# Insecticide resistance status in UK potato crops


## Summary

- This Insecticide Resistance Action Group (IRAG) publication summarises the resistance status of aphid pests of UK potato crops. Use it in conjunction with IRAG's 'Background to insecticide resistance and its management' publication
- The peach–potato aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*) are the main aphid pests of potatoes. Non-colonising aphids are also a concern because of their ability to transmit potyviruses, such as PVY
- Peach–potato aphids with high levels of resistance to pyrethroids continue to predominate across the UK
- Two species of non-colonising aphids, grain aphids (*Sitobion avenae*) and willow-carrot aphids (*Cavariella aegopodii),* with moderate levels of resistance to pyrethroids are present in the UK
- To minimise the risk of insecticide resistance developing and spreading, insecticide use should be minimised through the use of thresholds and integrated pest management (IPM) programmes
- Use products at their full label rate and use modes of action (MoA) in alternation in the spray programme (where more than one treatment is required). Mixtures may offer a short-term solution to resistance problems, but it is essential to ensure that each component of a mixture belongs to a different insecticide MoA class, and that each component is used at its full label rate
- Approved chemical names or the name of the chemical group they belong to are used throughout this document. The names of products registered in the UK that contain these insecticides are available at secure.pestcides.gov.uk/pestreg/ProdSearch.asp
- The AHDB 'Encyclopaedia of pests and natural enemies in field crops' contains information on treatment thresholds, life-cycles and monitoring methods for a range of relevant pests
- All IRAG publications can accessed via the dedicated web page – ahdb.org.uk/knowledge-library/irag


## Aphid pests of potato crops

Peach-potato aphid (*Myzus persicae*) and potato aphid (*Macrosiphum euphorbiae*) are the main aphid pests of potatoes. Glasshouse potato aphid (*Aulacorthum solani*) and buckthorn-potato aphid (*Aphis nasturtii*) are sporadic pests of potatoes, although numbers of the former have increased six-fold in yellow water trap catches from seed potato crops since 2014. Melon aphid (or cotton aphid) (*Aphis gossypii*) is mainly a glasshouse pest that occurs very occasionally on potato crops in the UK. In addition, bulb and potato aphid (*Rhopalosiphoninus latysiphon*) may also be found. All these species can colonise potatoes and, therefore, transmit persistent viruses, such as potato leaf roll virus (PLRV). Persistent viruses are transmitted following ingestion of sap and virus passing through the aphid digestive system. PLRV is picked up by potato-colonising aphids during prolonged feeding (~12 hours) on an infected plant. Once an aphid acquires the virus it is infective for life. The peach-potato aphid is regarded as the most efficient vector.

There are a number of aphid species that do not use potato as a host but, nevertheless, alight on potato plants and probe the leaves. These non-colonising species can transmit non-persistent, rapidly acquired potyviruses such as potato virus Y (PVY) and potato virus A (PVA). Laboratory methods have been used to study which aphid species are the most important in spreading potyviruses. Peach–potato aphid is considered to be the most efficient vector of PVY and laboratory results of virus infection bioassays are used to calculate Relative Efficiency Factor (REF) values, which reflect the transmission efficiency of a particular aphid species in relation to that of peach–potato aphid (Table 1). REF values for PLRV can be found here https://aphmon.fera.co.uk/plrv_vector_info.cfm

Up-to-date information on aphid pest monitoring in potato and an indication of regional virus pressure can be found at https://aphmon.fera.co.uk

**Table 1.** Currently used PVY Relative Efficiency Factor values for different aphid species. Adapted from Fox *et al.* (2017).

