Guidelines for Preventing and Managing Insecticide Resistance in Aphids on Potatoes
(Updated February 2014)

These guidelines apply primarily to the peach-potato aphid (*Myzus persicae*) in potato crops as this is the aphid species with the most significant insecticide resistance issues associated with it. This species is NOT a pest on crops such as cereals, peas and beans.

![Image of M. persicae adults and nymphs](image)

**Figure 1. M. persicae adults and nymphs**

**The problem**
Aphids are pests because they can transmit plant viruses and cause direct feeding damage. Like all living organisms, they have adapted over millions of years to their environment. However, by colonising crops, their pace of evolution has accelerated to contend with the chemical control tactics aimed against them. This process has resulted in the development of various forms of insecticide resistance in some UK aphid species.

**What causes insecticide resistance?**
Resistance mechanisms can be divided into two main categories:

**Metabolic**
Pests carrying this type of resistance make increased amounts of certain enzymes which break down or wrap up (sequester) insecticide molecules before they reach their target sites (these target sites are primarily in the insect nervous system). In *M. persicae* overproduction of enzymes called esterases confers resistance primarily to organophosphates, although carbamates and pyrethroids are also affected to a lesser extent. Individual aphids can contain different

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amounts of esterase and are categorised as being either: S (susceptible), R1 (moderately resistant), R2 (highly resistant) or R3 (extremely resistant).

**Target site**
In pests carrying this type of resistance, a mutation occurs in the various target proteins that insecticides specifically normally bind to and block or inactivate. The result is that they are no longer sensitive to insecticidal effect. Three target site mechanisms are known to exist in *M. persicae* in the UK:

- **MACE (Modified AcetylCholinEsterase):** confers strong resistance specifically to some dimethyl-carbamates. Pirimicarb is the only insecticide approved in the UK that is affected by MACE resistance. Pests are categorised as either MACE or non-MACE. *M. persicae* with this type of resistance are highly resistant to pirimicarb.

- **Knockdown Resistance** or kdr can arise through genetic mutations, usually denoted as ‘kdr’ and ‘super kdr’. They are associated specifically with resistance to pyrethroids. Aphids are categorised as either kdr or non-kdr (kds).

- **Neonicotinoid Resistance** (Nic-R++): confers strong resistance specifically to neonicotinoids. Aphids carrying this form of target site resistance are now found in southern European countries but have not been seen in the UK to date.

**Aphid Pests of Potato Crops and their Resistance Status**
*Myzus persicae* (peach-potato aphid) and *Macrosiphum euphorbiae* (potato aphid) are the main aphid pests of potatoes. Insecticide resistance is well-established in *M. persicae* (see below) but there is as yet no evidence of field resistance to insecticides in *M. euphorbiae*. However, elevated levels of carboxylesterases have been detected in laboratory assays of some individuals collected from the field in the UK. This indicates that *M. euphorbiae* does have the potential to become resistant to some insecticide groups. In order to prevent control failures associated with the development of resistance, growers should follow best practice and keep insecticide applications to the minimum necessary for preventing economic loss.

*Aulacorthum solani* (glasshouse potato aphid) and *Aphis nasturtii* (buckthorn-potato aphid) are sporadic pests of potatoes. *Aphis gossypii* (melon aphid or cotton aphid) is mainly a glasshouse pest that occurs very occasionally on potato crops in the UK. Although it is unusual to find significant numbers of these sporadic aphid pests on potato, both *A. nasturtii* and *A. gossypii* are known to be resistant to some insecticide groups. Further information on *A. gossypii* is provided at [http://www.hdc.org.uk/publication/0113-practical-measures-prevent-and-manage-insecticide-fungicide-and-herbicide](http://www.hdc.org.uk/publication/0113-practical-measures-prevent-and-manage-insecticide-fungicide-and-herbicide)

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Non-Colonising Aphid Species that act as Vectors of Potato Viruses (eg., Potato Virus Y)

There are some 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 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. *M. persicae* is considered to be the most efficient vector of PVY and the laboratory results are used to calculate Relative Efficiency Factor (REF) values, which reflect the transmission efficiency of a particular aphid species in relation to that of *M. persicae*. The table below summarises the REF values for some common aphid species.

Table 1. Currently used PVY Relative Efficiency Factor values for different aphid species. (From Potato Council Report R428 “Aphids and virus transmission in seed crops”)

