Insecticide Resistance Action Committee

Insecticide Resistance Training

Basic Module: Crop Protection

This module is designed to introduce the basic concepts behind the development and management of insecticide resistance in agricultural and horticultural crops. The presentation is targeted to those that may be being exposed to the concept of insecticide resistance for the first time or simply wishing to refresh their knowledge. More detailed information on the factors which influence resistance development and its management will be provided in future modules produced by IRAC International.

What is insecticide resistance ?

- Insecticides have been used by humans to control insects and other arthropods pests for over 400 years.

- Over time populations of insects can evolve to become less responsive to the insecticide that is used to control them.

- When insect population can no longer be controlled by a dose of insecticide which used to provide control of them this is termed as **insecticide resistance**. However, for it to be considered true resistance, the resistant insects must be able to pass on the ability to resist the insecticide to their offspring.

- Insects have the potential to develop resistance to all forms of insecticides, including; synthetic chemicals, biological extracts, proteins, peptides, pheromones, viruses and non-organic materials.

IRAC Technical definition:
"A heritable change in the sensitivity of a pest population that is reflected in the repeated failure of a product to achieve the expected level of control when used according to the label recommendation for that pest species".

Insecticide resistance is a natural occurrence and part of the natural process of evolution and adaption

IRAC

How does an insect become resistant ?

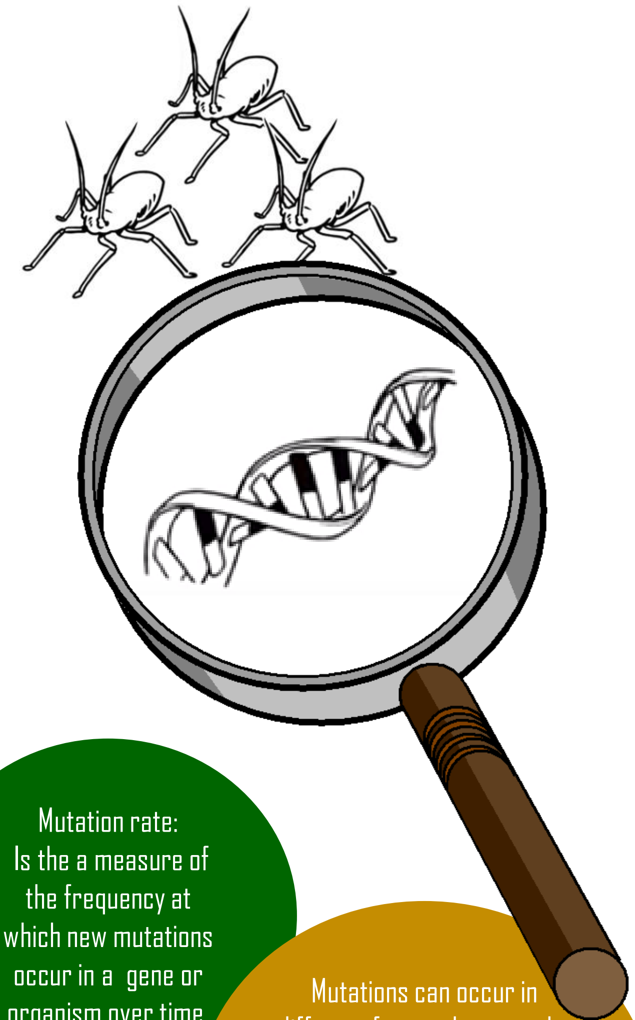
- Resistance occurs through **mutations** in the genetic make-up of the insect.

- DNA which is made up of a chain of paired nucleotides is often described as the genetic 'instruction book' for constructing living organisms.

- However, the replication of DNA is not a perfect process and errors can occur. These errors are called mutations.

- As the DNA provides the instructions for the development and function of the insect, a mutation can result in a change in insect physiology or biochemistry.

- Sometimes a mutation may have no impact on the insect, sometimes the mutation can be lethal. However, on occasion the mutation may result in the insect becoming less susceptible to an insecticide and this provides it with a competitive advantage when the same insecticide is applied again.

