremer and Lahdenperä 1981) grown in the greenhouse (Table 1). As the diagnostic tools used in plant quarantine improved, these viruses became less common in the cultivations. Many ornamental plant species grown outdoors are infected by soil-borne viruses transmitted by nematodes or fungi (Tapio 1972b, 1985, Bremer 1985, Keskinen 1991) (Table 1, 2). The *Phlox* spp. seem to be infected with the largest number of viruses (Tapio 1972b, 1985, Bremer 1985, Tegel 1987).

Major achievements in efforts to improve the quality and yield of berries and fruit in Finland were the schemes set up for producing healthy stocks of berry plants, fruit trees and ornamental plants at the Agricultural Research Centre of Finland (Bremer and Ylimäki 1978) and the foundation of the Healthy Plant Center in 1976, now located in Laukaa (Uosukainen and Kurppa 1988). Before the healthy plant production scheme for raspberries was introduced, 95% of the raspberry plants in the 20 plant nurseries inspected by Tapio (1961) were virus-infected. Later, it was shown that the yields of raspberries produced using virus-free plants were six times bigger than those of plants naturally infected with viruses (Bremer 1980).

A few viruses that infect berry and ornamental plants in Finland are difficult to eradicate from farms and gardens because sources of the viruses exist in the wild. Almost anywhere in Finland cultivated raspberries can be infected with viruses transmitted by aphids from virus-infected wild raspberries (Tapio 1961, 1964). Strawberries are frequently infected with aphid-transmitted viruses in the field, possibly because aphids of the genus *Chaetosiphon,* which are the most important vectors of strawberry viruses elsewhere, do not occur in Finland (Bremer and Pethman 1978). Viruliferous nematodes (*Trichodorus* spp., *Longidorus* spp.) and fungi (*Olpidium brassicae*) may exist in plant nurseries, gardens and parks where ornamental or other perennial plants have been grown for a long time (Tapio 1972b, 1985). Therefore, transport of soil from nurseries and gardens may present a risk of virus dissemination.

Vol. 6 (1997): 323–336.

Viruses in vegetable crops

The aphid-transmitted cucumber mosaic virus (CMV) was early associated with a mosaic disease of cucumbers grown in the greenhouse (Rainio 1941). However, neither CMV nor the seed-transmitted cucumber green mottle mosaic virus (CGMV), which were found in ten and two, respectively, of the 263 crops inspected by Linnasalmi (1966), have become economically damaging to any crop in Finland.

The studies of Linnasalmi (1964) showed that 62% of the 387 tomato crops inspected were infected with viruses in 1961–63. Most of the diseased plants had mottle symptoms and were infected with tobacco mosaic virus (TMV), whereas 10% had streak symptoms and were infected with TMV (6–8%) or mixedly infected with TMV and potato virus X (PVX) (2–4%) (Linnasalmi 1964, Linnasalmi and Murtomaa 1966). TMV and PVX are readily transmitted mechanically but no insect vectors are known. Therefore, once the two viruses had been identified as the cause of the tomato mosaic and streak diseases, they could be controlled by improved hygiene. TMV and PVX are no longer significant in tomato crops.

Tomato spotted wilt virus (TSWV) was recently introduced to a few greenhouses, probably in infected, imported ornamental plants (Lemmetty 1991b). TSWV has a very broad host range, causes severe yield losses in many ornamental plants and horticultural crops, and is transmitted by two species of thrips (*Frankliniella occidentalis* and *Thrips tabaci*) that occur as pests in greenhouses in Finland (Lemmetty and Lindqvist 1993). TSWV is subject to special quarantine and control measures in Finland. If the virus is detected, the infected crop is destroyed and the greenhouse cleaned according to special instructions. Therefore, TSWV is not established in Finland, but the risk of reintroduction from other countries in imported plants remains and is continuously monitored by Finnish plant quarantine authorities (Anne Lemmetty, pers. comm.).

Until recently, vegetatively propagated onions of the aggregatum group (*Allium cepa*) and garlic were heavily virus-infected in Finland (Jamalainen 1952, 1957, Bremer 1990, Kokkola 1992). Many viruses have been identified in both crops (Table 1) and several unidentified viruses have also been observed (Bremer 1990, Kokkola 1992, Table 2). The viruses were recently eradicated from a few local clones of onion and garlic (Bremer 1990, Kokkola 1992) and the virus-free clones are maintained at and available from the Seed Potato Center.

Viruses continue to be detected time to time in vegetable crops in Finland (Tables 1, 2), but with exception of the viruses occurring in vegetatively propagated crops of potato, onion and garlic, as discussed above, economically significant losses no longer occur.

Virus in other crops

Viruses in legumes were extensively studied in Finland and other Scandinavian countries 30 years ago (Tapio 1970). Many viruses and virus strains were detected (Table 1), particularly in the experimental fields of plant breeders. A large number of these viruses caused a severe disease in infected legume plants, but were not prevalent in the legume crops in the farmers' fields and therefore not economically damaging.

