Guidelines for controlling aphids in brassica crops and combating insecticide resistance in the peach-potato aphid, *Myzus persicae*
Three species of pest aphid infest the foliage of brassica crops

*Brevicoryne brassicae* (cabbage aphid) is probably the most damaging species. Although it can transmit plant viruses, the damage caused by colonies of *B. brassicae*, and their physical presence, create the greatest problems for growers. There is currently no evidence that any populations of *B. brassicae* are resistant to insecticides.

*Myzus persicae* (peach-potato aphid) is responsible for the transmission of plant viruses and in some cases, particularly on Savoy cabbage and Brussels sprout, its numbers may be so great that its presence reduces crop marketability. *Myzus persicae* populations frequently contain individuals that are resistant to certain insecticides – see below.

*Macrosiphum euphorbiae* (potato aphid) is currently a less important brassica pest. There is evidence that some populations may be less susceptible than others to certain insecticides, but this has no impact currently on the levels of control that can be achieved with approved insecticides.

All three species of aphid overwinter as adult and immature aphids on suitable host crops and winged forms migrate to new brassica crops in late spring. The timing of the migration is predictable to a certain extent, since studies have shown that it is related to location (latitude and longitude) and weather in the early part of the year (principally air temperature). The winged forms of all three species are captured and numbers recorded in the network of suction traps run by the Rothamsted Insect Survey.

Both *M. persicae* and *M. euphorbiae* are generalist species since they will infest and feed on a wide range of host plants. The hosts of *M. persicae* include potato, sugar beet, lettuce, brassicas, weeds and various protected crops. In contrast, *B. brassicae* is a specialist and feeds only on plants that are members of the cabbage family (Brassicaceae or Cruciferae). When planning a treatment regime and resistance management strategy it is therefore important to consider the possible routes of exposure on the range of host crops.

Obviously, these three aphid species are only part of the complex of pests that can infest brassica crops. Others include caterpillars, beetles and the cabbage root fly. Some of the methods used to control these other pests may also affect aphid
pests, and vice versa (see ‘Controlling other pests’, page 4).

Insecticide resistance in *Myzus persicae*

All living species show genetic diversity that arises from naturally occurring mutations. When insecticides are used, natural selection will favour individuals that are less susceptible to the insecticides. These insects may survive the treatment and reproduce to give a progressive build-up of the particular genetic trait (insecticide resistance) in the population.

This becomes apparent as control failures when these resistant insects start to dominate the population. *Myzus persicae* has developed various ways of surviving exposure to insecticides and because, in the UK, female *M. persicae* generally reproduce without mating, large populations can build up quickly. The next generation of aphids carries the same genes as their mother, including any insecticide resistance traits. This form of reproduction continues through the winter in glasshouses and clamps and on outdoor weeds and crops such as oil seed rape, so carrying resistance forward to the following season (although there is evidence that some insecticide-resistant aphids do not survive cold UK winters very well).

At present, three different resistance mechanisms are known in *Myzus persicae*

**Esterase** – resistant aphids with this mechanism make increased amounts of enzymes called esterases, which break down insecticides before they reach their target sites. This effect varies depending on the chemical structure of the insecticide. Resistance is greatest to organophosphorus (OP) insecticides although carbamates and pyrethroids are also affected to a lesser extent. Aphids can contain different amounts of esterase so some are more resistant than others. They can be classed as susceptible (S), moderately resistant (R1), highly resistant (R2) or extremely resistant (R3). The level of esterase can be measured using biochemical or DNA-based tests.

**MACE** – OP and carbamate insecticides attack? (affect/interfere with?) acetylcholinesterase, the enzyme that regulates the flow of a chemical messenger across the gap (synapse) between nerve cells. This disruption kills the insect. In MACE aphids, this enzyme has become specifically insensitive to the blocking effect of the dimethyl carbamate pirimicarb, rendering the aphids immune to this insecticide. Aphids either have or do not have the MACE mechanism. It can also be detected by biochemical or DNA-based tests.

**Knockdown resistance or kdr** – pyrethroids act on another protein in the aphids’ nervous system called a sodium channel, which is responsible for the passage of signals along the nerve. The insecticides hold these channels ‘open’ so that the nervous system becomes overexcited, leading to the death of the insects. Aphids with kdr contain a modified sodium channel protein, insensitive specifically to pyrethroids. The mechanism can be detected by a simple insecticide bioassay, although a DNA-based test is now available. Aphids either do or do not have kdr.

