The 6 Steps to Effective Virus Management in Certified or Home Saved Seed

Keeping virus out of seed stocks requires an integrated approach with all the individual steps important in achieving the end result.

Scottish seed has an excellent reputation for high viral health. But maintaining the high standards is becoming more difficult as pesticide availability is reduced, changes occur to the pathogen and climate change takes effect.

Use the six steps to ensure everything is being done to protect Scotland's reputation.

STEP 1: Seed and Location

- Know the virus level in your seed - use seed of as high a grade as possible.
- Keep field generations to a minimum.
- Avoid dual purpose cropping.
- High grade crops should be isolated.
- Locate crops away from sources of virus and high aphid vector pressure.
- Do not plant in or near to fields where groundkeepers have not been controlled.
- Where possible, drill cereal strips around crops to divert incoming infected aphids.

STEP 2: Virus removal

- Rogue crops soon after emergence – before the virus can spread.
- Remove groundkeepers from both seed and neighbouring crops.
- Destroy or completely cover potato dumps.
- Continue roguing throughout the season.

STEP 3: Understand your varieties and virus interactions.

- Know the variety resistance.
- Understand the virus propensity of your crops.
- Target high risk varieties **with extra control measures throughout the season.**

STEP 4: Use Decision Support Systems

- Track the enemy (aphids).
- Make use of information from yellow water trap and suction traps.
- Get yellow water traps set up and operational early (before emergence).
- Inspect crops regularly.

STEP 5: Target your spray programmes

- Monitor aphid flights and target your applications.
- As soon as key aphids are flying, spray.
- Mineral oils can reduce virus acquisition and transmission when sprayed early and frequently.
- Continued over-reliance on pyrethroids is likely to result in further resistance shifts.
- Follow guidelines to ensure an effective, reliable, and legal programme is followed.
- Systemic insecticides can be very effective against Potato Leaf Roll Virus (PLRV), but they are not effective for Potato virus Y (PVY) control.

STEP 6: Manage crops until the haulm is dead.

- Understand the limitations of your programme - aphids can transmit PVY in around a minute!
- Mature plant resistance is less effective in controlling variants of the most prevalent PVY^{NTN} strain.
- Early burn down reduces virus transmission risk.
- Spray applications must continue until the haulm is dead.
- Control regrowth to prevent late season transmission.

SRUC SCOTTISH AGRONOMY LTD SASA Helping Scotland Grow The James Hutton Institute AHDB POTATOES McCain

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Dear Seed Potato Grower,

The virus health of Scottish seed potatoes is a unique selling point in GB and around the world. However, the amount of virus in crops increased significantly during 2019 to its highest level for some decades. In 2020 the levels were similar again. However, the current indicators are for environmental factors (a colder winter) to assist in reducing levels in 2021.

The opportunity exists for growers and the industry to bear down on virus in 2021 to reduce virus levels not just for this year but into the following seasons.

The main virus of concern is Potato Virus Y (PVY) and the most prevalent variants are now recombinants of the PVY^{NTN} strain group. As this virus can cause significant direct yield losses, tuber blemishes and cracking, management practices must be continually reassessed to confirm that they are remaining effective. It should also be noted that there has been an increase in Potato Leaf Roll Virus (PLRV) which also causes significant yield and quality issues.

These issues cause real concern to the customers of seed potatoes in GB and abroad.

Our understanding of the effect of the changing environment, the changing pathogen, new varieties, and the effect of aphicide resistance is not as good as we would like. These guidelines have been produced after extensive discussion with industry and science experts. They represent the best available advice based on current evidence and provide the background information to the ***'six steps to effective virus management'*** to form a fully integrated pest management (IPM) programme.

Growers will need to discuss the recommended pesticide programmes with their BASIS qualified agronomist and tailor programmes to their unique set of circumstances.

Philip Burgess and Eric Anderson

On behalf of the Scottish Aphid Borne Virus Working Party.