| Common name | Species | Relative Efficiency Factor (REF) for Potato Virus Y (PVY) |
|---|---|---|
| **Peach–potato aphid** | *Myzus persicae* | 1.00 |
| **Pea aphid** | *Acyrthosiphon pisum* | 0.70 |
| **Grain aphid** | *Sitobion avenae* | 0.60 |
| **Willow–carrot aphid** | *Cavariella aegopodii* | 0.50 |
| **Buckthorn–potato aphid** | *Aphis nasturtii* | 0.40 |
| **Bird cherry–oat aphid** | *Rhopalosiphum padi* | 0.40 |
| **Rose–grain aphid** | *Metopolophium dirhodum* | 0.30 |
| **Leaf-curling plum aphid** | *Brachycaudus helichrysi* | 0.21 |
| **Potato aphid** | *Macrosiphum euphorbiae* | 0.20 |
| **Glasshouse potato aphid** | *Aulacorthum solani* | 0.20 |
| **Shallot aphid** | *Myzus ascalonicus* | 0.20 |
| **Violet aphid** | *Myzus ornatus* | 0.20 |
| **Bulb and potato aphid** | *Rhopalosiphoninus latysiphon* | 0.20 |
| **Blackcurrant-sowthistle aphid** | *Hyperomyzus lactucae* | 0.16 |
| **Black bean aphid** | *Aphis fabae* | 0.10 |
| **Cabbage aphid** | *Brevicoryne brassicae* | 0.01 |

# Insecticide resistance status of aphid pests of potatoes

## *Peach-potato aphid*

The various mechanisms of resistance in peach-potato aphids have been monitored for many years (see the 'Background to insecticide resistance and its management' publication for details).

Aphids with high esterase (conferring variable resistance to a number of insecticide groups, including pyrethroids), MACE (conferring strong resistance to some dimethyl-carbamates within the carbamate mode of action group) and kdr (conferring moderate resistance to pyrethroids) were widely distributed on potato crops in the past in eastern England. MACE and esterase resistance then appeared to decline to low levels by 2000, possibly because peach-potato aphids carrying these resistance mechanisms suffer greater mortality during times of stress (e.g. during colder winters).

New forms of peach–potato aphid that carry an alternative form of kdr, called 'super-kdr', which gives strong resistance to pyrethroids, are now prevalent in the UK. These aphids appear to be better adapted to the current UK environment.

Peach-potato aphids that carry strong neonicotinoid resistance (conferred by a combination of a metabolic mechanism and a target site mechanism) are now common in some peach growing regions of southern mainland Europe and have spread to Greece, North Africa and, most recently, to Belgium (on sugar beet), as well as other crops (including potatoes). This situation is being monitored in the UK. Currently, there is no

evidence of strong resistance to neonicotinoids in peach-potato aphids here. As a result, this chemistry, available as foliar applications of acetamiprid, has an important role to play in potatoes.

The maximum number of applications of any neonicotinoid containing product (see Table 3) is a statutory restriction introduced by CRD, in collaboration with IRAG, as a pro-active resistance management measure for peach–potato aphid.

Ongoing resistance screening work has also shown that there is currently no evidence of resistance to flonicamid or spirotetramat in peach–potato aphids in the UK.

## *Other potato colonising aphids*

Elevated levels of carboxylesterases have been detected in laboratory assays of some potato aphid individuals collected from the field in the UK. This indicates that potato aphid does have an increased risk of becoming resistant to some insecticide groups. However, there is, as yet, no evidence of field resistance to insecticides in potato aphids.

Melon aphid (also referred to as cotton aphid) has been reported to be resistant to one or more of the following insecticide groups: carbamates, organochlorines, organophosphates, pyrethroids and neonicotinoids. However, samples collected from the UK have not been tested recently. Similarly, buckthorn-potato aphid has been reported to be resistant to carbamates but samples from the UK have not been tested for insecticide resistance recently. There is no evidence of insecticide resistance in glasshouse potato aphid.

## *Non-colonising aphids*

Of the non-colonising aphid species, the only insecticide resistance issues that are currently known are with grain aphid and willow-carrot aphid. Grain aphid has been shown to carry kdr resistance, conferring moderate resistance to pyrethroids. A molecular test is available which can be used to screen grain aphids from the GB suction trap network for the kdr mutation.