Foliar symptoms resembling those caused by aphid-transmissible viruses have occasionally been observed in sugarbeets and fodderbeets (Table 2). Wind-borne aphids may sometimes carry the semi-persistently transmitted beet yellows virus (BYV) over the sea to southwestern Finland. This assumption is supported by the occurrence of symptoms resembling those caused by BYV in beets in Finland in years when epidemics caused by BYV occur in southern Sweden (E. Tapio, unpublished). Beet soil-borne virus has been detected in the roots of sugarbeets collected from several farms in Finland (Bremer et al. 1990).

No virus has been reported in any brassicas in Finland. Turnip mosaic virus that occurs in brassicas elsewhere has been detected only in rhubarb in Finland (Heinonen 1978).

Some of the viruses detected many years ago (Table 1, 2) have not been restudied recently in Finland. If the host range of a virus is restricted to the crop plant in which it has been detected, the virus may eventually be eradicated when new, virus-resistant cultivars will be introduced to cultivation. Further, if the virus has no vector or other means of dispersal in the environment in which it is introduced, it may be eradicated when the originally infected plant will be harvested or will die. However, no virus listed here is known to have ceased to exist in Finland. A few viruses may not have been detected in Finland because only the main crops and/or crops with severe disease symptoms have been inspected, the minor crops, crops with no obvious disease symptoms and wild plants having remained largely uninspected. Therefore, when new crop species and cropping systems are introduced in the future, new virus diseases caused by viruses and vectors that are currently unknown or considered non-important may appear in Finland.

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SELOSTUS

Maatalous- ja puutarhakasveissa havaitut virukset ja niiden merkitys Suomessa

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Intensiivinen kasvivirustutkimus alkoi Suomessa vasta n. 40 vuotta sitten, vaikka virusten tartuttamista viljelykasveista on dokumentoituja havaintoja yli 60 vuoden ajalta. Suomen maanviljelyssä tapahtui suuria muutoksia toisen maailmansodan jälkeen. Maatiloilla ja puutarhaviljelmillä erikoistuttiin tiettyihin viljelykasveihin, minkä seurauksena virustautiongelmat pahenivat. Tiedot viruksista ja niiden torjunnasta olivat puutteellisia eikä viruksetonta lisäysaineistoa ollut käytettävissä suvuttomasti lisättävistä lajeista. Siten 1950- ja 1960-luvuilla tutkimus keskittyi virusten ja niitä siirtävien vektorien (hyönteiset, ankeroiset, sienet) kartoittamiseen ja torjuntamenetelmien kehittämiseen.

Viljojen ja heinien virustutkimus sai merkittävän sysäyksen Pohjanmaalla 1950-luvulla esiintyneestä kaurantuhosta. Tauti todettiin kaskaslevintäisen kauran kääpiökasvuviruksen aiheuttamaksi ja torjuttiin lopettamalla heinän viljely kauran aluskasvina, jolloin virusta kantavien ja heinissä talvehtivien kaskaantoukkien määrä väheni. Ohran kääpiökasvuvirus (BYDV) on nykyisin tärkein vilja- ja heinäkasvien viruksista ja aiheuttaa epidemioita viljoissa niinä vuosina, jolloin kirvoja (erityisesti tuomikirvoja) on runsaasti. Epidemioita pystytään kuitenkin ennustamaan kirvapopulaatioiden kehittymistä seuraamalla.

Perunanvirusten merkitys väheni, kun terveen siemenperunan tuotanto käynnistyi v. 1976 perustetussa Siemenperunakeskuksessa. Kirvalevintäinen perunan Y-virus (PVY) sekä kuorirokkosienen levittämä perunan maltokaarivirus (PMTV) ovat kuitenkin yhä merkittäviä taudinaiheuttajia perunaviljelmillä. Virusten aiheuttamia tappioita marjantuotannossa ja koristekasvien viljelyssä on merkittävästi vähentänyt terve lisäysaineisto, jota tuotetaan v. 1976 toimintansa aloittaneella Laukaan tutkimus- ja valiotaimiasemalla. Vihanneskasveista tomaatti ja sipulit ovat olleet virusten pahoin vaivaamia. Tomaatin virustautien merkitys väheni hygienian parantuessa kasvihuoneviljelyssä. Ryväs- ja valkosipuleista on tuotettu muutamia viruksettomia klooneja, mutta useimmilla tiloilla kasvustot ovat edelleen virusten saastuttamia. Tehostunut virusten tarkastus maahantuoduista kasveista vähensi monien kasvihuoneissa viljeltyjen koristekasvien, kuten krysanteemin ja neilikan, virustautisuutta 1980-luvulla. Kasvintarkastustoiminnalla on edelleen suuri merkitys uusien virustautien maahantulon estäjänä, sillä virusten luonnollinen levintä Suomeen Euroopan muilta viljelyalueilta on vähäistä Itämeren eristäessä maamme näistä alueista. Sen sijaan muutamat, kirvojen mukana pysyvästi leviävät virukset kulkeutuvat Suomeen ajoittain kirvojen kaukolevinnän yhteydessä.