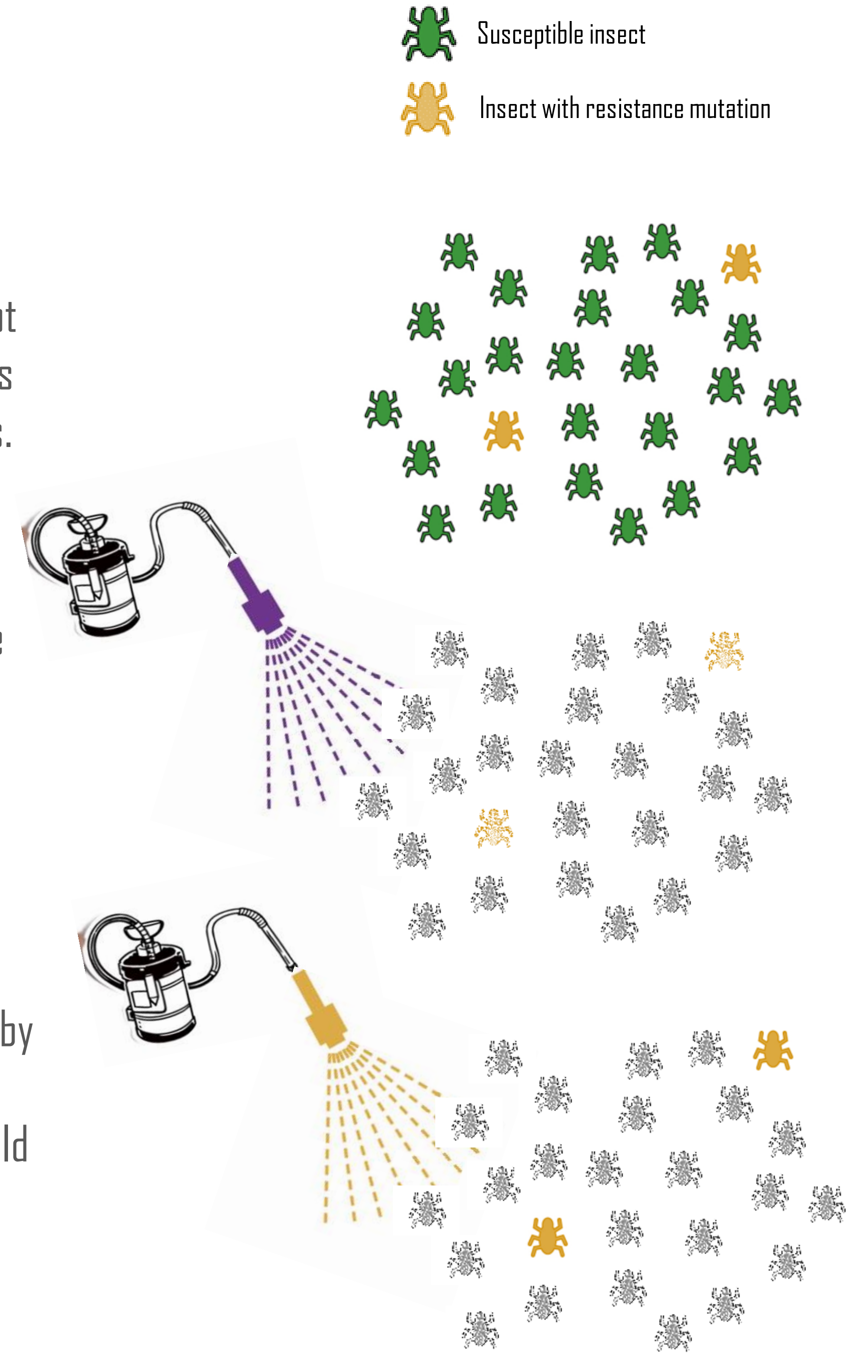


Mutation rate:
Is the a measure of the frequency at which new mutations occur in a gene or organism over time.

Mutations can occur in different forms, there can be a change in a single nucleotide, deletion of part of the DNA sequence or even a multiplication of some sections of the DNA sequence.

IRAC

How does insecticide resistance become a problem ?