Understanding viruses and their transmission

There are many different viruses of potatoes transmitted by a wide range of organisms (aphids, nematodes and fungi). However, the main issue of concern is those transmitted by aphids. This guide has been developed to assist with the **control of Aphid Transmitted Viruses.**

There are two groups of aphid-borne viruses that are of concern: **persistent** viruses (such as *Potato leaf roll virus* - PLRV) and **non-persistent** viruses (e.g., *Potato virus Y* – PVY^{O}, PVY^{N}, PVY^{NTN} *Potato virus A* – PVA, *Potato virus V* – PVV).

The persistent virus PLRV resides in the phloem sap of plants and is acquired from infected plants by aphids feeding on the plants and ingesting sap. The ability of an aphid to transmit PLRV is then delayed for several hours as the virus passes through the digestive system of the aphid and then enters its saliva ready for transmission to occur. Consequently, **only potato colonising aphids transmit PLRV**. Once the virus has been acquired by an aphid, it remains infective for the rest of the aphid's life.

The non-persistent viruses such as PVY (and their strains such as PVY^{O}, PVY^{N}, PVY^{NTN}), PVA and PVV are rapidly acquired when an aphid feeds on an infected plant because these viruses reside in most plant tissues including the leaf epidermal cells of plants. **Non-persistent viruses are carried on the aphid mouthparts and can be passed on to another plant within a few minutes during aphid feeding or plant probing.** Consequently, winged aphids which briefly probe plants to determine whether they are suitable hosts and then move onto another plant, have the potential to spread viruses quickly within the crop. These winged aphids may be non-potato colonising or potato colonizing aphids, and **several non-potato colonising aphid species are involved in PVY virus transmission.**

Step 1 Seed and Location

The key focus should be on targeting and managing sources of virus.

Sources of Aphid Transmitted Potato viruses
Infected seed planted in the field
Infected neighbouring ware or seed crops
Potato groundkeepers in both potato and non-potato crops
Potato dumps where there is haulm growth

Sourcing high quality virus-free seed to minimise the risks of spread from infected plants within the crop is the single most important step in reducing virus spread. If it is your own seed, you should know what level of virus it may or may not contain. If brought in, then buy from trusted suppliers and ask for reassurance that the crop was free from virus infection. Tubers can be tested for virus before planting if there is a risk of infection. Tuber samples must be representative of the stock tested and randomly selected, preferably from the field (individual plants) before harvest. The results should be interpreted with regard to the sample size and confidence limits associated with such samples.

Aim to grow crops in an environment in which all sources of aphid-transmitted viruses are kept to a minimum. Isolate seed crops from external sources of virus. Adjacent fields should be checked for the presence of infected groundkeepers and action taken as appropriate.

Nearby ware crops should be as free from virus as possible - the use of untested home-saved seed to grow ware will increase the risk. Preventing haulm growth on dumps is essential.

Additional IPM options:

- Consider sowing cereal strips at the edges of both seed and ware crops, as they can "cleanse" the mouthparts of transitory viruliferous aphids before they fly onwards into the seed crop.
- In years of early aphid flights straw mulches may be considered as an additional IPM tool, particularly if used in combination with mineral oils. The efficacy of mulches in minimising virus transmission is currently being assessed in GB conditions.

Step 2 Virus removal

If there is any virus present in your crop it will become a significant source of disease if aphids enter the crop. Thorough roguing of infected plants and groundkeepers at an early stage – as early in the growth of the crop as practical – and before aphid vectors are flying is key.

Roguing of groundkeepers from non-potato crops, and potato plants exhibiting virus symptoms from nearby ware is also a component of virus management in seed potatoes.

Keep inspecting crops throughout the season and removing any infected plants as symptoms appear.

Identification of virus symptoms in seed potatoes is a skilled operation. Growers and their roguers should be trained. (SRUC provide a training course for roguers; contact Innes.Jessiman@sac.co.uk for more information).

Step 3 Understand your varieties and virus interactions.

