# Grower Summary

**FV 382b**

Project title: Carrots: The Epidemiology of Carrot yellow leaf virus (CYLV) - the development of a decision support system for the management of carrot viruses in the UK

Final 2015

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| **Project title:** | Project title: Carrots: The Epidemiology of Carrot yellow leaf virus (CYLV) - the development of a decision support system for the management of carrot viruses in the UK |
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| **Report:** | Final report, December 2015 |
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| **Date project commenced:** | 1 April 2014 |
| **Date project completed**<br>**(or expected completion date):** | 31/02/2015 |

# GROWER SUMMARY

## Headline

Novel viruses detected through previous projects have a national and international distribution in carrots and/or weeds. The incidence of these viruses is variable with season and region.

*Carrot yellow leaf virus* (CYLV) and Carrot torrado virus (CaTV) have been transmitted by both willow-carrot aphid (*Cavariella aegopodii*) and peach-potato aphid (*Myzus persicae*). Control of peach-potato aphid should be considered within future carrot virus management programmes.

## Background

Arising from previous carrot virus studies (FV 382, FV 382a and Adams et al., 2014), several key knowledge gaps were identified in the understanding of carrot virus epidemiology. Closing these gaps will allow the industry to better understand the effects of viral infection in carrot fields and in doing so move from a reactive to a proactive approach to virus management. The fundamental principles of plant virus management are:

- Plant clean seed
- Grow in absence of vectors
- Grow in absence of virus reservoirs
- Isolate from similar crops
- Use resistant, or tolerant, varieties

Although these points were formulated for virus management in seed potato crops, the key principles are transferable to any crop. The first four of these principles have been investigated as part of the work reported here.

The importance of *Parsnip yellow fleck virus* (PYFV) and *Carrot red leaf virus* (CtRLV) as viruses causing economic damage have been recognised in Europe for over 20 years due to the foliar symptoms (CtRLV) and viral die-back of seedlings (PYFV). However, with the recent association of the little studied *Carrot yellow leaf virus* (CYLV) as the causal agent of internal root necrosis, the industry faces a third major viral threat. Additionally there were further novel viruses found during FV 382a namely Carrot torrado virus (CaTV) and Carrot closterovirus-1 (CtCV-1). As these viruses were previously unknown there is limited knowledge about their epidemiology, aetiology, incidence and impact. Consequently there is also limited information that can be given to growers regarding the potential threat from these viruses and how best to manage crops to reduce their incidence. The aim of this project was to start to close the knowledge gaps regarding these recently emerged viruses.

## Summary

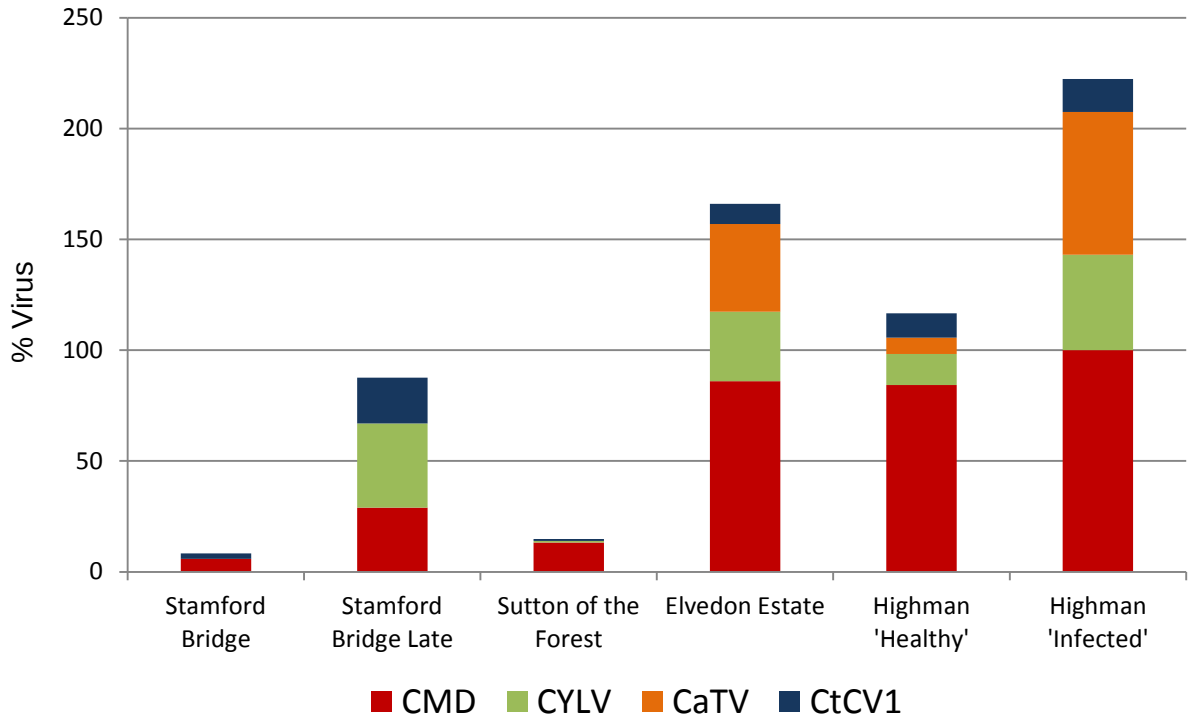
CYLV was transmitted with low efficiency by the willow-carrot aphid (*Cavariella aegopodii*) the peach-potato aphid (*Myzus persicae*) and the willow-parsnip aphid (*Cavariella theobaldi*), although the virus could not be transmitted early enough within the project to attempt a demonstration of a link to root necrosis through a full carrot growth cycle. Work related to this project has also shown that the virus CaTV is transmitted by aphids, a first demonstration of aphid transmission for a torradovirus. Through this project work there has been a demonstration of *Myzus persicae* as a potential virus vector in carrots as well as the potential for other *Cavariella* species to also play a role in carrot virus epidemics. This will have implications for aphid control strategies as this the peach-potato aphid is known to have has multiple aphicide resistance mechanisms and management of this species presents major challenges for season long control of aphids. Additionally the current resistance status of willow-carrot aphid is unknown. During the course of the project there