<table>
<thead>
<tr>
<th>Aphid species</th>
<th>Common name</th>
<th>REF value (for PVY)</th>
</tr>
</thead>
<tbody>
<tr>
<td><em>Acyrthosiphon pisum</em></td>
<td>pea aphid</td>
<td>0.70</td>
</tr>
<tr>
<td><em>Aphis fabae</em></td>
<td>black bean aphid</td>
<td>0.01</td>
</tr>
<tr>
<td><em>Brevicoryne brassicae</em></td>
<td>cabbage aphid</td>
<td>0.01</td>
</tr>
<tr>
<td><em>Cavariella aegopodii</em></td>
<td>willow-carrot aphid</td>
<td>0.50</td>
</tr>
<tr>
<td><em>Drepanosiphum platanoides</em></td>
<td>common sycamore aphid</td>
<td>0.00</td>
</tr>
<tr>
<td><em>Hyperomyzus lactucae</em></td>
<td>blackcurrant-sowthistle aphid</td>
<td>0.16</td>
</tr>
<tr>
<td><em>Macrosiphum euphorbiae</em></td>
<td>potato aphid</td>
<td>0.20</td>
</tr>
<tr>
<td><em>Metopolophium dirhodum</em></td>
<td>rose-grain aphid</td>
<td>0.30</td>
</tr>
<tr>
<td><em>Microlophium carnosum</em></td>
<td>common nettle aphid</td>
<td>0.00</td>
</tr>
<tr>
<td><em>Myzus persicae</em></td>
<td>peach-potato aphid</td>
<td>1.00</td>
</tr>
<tr>
<td><em>Rhopalosiphum padi</em></td>
<td>bird cherry-oat aphid</td>
<td>0.40</td>
</tr>
<tr>
<td><em>Sitobion avenae</em></td>
<td>grain aphid</td>
<td>0.60</td>
</tr>
</tbody>
</table>

Of the non-colonising aphid species, the only insecticide resistance problem that is currently known is with the grain aphid (*S. avenae*) which has been shown to carry target site resistance (kdr) to pyrethroids conferring ~40 fold resistance in laboratory-based bioassays applying lambda-cyhalothrin. The highest frequencies of *S. avenae* carrying kdr have been found in cereal crops where growers have reported control problems with pyrethroid sprays. However, further research needs to be done to measure the level of resistance conferred by kdr to aphids exposed to foliar applications in the field.

Status of Resistance in *M. persicae*

The various mechanisms of resistance in *M. persicae* have been monitored for many years using a range of diagnostic methods. Aphids with high esterase, MACE and kdr were widely distributed on potato crops in eastern England in 1996. However, with the exception of kdr, resistance levels then appeared to decline to low levels by 2000, possibly because *M. persicae* carrying...
carboxylesterase and MACE resistance appear to suffer greater mortality during times of stress, e.g. during the winter. However, MACE aphids resurged in central and eastern Scotland in 2001, and in recent years have become almost ubiquitous in the UK (see Figure 2). The reasons for this change appear to relate to new forms of \textit{M. persicae} carrying MACE arriving in this country and proliferating because they are well adapted to the current UK environment. These MACE aphids also carry a ‘new’ form of super-kdr which confers resistance to pyrethroids.

There is still no evidence of strong resistance to neonicotinoids in \textit{M. persicae} in the UK and so this chemistry that includes thiamethoxam, thiacloprid and acetamiprid has an important role to play in potatoes. However, \textit{M. persicae} carrying strong neonicotinoid resistance (conferred by a combination of a metabolic mechanism and a target site mechanism (target site resistance is more widespread) are now common in some peach growing regions of southern mainland Europe and are spreading to adjacent broad leafed crops. This situation is being carefully monitored in the UK, and guidelines will be updated if the situation changes in this country. An ongoing screening programme has also shown that there is currently no evidence of resistance to pymetrozine or flonicamid in \textit{M. persicae} in the UK.

\textbf{Figure 2:} \textit{Myzus persicae} field samples that have contained MACE aphids (Data courtesy of the project “Combating resistance to aphicides in UK aphid pests”)

\begin{figure}[h]
\centering
\includegraphics[width=\textwidth]{figure2.png}
\end{figure}
Almost all seed potato crops, and many ware crops, are treated for aphids and often several times with pyrethroid, carbamate, neonicotinoid and other insecticides, either alternately or (depending on the products) in mixtures. The latter situation in particular imposes strong selection for insecticide resistance and therefore mixtures should only be used when fully justified and as part of an appropriate management strategy. It is essential to monitor for resistant forms during the early part of aphid infestation to assess over-wintering success and to design a spray programme based on these findings to minimise the risk of resistance in any season. See below for contact details if you suspect resistance**.

**Contact for resistance testing: stephen.foster@rothamsted.ac.uk.

**Implications of resistance in *M. persicae* for aphicides approved on potatoes**

The implications for insecticide product choice are specific to various forms of resistance in *M. persicae*. Table 2 (below) lists the active ingredients available for aphid control in potatoes and indicates the form of resistance which would impact on the level of control achieved. Combinations of the three primary resistance mechanisms are sometimes found in individual *M. persicae* although in recent years the UK population on field crops has consisted mainly of aphids carrying both MACE resistance (to pirimicarb) and super-kdr resistance (to pyrethroids). Fortunately, alternative chemistry which circumvents both of these resistance mechanisms is available.