Varietal resistance to viruses

Some varieties are highly resistant to some virus species and do not display symptoms nor become sources of virus. The resistance (rated from 1 -highly susceptible- to 9 -highly resistant) of most varieties can be found in the AHDB variety database https://varieties.ahdb.org.uk/. They do not indicate the severity of symptoms seen in infected plants but to the proportion of daughter tubers infected with virus at the end of the growing season. Depending on when a variety was entered for NL testing, a rating for virus resistance may not be available or it may refer to resistance to strains of PVY which were prevalent at the time, but which may be less important now. Varieties with high resistance ratings (7 or higher) should be inspected for disease but can be considered at low risk of spread for the virus strain against which they were tested to daughter crops.

Symptoms of virus

Some varieties are known to be susceptible to virus but do not display clear symptoms e.g. Estima. There are no published figures or assessment of tolerance, (sometimes termed 'honesty' of disease expression) which is largely dependent upon the specific virus strain and environmental conditions. This characteristic is important as symptomless, infected plants can become sources of virus to spread into neighbouring crops.

Varietal propensity for virus

The term 'varietal propensity' is used to describe whether virus symptoms observed within a variety are above or below the average observed across the whole Scottish seed crop. The variety propensity score for PLRV or PVY can be used to risk assess different varieties. Full details on varietal propensity can be found at https://www.sasa.gov.uk/seed-ware-potatoes/virology/varietal-propensity-virus-infection

For those varieties with a high propensity additional stringent control measures may need to be implemented.

Table 1: Varieties with high propensity to virus

PVY strains	PVA strains	PLRV
Maris Piper	Hermes	Maris Piper
Maris Peer	Desiree	Maris Peer
VR808	Estima	Russet Burbank
Charlotte	Russet Burbank	Daisy
King Edward	Galactica	Cara
Desiree		Estima
Wilja		
Atlantic		
Slaney		

Step 4: Use Decision Support Systems.

Before the season starts

The cold winter will affect early aphid flights and mathematical models have been developed which predict the first flights of aphids. In 2021 these predict the first flights of *Myzus persicae* (Peach Potato Aphid) to be on 23-26th June. This is 2 weeks later than an average summer and 4 weeks later than in 2020. These models also predict lower numbers of aphids. For more information on aphid prediction visit https://www.sasa.gov.uk/wildlife-environment/aphid-monitoring/aphid-predictions –

Similar predictions are available for some non-colonising aphids, such as the cereal aphids. Visit https://ahdb.org.uk/aphid-forecasts for more detailed information.

During the season

The appearance of aphids throughout the season can be monitored from the AHDB network of aphid water traps (http://aphmon.fera.defra.gov.uk/). This is the most directly relevant source of information. **Subscribe for alerts from the website.**

Additional Information from the UK network of aphid suction traps can be found on the following websites.

- SASA Link to SASA aphid monitoring (Subscribe to weekly updates) and
- Rothamstead Research https://insectsurvey.com/aphid-bulletin

This information should be used as an early warning system for general areas and growers should use data to gauge the threat from aphids and virus spread in their area and monitor this throughout the season.

The timing and presence of key aphid species caught in the aphid water traps or suction traps can be used as a guide to the risk of virus spread and the most appropriate means of control.

Yellow water traps

These should be present in crops from **before emergence** to ensure they are operating during the critical early stages of crop growth. The traps are generally emptied weekly and sent for analysis. It can therefore be over a week between an aphid being caught and the result being reported.

Key aphids

Once any of the following aphids (Table 2) begin to appear in local water traps or suction traps then there is risk of transmission of non-persistent viruses and aphid management programmes should start.

Table 2: Key aphid species which can transmit virus. Those highlighted are potato colonisers and can transmit both PVY and PLRV.

Species	Common Name	PVY REF*
Myzus persicae	Peach-Potato Aphid	1.00
Acyrthosiphon pisum	Pea Aphid	0.70
Sitobion avenae	Grain Aphid	0.60
Cavariella aegopodii	Willow-Carrot Aphid	0.50
Aphis nasturtii	Buckthorn-Potato Aphid	0.40
Rhopalosiphum padi	Bird Cherry-Oat Aphid	0.40
Metopolophium dirhodum	Rose-Grain Aphid	0.30
Brachycaudus helichrysi	Leaf-Curling Plum Aphid	0.21
Aulacorthum solani	Glasshouse and Potato Aphid	0.20
Macrosiphum euphorbiae	Potato Aphid	0.20
Myzus ascalonicus	Shallot Aphid	0.20
Myzus ornatus	Violet Aphid	0.20
Rhopalosiphoninus latysiphon	Bulb and Potato Aphid	0.20
Hyperomyzus lactucae	Currant-Sowthistle Aphid	0.16
Aphis fabae	Black-Bean Aphid	0.10
Brevicoryne brassicae	Cabbage Aphid	0.01