**Occurrence of the different resistance mechanisms**

Esterase resistance (R2 and R3) was first recorded in the UK in the early 1970s. In recent years it has become rare and is not considered to be very important due to the decline in OP use. MACE and kdr resistance continue to be common, with important consequences for the use of pirimicarb and pyrethroids respectively. Although individual *M. persicae* differ considerably in colour (green, pink, red) there is no consistent association between aphid colour and a particular resistance mechanism. Table 1 indicates how each resistance mechanism alone is likely to affect control of *M. persicae*.

The incidence of MACE and kdr resistances is now monitored regularly in aphids from crops and from a number of suction traps operated by the Rothamsted Insect Survey. This provides information which can be used to refine treatment recommendations during the season.

**Resistance to other insecticides**

So far there has been no indication in the UK of resistance to neonicotinoid insecticides in *M. persicae*, of which imidacloprid was the first to be marketed. Newer neonicotinoids include acetamiprid, clothianidin, thiacloprid and
thiamethoxam. However, *M. persicae* from the UK and mainland Europe have shown different sensitivities to these compounds, so future recommendations may have to take account of any changes in this situation. Reports of *M. persicae* strongly resistant to neonicotinoids have so far been restricted to peach trees in continental Europe and no control failures for this pest have been reported on other, alternate hosts. However, neonicotinoid resistant *M. persicae* have been shown to develop well when moved to a range of alternate hosts including potato, oilseed rape and lettuce, indicating that aphids with this form of resistance need not be restricted to peach. There is currently no evidence of resistance to pymetrozine, flonicamid (not approved currently on brassicas) or spirotetramat.

Assessing the risk of resistance developing is a key part of the approvals process, with companies and the Chemicals Regulation Directorate (CRD) working closely to ensure appropriate management strategies are in place. In response to the increasing use of neonicotinoids, in particular on host crops of *M. persicae*, specific statutory restrictions on the number of applications across a range of host crops, including brassicas, are in place for this chemical group. These restrictions have also taken account of the potential for indirect exposure when neonicotinoids are being used to control other pests. Full details are available from a CRD guideline (601) (see ‘useful links’). Growers should always follow label advice on resistance management, including any restrictions on use and alternation with other chemical or non-chemical control methods.

**Controlling other pests**

*Myzus persicae* cannot be managed in isolation, as insecticides used to control other aphid species or other pests such as caterpillars may have an impact on *M. persicae*. In addition, *M. persicae* does not infest crops in a predictable manner every year. In particular, *B. brassicae* is often the focus of control strategies and the best insecticide for this may not be the best to avoid resistance in *M. persicae*.

**Controlling brassica aphids whilst minimising the impact of resistance**

The size and timing of aphid infestations vary from year to year and it is very difficult to predict how large an infestation will be in any particular crop, particularly throughout a full growing season. However, the Rothamsted Insect Survey produces long-range forecasts of the timing of the first flight of *M. persicae*, *B. brassicae* and *M. euphorbiae* into newly-planted crops in the spring and also provides an indication of the likely severity of infestations early in the season. These forecasts are available from the Rothamsted Insect Survey (see ‘useful links’).

The first, and most effective, approach to resistance management is to minimise insecticide use by following appropriate threshold guidance and using IPM programmes, with other both chemical and non-chemical means of control. If treatments are necessary then the main principle is to alternate chemical groups (shown in Table 1).

It is also worth taking account of natural fluctuations in aphid numbers when making treatment decisions. Aphid populations usually ‘crash’ in July-August and so it may be possible to delay spraying and let the ‘crash’ do some of the work.

It is important to be vigilant as aphid numbers increase again after the crash – usually in September. Aphids become much harder to control in the autumn, particularly on large plants such as Brussels sprout.

Monitor the numbers of natural enemies, such as hoverfly larvae, in crops. Although it is risky to rely on natural enemies completely, the application of a selective insecticide should allow them to continue feeding on aphids.

It is also important to monitor the effectiveness of each treatment. If control appears unsatisfactory, and other possible causes have been excluded, apply a product from a different group or consult an advisor.