Consideration of resistance risk is a key part of the pesticides approvals process, with companies and the Chemical Regulations Directorate (Health and Safety Executive) working closely to ensure appropriate management strategies are in place. Growers should always follow label advice on resistance management, including any restrictions on use and alternation with other chemical or non-chemical control methods.
Table 2. Aphicides available for professional use on potatoes. Examples of products containing each active ingredient are provided. For several of the active ingredients more than one product is available. *(Nic-R++ M. persicae have not yet been found in the UK).*

<table>
<thead>
<tr>
<th>Chemical group</th>
<th>Active ingredient(s)</th>
<th>Example product*</th>
<th>Maximum permitted number of applications</th>
<th>Mainly resisted by:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyl carbamate</td>
<td>Pirimicarb</td>
<td>Aphox</td>
<td>No limit</td>
<td>MACE Carboxylesterase R₃</td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>Acetamprid</td>
<td>InSyst</td>
<td>Ware 1; seed 2. No more than 2 neonicotinoids per crop</td>
<td>Nic-R**</td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>Thiacloprid</td>
<td>Biscaya</td>
<td>Ware 1; seed 2. No more than 2 neonicotinoids per crop</td>
<td>Nic-R**</td>
</tr>
<tr>
<td>Neonicotinoid</td>
<td>Thiamethoxam</td>
<td>Actara</td>
<td>Ware 1; seed 2. No more than 2 neonicotinoids per crop</td>
<td>Nic-R**</td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>Esfenvalerate</td>
<td>Sven</td>
<td>4</td>
<td>kdr/super kdr</td>
</tr>
<tr>
<td>Pyrethroid</td>
<td>Lambda-cyhalothrin</td>
<td>Hallmark with Zeon Technology</td>
<td>No limit</td>
<td>kdr/super kdr</td>
</tr>
<tr>
<td>Pyridine azomethine</td>
<td>Pymetrozine</td>
<td>Plenum</td>
<td>Ware 2; seed 3</td>
<td>No resistance</td>
</tr>
<tr>
<td>Pyridine carboxamide</td>
<td>Flonicamid</td>
<td>Teppeki</td>
<td>2</td>
<td>No resistance</td>
</tr>
</tbody>
</table>

*The table contains example products - the list is not exhaustive and other products may be available. The table lists the main mechanisms of resistance, however, not all resistance mechanisms are necessarily known.

**Practical recommendations for potato growers**

- Monitor chitting sheds for the onset of aphids.
- Follow best practice to minimise the effects of outgrade piles (see the Potato Council Guide “Managing the risk of late blight” which has a section on outgrade piles).
- On the growing crop, in principle alternation of products is less likely to lead to resistance build-up than applying mixtures. However, mixtures may be
justified to control the spread of virus or if more than one pest is present on
the same crop at treatment threshold levels. If tank mixes are used for this
purpose, the components should be from different chemical classes and be
applied at the full recommended rates.

• On ware crops, in most seasons only one application (if at all) is likely to be
necessary (provided it is fully effective). That is, in situations where aphid
numbers are building up rapidly in mid-summer (usually late June) but natural
enemy numbers are low. Note that aphid populations always decline naturally,
usually in early to mid-July. Later immigrations can occur in some
years/localities, so regular monitoring through the season is essential.

• Neonicotinoid products* and aphid feeding blockers such as pymetrozine or
flonicamid are likely to prove most effective against *M. persicae* whatever
their resistance status. Pirimicarb will also be effective where MACE aphids
are not present but in recent years *M. persicae* with MACE resistance have
become very common in the UK. Do not reduce rates to increase the number
of applications.

• *M. persicae* is able to colonise a range of crops including oilseed rape, sugar
beet, brassicas, lettuce and ornamentals and populations can move from
other crops on to potatoes. Where possible consider product choice in light of
your knowledge of the use of insecticides in other crops. Over-use of active
ingredients may lead to the more rapid development of resistance and as a
result specific restrictions on the number of applications across a range of
crops are in place.

• Monitor treatment efficacy at a suitable time after application (this will be
dependent on the active compounds used but generally should be done after
three days; pymetrozine and flonicamid will take longer to kill aphids). Be
aware that poor control can sometimes be due to poor spray coverage and
not resistance.

• Do not make repeat applications of any insecticide if it appears not to work at
the full recommended rate and it has been applied correctly; use an
alternative.

• Do not apply insecticides below label rates as this can lead to a subsequent
increase in resistance problems.

• Follow any label guidance (or other technical literature) on resistance
management strategies. If in doubt consult a BASIS-registered advisor.

*Use of neonicotinoid products on potatoes.
On 24 May 2013, restrictions on the use of seed treatments of the clothianidin,
imidacloprid and thiamethoxam neonicotinoid insecticides were adopted by the
European Commission. The restrictions will apply from 1 December 2013. At the
time of writing this guide, the restrictions do not limit the professional use of
neonicotinoid sprays on potato crops.

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Further information

Efficacy guidelines available from www.pesticides.gov.uk:

- 601 – Resistance warnings on labels of insecticide and acaricide products.
- 606 – Resistance risk analysis and use of resistance management strategies


Information on the classification of pesticides by the mode of action group, which it is essential to know when designing a control strategy, is regularly updated on the following website:

IRAG www.pesticides.gov.uk/guidance/industries/pesticides/advisory-groups/Resistance-Action-Groups/irag

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