was evidence of high numbers of aphids in infected crops indicating that current aphid control measures were not wholly effective. The resistance status of willow-carrot aphid and the relative importance of peach-potato aphid as a vector in carrot crops should be investigated in future work.

The novel virus Carrot closterovirus-1 (CtCV-1), as well as Carrot yellow leaf virus (CYLV) and other carrot viruses appear to have a national distribution in both field crops (see Figure A) and alternate host sources. This is a first demonstration that these viruses are present across the UK and in Europe, outside of the previously studied geographic area.

In some fields all carrots sampled were positive for at least one virus and in most cases infected carrots were harbouring multiple virus infections. The presence of carrot viruses in fields at very high incidences gives a high potential for onward transmission of these viruses to infect other carrot crops within the growing season. If these crops were then to be stored under straw in the field this would give the potential for over-wintering of both the virus and the aphid vectors, particularly peach-potato aphid. An overlap between the stored crop and successive crops in nearby fields would, therefore, give a potential risk for these stored crops to form a source of inoculum for young emerging crops.

**Figure A**. Proportion of viruses in carrot fields in Yorkshire and Norfolk. Data are presented as cumulative % virus in 120 carrots sampled per field.




Carrot torrado virus was notably absent from weed sources but present within carrot crops in both sampling years. There are two possible explanations for this: there is another, as yet unidentified, environmental source of CaTV; or alternatively, CaTV may be a virus which circulates within carrot crops either originating from previous carrot crops or being brought into crops with seed and being spread from within the crop. The potential for viruses to circulate within carrot crops allowing infections to bridge seasons has been previously discussed as a potential transmission route for CtRLV and the CMD complex. From these data there is a distinct possibility that this is also a route by which CaTV is being transmitted. However, the role of seed-borne infections should not be discounted as even a low rate of onward transmission from infected seed could give rise infection sources within carrot fields. Any future work should also include investigations aimed to identify the relative importance of seed as a source of virus infection in carrots and the role played by overwintering crops in carrot virus epidemics.

If we reconsider the fundamental principles of plant virus management in the light of these new data we can now say:

- Plant clean seed: There is a potential that carrot seed may be a source of CaTV
- Grow in absence of vectors: *Myzus persicae* must now be considered as a vector of carrot viruses along with other *Cavariella* species including *C. aegopodii*.
- Grow in absence of virus reservoirs: Both common weed hosts and carrot crops may form a source of virus infections into uninfected crops.
- Isolate from similar crops: The separation of crops in this respect could be isolation from other carrot crops 'in time' as well as geographic isolation.
- Use resistant (or tolerant?) varieties: There is still limited data on the susceptibility of a range of varieties. The majority of work reported here has been carried out on cv. Nairobi as this is the variety most commonly grown in the UK.