* The transmission efficiency for aphid species is used to calculate a potential transmission risk and is expressed as a relative efficiency factor (REF). The efficiency of transmission of *Myzus persicae* is nominally set to a REF of 1 and REFs for other species are calculated relative to this. This table represents average data. Some differences can occur with different virus/aphid combination.

Step 5 Target your spray programmes

Aphid management programmes

Application of pesticides has an important role to play in the reduction of virus spread. However, applications will only be effective as a part of the full Integrated Pest Management (IPM) strategy (steps 1 to 6) outlined in this document.

The availability of insecticides and our knowledge of the efficacy of those that remain is changing. This section outlines the current best practice for the use of PPP (Plant Protection Products) for controlling aphids in seed crops.

The latest published information on the resistance of aphids to pesticides is published by IRAG (Insecticide Resistance Action Group https://ahdb.org.uk/irag).

The most effective, approach to manage resistance is to minimise insecticide use by following appropriate threshold guidance and using integrated pest management (IPM) programmes, including chemical and non-chemical (e.g. resistant varieties) means of control. There is not a single solution – it is about using actions that complement each other.

Using Pyrethroids

Pyrethroids (esfenvalerate and lambda-cyhalothrin) have been used in GB as the main pesticide to control non-persistent virus spread for many years. They can provide a rapid 'knockdown' of aphids and prevent spread of PVY strains. However, over reliance on a single class of frequently used insecticide has resulted in selection for **pyrethroid resistance** in some aphid species. Resistance to pyrethroids by **peach potato aphid** is known to be widespread. Testing of aphids for resistance is complex and relies on either live samples or detailed genetic understanding. Our knowledge in this area is not as good as we would like (Table 3).

Pyrethroid use also has a detrimental effect on beneficial insects, which may play a part in control of aphid populations.

Grain aphids are known to show moderate resistance to pyrethroids and testing of aphids from the Edinburgh suction trap showed that 19% of the aphids had moderate pyrethroid resistance.

Tests of **bird cherry-oat** aphids from England/Wales and Scotland did not show evidence of reduced sensitivity to pyrethroids.

Other aphids such as **potato aphid, pea aphid** and **willow-carrot aphid** are not regularly tested for their sensitivity to pyrethroids. Based on results from a small number of samples, it is currently assumed that there is moderate resistance in the willow-carrot aphid.

The use of Pyrethroid insecticides may be subject to regulatory review. As such, alternative strategies need to be explored.

Reliance on pyrethroid products needs to be reduced.

Table 3: Resistance to Pyrethroid insecticides in Scotland.

Species	Common Name	Information on pyrethroid resistance
Myzus persicae	Peach-Potato Aphid	Widespread and highly resistant
Sitobion avenae	Grain Aphid	Moderate resistance present
Cavariella aegopodii	Willow-Carrot Aphid	Moderate resistance assumed to be present
Rhopalosiphum padi	Bird Cherry-Oat Aphid	No evidence of resistance in GB but only single sample tested from Scotland. Resistance reported from other countries

Using translaminar (systemic) products

Translaminar (systemic) insecticide products (*acetamiprid*, *flonicamid* and *spirotetramat*) are taken up by leaves and therefore kill aphids that are feeding (and are of limited use to control the transmission of non-persistent viruses). These products are recommended for the control of colonising aphids, particularly peach-potato aphids. These treatments will be particularly effective in the control of PLRV and should be applied to control these aphids as necessary, with a minimum interval of 14 days between sprays. There is no evidence of resistance to these products in the UK.