In 2015, up to 76% of grain aphids from the York suction trap had the kdr mutation. At that time, the higher kdr frequencies tended to be recorded at traps in more intensive cereal growing areas (eg., Kirton 42% and Broom's Barn 46% of grain aphids, respectively).

In 2019, samples from 5 traps were tested and up to 30% of the aphids were carrying the mutation. In 2020, it was between 2 and 71%. Table 2 shows that samples were not from the same trap locations in both years.

In all years, the kdr mutation was found only in the heterozygous (SR) form in the grain aphids. Laboratory bioassays have shown that kdr-SR heterozygotes carry only moderate (30-40 fold) resistance to pyrethroids, and that these forms are still controlled effectively, providing the full field rate is applied (S Foster, Rothamsted Research, unpublished). There are concerns that kdr homozygotes (kdr-RR), should they evolve, may be associated with stronger resistance, making them more difficult to control. In peach-potato aphid, the homozygous form confers ~90 fold resistance to pyrethroids.

**Table 2.** Grain aphid kdr testing results (NT = not tested).

| Suction trap location | 2019 | | | 2020 | | |
|---|---|---|---|---|---|---|
| | Number tested | Number with kdr | % kdr | Number tested | Number with kdr | % kdr |
| **Starcross** | 100 | 7 | 7 | 120 | 2 | 2 |
| **Brooms Barn** | 92 | 2 | 2 | 64 | 4 | 6 |
| **Writtle** | 62 | 3 | 5 | NT | | |
| **Kirton** | 65 | 14 | 21 | NT | | |
| **Newcastle** | 56 | 17 | 30 | NT | | |
| **Hereford** | NT | | | 65 | 10 | 15 |
| **York** | NT | | | 65 | 46 | 71 |
| **Edinburgh** | NT | | | 26 | 5 | 19 |

Grain aphids are also caught in the yellow water traps placed in seed potato fields, but these are not tested for the kdr mutation. The numbers caught in the traps have remained consistently low from 2012 to 2020 (fewer than five aphids per trap across the whole growing season).

Between 2018 and 2020, a small number of samples of willow-carrot aphid were tested for their sensitivity to lambda-cyhalothrin in lab bioassays. At the field rate, between ~ 30 and 70% of the adults were affected by the insecticide. As no fully sensitive clone was available, it was not possible to calculate resistance factor (RF) values for the samples. In 2021, a willow-carrot aphid sample collected from fennel in Suffolk was shown to have a significantly lower $LC_{50}$ value than all the previously tested samples. Using the $LC_{50}$ values for this sample as the baseline, the RF values for the previously collected aphids range from 27 to 259 (Table 3).

**Table 3.** $LC_{50}$ responses to lambda-cyhalothrin (ng/cm$^2$ after 5h in coated glass vial bioassays) of GB *Cavariella aegopodii* field samples.

| Sample code | *N*[a] | *$LC_{50}$*[b] | *95% CL*[c] | *Slope* | *RF* |
|---|---|---|---|---|---|
| **Ca2_2021 (S-Baseline)** | 104 | 2.42 | 1.82-3.30a | 1.8 | 1 |
| **Ca2_2019** | 99 | 61.2 | 31.1-95.7b | 1.9 | 27 |
| **Ca2_2018** | 140 | 92.3 | 53.5-172.0bc | 1.2 | 38 |
| **Ca3_2018** | 140 | 124.5 | 60.6-353.7c | 0.8 | 51 |
| **Ca1_2019** | 243 | 124.9 | 99.9-163.0c | 2.4 | 52 |
| **Ca1_2014** | 147 | 232.7 | 112.8-972.7c | 0.9 | 96 |
| **Ca4_2018** | 77 | 245.2 | 109.9-1194c | 1.2 | 101 |
| **Ca1_2018** | 129 | 422.3 | 162.3-3007c | 0.8 | 175 |
| **Ca1_2021** | 228 | 627.6 | 97.84-2601c | 0.5 | 259 |

[a] Total number of aphids tested (including controls).
[b] Concentration resulting in 50% dead or irreversibly poisoned (in ng/cm$^2$).
[c] Confidence limits at 95%; values followed by the same letter do not differ significantly.