Growing plants from seed that has been treated with imidacloprid can suppress aphid colonisation for many weeks after transplanting. HDC-funded
Trials have shown that the use of imidacloprid-treated seed is, on average, comparable to 3-4 foliar sprays of insecticide. More recently, Defra-funded research has confirmed that the effects of imidacloprid seed treatment can persist throughout the life of a crop, although foliar sprays may be required later in the season to maximise control. The first foliar spray following Gaucho seed treatment should not contain a neonicotinoid (e.g. thiacloprid or acetamiprid). It is important to alternate chemical groups with different modes of action throughout the life of the crop.

**Pirimicarb** is a selective insecticide with contact, fumigant and transaminar activity and has little effect on most beneficial insects. It can be very effective against *B. brassicae* but will be ineffective against *M. persicae* due to the widespread prevalence of the MACE resistance mechanism.

**Pymetrozine** is another selective insecticide that is effective against *B. brassicae* and *M. persicae*. The addition of a seed oil or methylated seed oil is needed to maximise control of *B. brassicae*. There is no evidence of resistance to pymetrozine in *M. persicae*.

**Chlorpyrifos** is an OP insecticide and is relatively broad-spectrum. However, *M. persicae* with Esterase-R3 levels of resistance will not be controlled by this insecticide. There is an ‘off-label’ approval for **dimethoate** which is another OP insecticide.

**Thiacloprid** and **acetamiprid** kill insects in the same way as imidacloprid, and are likely to exert selection pressure for the same resistance mechanism. It is vital that growers minimise the selection pressure for neonicotinoid insecticides and it is advisable to alternate them with other insecticide groups. For example, it would not be good practice to apply thiacloprid as the first spray treatment on brassica crops grown from seed treated with imidacloprid or to use two applications sequentially on crops where two neonicotinoids are permitted. Full details on neonicotinoid resistance restrictions and labelling are provided in CRD guideline 601 (see ‘useful links’).

**Spirotetramat** is a systemic and ambimobile insecticide effective against a broad range of sucking pests, including aphids.

**Pyrethroids**, such as lambda-cyhalothrin and deltamethrin, are approved for aphid control on some brassica crops. However, *Myzus persicae* with the commonly occurring *kdr* resistance mechanism will not be controlled by pyrethroids. Pyrethroids are broad spectrum insecticides and there is evidence that they can make aphid infestations ‘worse’ by killing beneficial insects and also failing to control the aphids effectively. They are an effective option for controlling other foliar pests such as caterpillars, but growers should consider the whole pest complex carefully before making their choice of insecticide. Pyrethroid resistance in pollen beetle (*Meligethes* spp.) is widespread in Europe and developing in the UK.

Oilseed rape is the main crop at risk from pollen beetle, but the adults emerging in summer migrate to brassicas, notably cauliflower and calabrese, and also ornamentals. Further detailed advice will become available, but it is important to rotate the use of different active substances of different mode of action class in a planned strategy for control. Do not use sequential applications of any one mode of action. The latest advice on resistance management is available from the HGCA website and IRAG (see ‘useful links’).

Pyrethroid resistance in brassica whitefly (*Aleyrodes proletella*) and onion thrips (*Thrips tabaci*) is also widespread in the UK.
Most of the insecticides approved for aphid control on brassica crops work through contact action, although some have translaminar or a certain amount of systemic activity. Such insecticides require direct contact with the target. In crops of dense canopy or where aphids are on the underside of leaves, control will be impaired or even ineffective. The exceptions are imidacloprid, which has systemic action and pirimicarb which has fumigant action in appropriate conditions.

Insecticide mixtures (whether pre-formulated) or tank mixed are not a ‘cure-all’ for resistance, and run the risk of selecting for more than one type of mechanism with a single application. They should be used with care and only when there is a clear need to apply two insecticides simultaneously. One example would be when a single insecticide is incapable of controlling two or more pests occurring on a crop at the same time. If tank mixtures are used, they should contain compounds from different insecticide groups and the full recommended rate of each compound. (Further information is available from CRD guideline 607 (see ‘useful links’)).

Pay careful attention to insecticide labels. Modern labels often contain general information on resistance management, as well as any statutory restrictions on how many times a product can be used per crop during a growing season. These restrictions are based on consideration of resistance risks and are intended to sustain the effectiveness of insecticides and prevent resistance occurring.