Using mineral oils

There is strong evidence, from UK and abroad, that mineral oils can be used to reduce non persistent virus transmission. The control achieved is highly variable (Open link to AHDB Project report 449)and highly dependent upon seasonal conditions and aphid activity. There are no mineral oil products approved as plant protection products (PPP) in the UK. However, there are some products available as spray adjuvants which must be used with an approved PPP such as an insecticide, fungicide or herbicide. These products can only be applied up to tuber initiation.

- Early application of mineral oils is required to be effective. In trials, initial applications have been made at 30% emergence if aphids are present.
- The control virus transmission following full programmes of mineral oil applications has been found to be highly variable.
- Mineral oils need to cover the foliage to be effective. In some high-risk situations and during rapid canopy expansion, spray intervals have been reduced to 3 days to ensure good coverage.
- Vegetable oils have been less well studied in UK and we have no evidence on their effectiveness.
- Mineral oil adjuvants are **not compatible with all PPP's** (including some blight products) and advice on compatibility must be obtained before use.
- Application of mineral oils can have some effects on foliage (transient local necrosis). While this has not been considered a hindrance to crop inspection in most cases, it is recommended to avoid treatment 1-2 days before crop inspection.

Virus control programmes

A single, prescribed programme of applications will not be suitable for all situations. The following principles should be used in the development of programmes to ensure greatest benefit.

- Mineral oils are most effective when applied at early growth stages, with evidence suggesting that they should be applied from 30% emergence if aphids are present.
- Mineral oils rely on covering new foliage growth with a film of oil. Frequent application, every three days in very high-risk situations, may be appropriate.
- Current mineral oil products (applied as adjuvants) can only be applied until tuber initiation.
- Pyrethroids are permitted throughout crop growth with restrictions on the number of sprays per season (see table 4). However, they should not be relied upon if peach-potato aphids, grain aphids or willow-carrot aphids are present as these species are likely to be resistant.
- Pyrethroids, where effective, can achieve a rapid knock-down and act as a deterrent to aphid probing of treated leaves, thus reducing the risk of virus being acquired and transmitted.
- Pyrethroid use should be targeted to the period after tuber initiation where aphid species are present that are likely to be sensitive. Where required applications should be every 7 days.
- Translaminar products (*acetamiprid*, *flonicamid*, *spirotetramat*) should be applied to control **colonising** aphid species (especially *Myzus persicae*) when recorded as present through monitoring systems. Applications should be repeated at 14-day intervals if necessary.
- Individual translaminar products must be not used be used consecutively. Alternate products to prevent resistance development.
- Programmes must continue until haulm is completely dead at the end of the season. Pay particular attention to any regrowth.

It is essential that label recommendations for all products are followed. These label recommendations include restrictions aimed at preventing resistance development.

Table 4
List of active ingredients approved for use on seed potato crops in 2021:

Aphicide group	Active ingredient	Max No. of applications of each product	Comments
Pyrethroid	esfenvalerate	4	• Knockdown activity • Resistance by key species, especially peach-potato aphid • At risk of withdrawal
Pyrethroid	lambda-cyhalothrin	4	• Knockdown activity • Resistance by key species, especially peach-potato aphid • At risk of withdrawal
Neonicotinoid	acetamiprid	2 (1 on ware)	• Translaminar activity. • Not to be used in consecutive sprays
Pyridine carboxamide	flonicamid	2	• Translaminar activity. • Not to be used in consecutive sprays. • 21-day spray interval • Not to be used with oil-based adjuvants in ware crops. • Possible withdrawal during 2022
Tetramic acid	spirotetramat	4	• Translaminar activity. • Not to be used in consecutive sprays. • Application only after flowering in those varieties which produce flowers.

Step 6: Manage crops until the haulm is dead.

Early burn down: Limitations to the control of aphids with pesticides reinforce the need for early and complete burndown of crops. Once no green material remains, virus cannot spread into daughter tubers.

Dual purpose crops: The production of seed tops is not recommended. The extended growing season necessary increases the risk of aphid infestation and virus spread. In addition, pesticide application restrictions are further limited for these crops.

Regrowth: Early burn down increases the potential for regrowth. This fresh green material is very attractive to aphids and present a risk of late season transmission. Control programmes must continue until no green tissue remains.