The willow-carrot aphid is now assumed to be a major contributor to PVY transmission pressure in most areas of GB. It has increased in numbers caught in yellow water traps in seed potato crops during the growing season by approximately six-fold since 2013.

## Current insecticide options for aphid control

There are several modes of action (MoA) approved for use on commercially grown potatoes in the UK. The active ingredients available for aphid control in potatoes, spray restrictions and notes on resistance that would impact the control level achieved are detailed in Table 4. Further information on the MoA classification scheme can be found at irac-online.org/modes-of-action

Almost all seed potato crops are treated for aphids. On ware crops, more than one application is unlikely to be necessary in most seasons (provided it is fully effective), including seasons where aphid numbers build up rapidly during summer (usually late June) and natural enemy numbers are low. In early to mid-July, aphid populations nearly always decline naturally. Later aphid immigrations can occur in some years/localities, so regular monitoring through the season is essential.

Treatment efficacy should be monitored at a suitable time after application (this will be dependent on the active ingredients used but generally should be done after three days; flonicamid will take longer to kill aphids).

To maximise efficacy and to protect insecticides from resistance, it is essential to follow best practice measures. The measures, many of which are common across crop production, are detailed in the IRAG's 'Insecticide resistance and its management' publication.

**Table 4**. Aphicides available for professional use on potatoes in the UK, along with the mode of action (MoA), restrictions on use and notes on current UK resistance. For several of the active ingredients, more than one product is available.

| Mode of action (chemical group) | Active ingredient(s) | Maximum permitted number of applications† | Peach–potato aphid resistance status in UK |
|---|---|---|---|
| **3a (pyrethroids)** | Cypermethrin | 2 | Strong resistance widespread |
| **3a (pyrethroids)** | Esfenvalerate | 4 | Strong resistance widespread |
| **3a (pyrethroids)** | Lambda-cyhalothrin | † | Strong resistance widespread |
| **4a (neonicotinoids) ††** | Acetamiprid | 1 (ware), 2 (seed) | No resistance |
| **23 (tetronic and tetramic acid derivatives)** | Spirotetramat | 4 | No resistance |
| **29 (chordotonal organ Modulators)** | Flonicamid | 2 | No resistance |

† Refer to the product label for this information

# Further information

AHDB encyclopaedia of pests and natural enemies: ahdb.org.uk/knowledge-library/encyclopaedia-of-pests-and-natural-enemies

AHDB information on aphid/virus management in potatoes: ahdb.org.uk/knowledge-library/aphid-and-virus-potatoes

Fera PVY vector information: aphmon.fera.defra.gov.uk/pvy_vector_info.cfm

Population genetic analysis of pyrethroid resistant grain aphid (*Sitobion avenae*) using high resolution microsatellite markers project: ahdb.org.uk/114r480-grain-aphid-characterisation

Pyrethroid sensitivity in UK cereal aphids 2019–20 project: ahdb.org.uk/pyrethroid-sensitivity-in-uk-cereal-aphids-2019-20

Annual reports from the industry-funded insecticide resistance testing project are available from: ahdb.org.uk/monitoring-and-managing-insecticide-resistance-in-uk-pests

Many principles of insecticide resistance management are common across crops and pest targets. These are detailed in IRAG's 'Insecticide resistance and its management' publication. All IRAG publications can be accessed via: ahdb.org.uk/knowledge-library/irag

## *References*

Fox, A., Collins, L. E., Macarthur, R., Blackburn, L.F. & Northing, P. (2017). New aphid vectors and efficiency of transmission of Potato virus A and strains of Potato virus Y in the UK. Plant Pathology, 66: 325-335

  