If in doubt, seek advice from the insecticide manufacturer or retailer, or from your consultant or crop advisor. This also applies if you observe unexpected survival of aphids to insecticides other than the known problems referred to above. In most cases, poor control is explicable through causes other than resistance. However, it could also herald a new and emerging resistance problem that needs to be investigated at the earliest stage possible.
Useful links

Rothamsted Insect Survey
http://www.rothamsted.ac.uk/insect-survey/

Syngenta/HDC Pest Bulletin
http://www.syngenta-crop.co.uk/pestupdate/

Horticultural Development Company
http://www.hdc.org.uk/

UK Insecticide Resistance Action Group

Insecticide Resistance Action Committee
http://www.irac-online.org/

IRAG publication ‘Guidelines on insecticide resistance in Myzus persicae’

Efficacy guidelines 601 ‘Resistance warnings on labels of insecticide and acaricide products’, and guideline 606 ‘Resistance risk analysis and use of resistance management strategies’, available from
http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/G/g601.pdf
http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/G/g606.pdf

Efficacy guideline 607 ‘Insecticide mixtures: justification for use and implications for resistance management in the United Kingdom’, available from
http://www.pesticides.gov.uk/Resources/CRD/Migrated-Resources/Documents/G/g607.pdf

HGCA Guidance on pollen beetle resistance to pyrethroids in Oilseed rape, incorporating latest IRAG resistance management advice
IRAG Guidelines for controlling aphids in brassica crops and combating insecticide resistance in the peach-potato aphid, *Myzus persicae* [JULY 2012]

Table 1. How each resistance mechanism alone is likely to affect control of *Myzus persicae* on brassica crops

(XXX = good control, XX = fair control, X = poor control, none = no control likely).

<table>
<thead>
<tr>
<th>Insecticide group</th>
<th>Examples*</th>
<th>S</th>
<th>R1</th>
<th>R2</th>
<th>R3</th>
<th>MACE</th>
<th>kdr</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dimethyl carbamates</td>
<td>Pirimicarb</td>
<td>XXX</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
<td>None</td>
<td>XXX</td>
</tr>
<tr>
<td>Acetamiprid</td>
<td>Imidacloprid</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
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<tr>
<td>Nicotinoids</td>
<td>Thiacloprid</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
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</tr>
<tr>
<td>Organophosphates</td>
<td>Chlorpyrifos</td>
<td>XXX</td>
<td>XX</td>
<td>X</td>
<td>None</td>
<td>XXX</td>
<td>XXX</td>
</tr>
<tr>
<td>Pyrethroids</td>
<td>Deltamethrin</td>
<td>XXX</td>
<td>XXX</td>
<td>XX</td>
<td>XX</td>
<td>None</td>
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<tr>
<td>Lambda-cyhalothrin</td>
<td></td>
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<tr>
<td>Pyridine azomethines</td>
<td>Pymetrozine</td>
<td>XXX</td>
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<tr>
<td>Cuticle disruptors</td>
<td>Fatty acids</td>
<td>XX</td>
<td>XX</td>
<td>XX</td>
<td>XX</td>
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<tr>
<td>Lipid biosynthesis inhibition</td>
<td>Spirotetramat</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td>XXX</td>
<td></td>
</tr>
<tr>
<td>Mixtures**</td>
<td>Pirimicarb + Lambda-cyhalothrin</td>
<td>XXX</td>
<td>XXX</td>
<td>XX</td>
<td>XX</td>
<td>XX</td>
<td>XX</td>
</tr>
</tbody>
</table>

* These examples include both product on-label recommendations and extensions of authorisations for minor uses
** Currently only available as a tank mixture of solo products

It is important to remember that these ‘scores’ are for each mechanism in isolation (and can be crop-dependent). However, mechanisms can occur in combination, and a good score in one of the above columns for a particular aphid population can be wiped out by the presence of one of the other mechanisms. Special care is needed when considering the effectiveness of pirimicarb + pyrethroid mixtures; although these should give good control of aphids with any single resistance mechanism, a combination of MACE and *kdr* in individual aphids will lead to control problems. Since mixtures select most strongly for multiple mechanisms, they are best avoided for controlling *M. persicae*. 