Although the link between CYLV and necrosis could not be experimentally demonstrated within this project, the virus has been shown to be aphid transmitted. Work related to this project has shown that the virus CaTV is transmitted by aphids, a first demonstration of aphid transmission for a torradovirus. The novel viruses CtCV-1 and CaTV, as well as CYLV appear to have a national distribution in both field crops and alternate host sources, giving potential for transmission into carrot crops as well as other members of the apiaceae, such as field grown herbs. They also appear to be present in carrot fields in Europe and may therefore be of international importance in carrot production. The role of weeds in the epidemiology of these viruses remains to be confirmed, however, they may play an important role as sources of CYLV and CtCV-1. From these data weeds appear to be of limited significance as a source of CaTV infections. The finding of greatest significance for growers is the demonstration of *Myzus persicae* as a potential vector in carrots. This will

have implications for aphid control strategies as this aphid species has multiple aphicide resistance mechanisms and will present major challenges for season long control of aphids.

## Financial Benefits

At this stage it is difficult to give a clear cost-benefit to growers as the cumulative impact of carrot viruses on the UK carrot industry is still unclear. Virus associated losses to the industry will come from two sources:

a) Necrosis within roots leading to crop rejections as affected roots will be unsuitable for market.

b) Virus infections will lead to a reduced yield due to loss of photosynthetic area in affected foliage.

With a better understanding of the sources of carrot virus epidemics and the key vectors systems can be developed to minimise virus infections and consequently reduce both yield and quality losses.

## Action Points

Although the relative importance of each vector aphid species and each virus source is not known, the demonstration of a range of aphid species transmitting viruses to carrots must be considered when formulating aphid/virus management programmes:

- The peach-potato aphid (*Myzus persicae*) appears to be as efficient at transmitting carrot viruses as the willow-carrot aphid (*C. aegopodii*). This species is recognised as having multiple aphicide resistance mechanisms. Additionally other Cavariella species, the parsnip aphid (*C. pastinaceae*) and the willow parsnip aphid (*C. theobaldi*) may also play a role in carrot virus transmission. These aphid species and aphicide resistance management should be considered within aphid monitoring and virus control programmes.

- Due to the limited number of chemical control options available to growers, it will be difficult to maintain a season long virus control programme. Alternate virus management methods should also be employed to give an integrated control strategy. These approaches could include fleece coverage of young crops as a barrier to infection; IPM approaches to increase natural predators; use of aphid monitoring programmes to better target spray application; isolation of crops from virus sources if possible.

## Overview of carrot viruses

Virus names are only written in italicised script once they are formally recognised by the International committee on Taxonomy of Viruses (ICTV). Generally speaking plant viruses are named using the following convention:
Common name of initial host – Symptom observed – Virus
This can lead to some confusion if a virus has multiple host species e.g. Cucumber mosaic virus has over 1200 known hosts; or when a symptom is idiosyncratic to a particular variety or is a temporary reaction. Virus nomenclature has been further complicated by the use of novel sequencing techniques, such as those used in FV 382a, where previously unknown viruses are discovered with no direct reference to symptomatic context. In these cases the virus is named after the genus level to which it can be assigned. If the virus is from a novel genus, then it is named after the 'new' genus name.
The information below is designed to give an overview of the viruses referred to in this report.

### ***Parsnip yellow fleck virus*** **(PYFV)**

PYFV is important as an early season disease where it is associated with seedling death (see Figure B). The virus requires *Anthriscus yellows virus* (AYV) for transmission, and this second virus provides a 'molecular glue' to enable the PYFV to be retained within the aphid foregut. The aphid can be thought of as a 'flying syringe' drawing up the virus and then passing it on through subsequent feeding activity. Transmission is rapid, typically taking less than a few minutes to pass on the virus. The main vector of this virus is considered to be *Cavariella aegopodii*, the willow-carrot aphid.

**Figure B.** Seedling death in carrots caused *Parsnip yellow fleck virus*

AHDB-Horticulture project FV 228a demonstrated that the source of PYFV infections in carrots are most likely to be associated with cow parsley (*Anthriscus sylvestris*), a common hedgerow weed. As carrots are not a host of AYV, once they are infected with *Parsnip yellow fleck virus* the virus cannot be passed on.

In many seasons, PYFV does not commonly occur. The reasons for this sporadic occurrence are still unknown, but it is possibly due to its complicated epidemiology involving AYV, which limits onward spread in carrot crops. Work conducted at Warwick Crop Centre suggested a close relationship between observed symptom, root weight and the proportion of plants infected with PYFV suggesting that this virus can cause stunting in mature carrot crops (Dez Barbara, pers. comm.).

## Carrot Motley Dwarf disease (CMD)

Carrot Motley Dwarf (CMD) is a disease complex comprising of *Carrot red leaf virus* (CtRLV), *Carrot mottle virus* (CMoV) and Carrot red leaf associated viral RNA (CtRLVaRNA). The disease complex can only be transmitted if CtRLV is present as the other two viral components are enclosed within the CtRLV virus particle during aphid acquisition and transmission. However, the individual component pathogens can be found in single infections. The virus is taken up by the aphid and passes through the gut and into the salivary gland where it can be passed on through feeding activity. This process can take several hours. Carrot infections are thought to originate from other carrots rather than weed hosts.

**Figure C.** Leaf reddening and dwarfing caused by infection with CMD disease complex

CtRLV is associated with leaf reddening (see Figure C) and CMoV with mottling which is a dappled yellowing of the leaf. However, in experimental studies, single infections by either of these viruses resulted in mild symptoms. The two viruses in co-infection have a greater effect on the plant and the result is called carrot motley dwarf disease. The third virus in the complex, CtRLVaRNA, is not known to have any noticeable effect on disease symptoms.
While foliar symptoms may be obvious, there is little data on root symptoms or crop loss due to these viruses. Anecdotally infections with CMD have been linked to root symptoms such as excessive lateral root hairs (bearding) and root cracks and splits (splitting or kippering). Visual identification of this disease complex is not helped by leaf reddening etc. being a general response to stress or physical damage and there are also similar symptoms caused by infections with other pathogens such as phytoplasmas.

## *Carrot yellow leaf virus* (CYLV)

Although this virus has been known to occur in the UK since 1980, very little research was conducted into the virus as it was considered a minor issue. However, FV 382a demonstrated that this virus was strongly associated with carrot internal necrosis (Figure D).

**Figure D.** Carrot root cross section showing presence of internal necrosis associated with infection from CYLV

The virus is known to be transmitted by a similar mechanism to PYFV, where the virus is sucked into the foregut of the aphid and can be rapidly transmitted into a new host. Unlike PYFV, *Carrot yellow leaf virus* does not require a helper virus and onward transmission in carrot crops will occur. Foliar symptoms are thought to be an upright growth habit and yellowing of foliage (see Figure E). The virus was previously known to be transmitted by *C. aegopodii*, the willow-carrot aphid, *C. pastinaceae*, the parsnip aphid, and *C. theobaldi*, the willow-parsnip aphid. Transmission work carried out during this study has also demonstrated the ability of *Myzus persicae*, the peach-potato aphid, to transmit the virus. This study has shown the virus to be present in a wide range of apiaceous weed hosts as well as carrot crops, however, the relative importance of each virus source is not yet known.

**Figure E.** Yellowing of foliage caused by viral infection in carrot. As this carrot contained multiple viruses the symptom cannot be definitively linked to infection with CYLV.

## Carrot clostero virus-1 (CtCV-1)

This virus was first described through sequencing findings during FV 382a. Genetically the virus is very similar to CYLV, and is assumed to have a similar biology. Vectors, modes of transmission and field symptoms have not yet been confirmed for this virus. The findings of this study are the first step in showing this virus is widespread in weeds and carrots both in the UK and further afield. Further biological characterisation work is ongoing.

## Carrot torrado virus (CaTV)

This virus was also first described through sequencing findings during FV 382a. This virus belongs to a recently discovered genus, the torradoviruses (van der Vlugt, 2015). Most members of this genus are tomato affecting viruses, and CaTV is the first virus in this group to affect the *Apiaceae*. The tomato infecting torradoviruses are known to be whitefly transmitted. The results of this study represent the first demonstration of aphid transmission of a torradovirus, with the virus being shown to be transmissible by both *C. aegopodii*, the willow-carrot aphid, and *M. persicae*, the peach-potato aphid. The virus is not currently thought to cause an observable symptom, but may contribute to yield reduction. As the virus was not detected from any of the weeds tested in this study it is likely that infected carrots are the source of carrot epidemics. Seeds were shown to be contaminated with the virus, but further work is needed to demonstrate the importance of seed-borne infections.