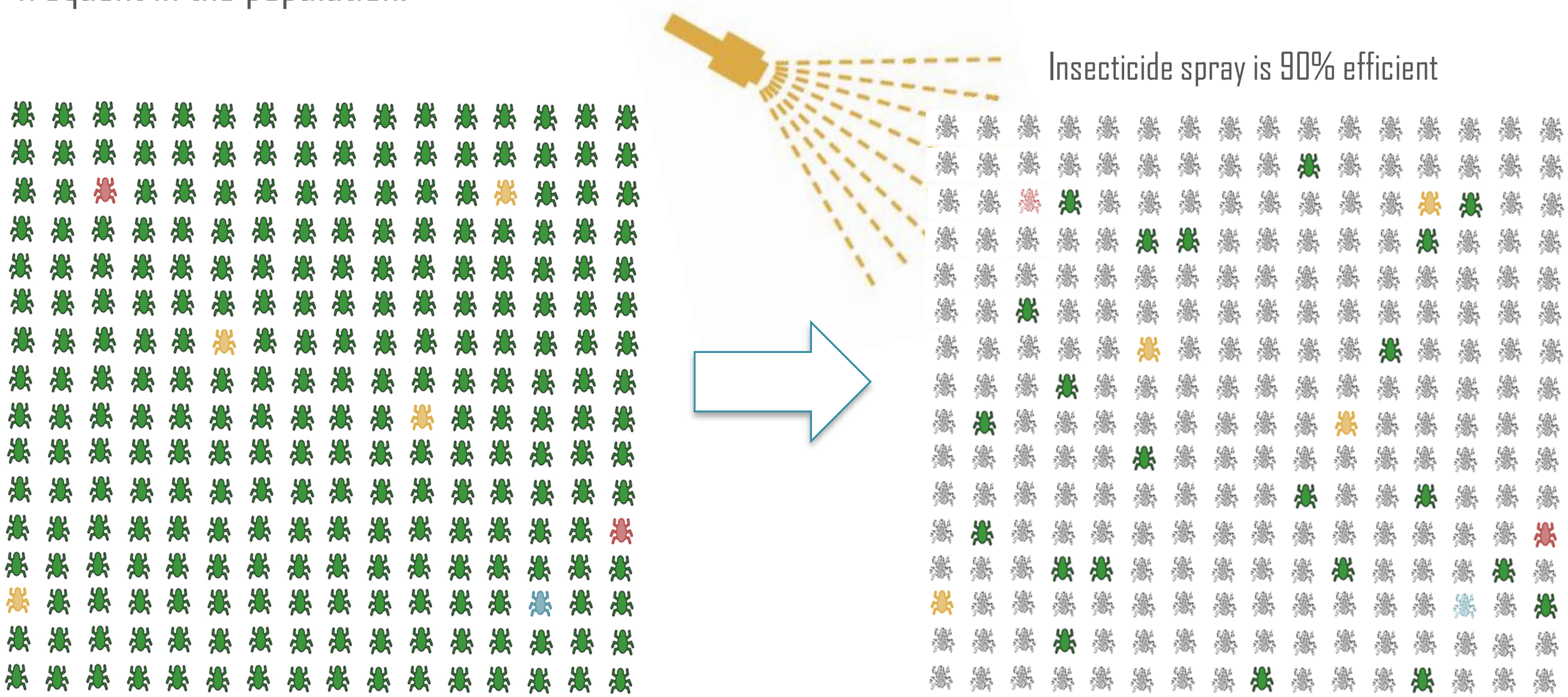
- In most circumstances a resistance mutation may not have any impact. The insect with a mutation continues to live and reproduce like other insects of its species.

- If an insecticide is applied that is **not affected** by the resistance mutation, both susceptible and resistant insects would be controlled.

- However if an insecticide is applied that is **affected** by the resistance mutation only the susceptible insects would be controlled and the resistant individuals would survive and then go on to reproduce.

How does insecticide resistance become a problem ?

- In any given agricultural field or glasshouse environment there could be hundreds to millions of pest insects present and there may be several mutations present that confer resistance to different insecticides.
- When an insecticide is sprayed, the insects which carry the resistance mutation survive and become more frequent in the population.



Frequency of insects with mutation

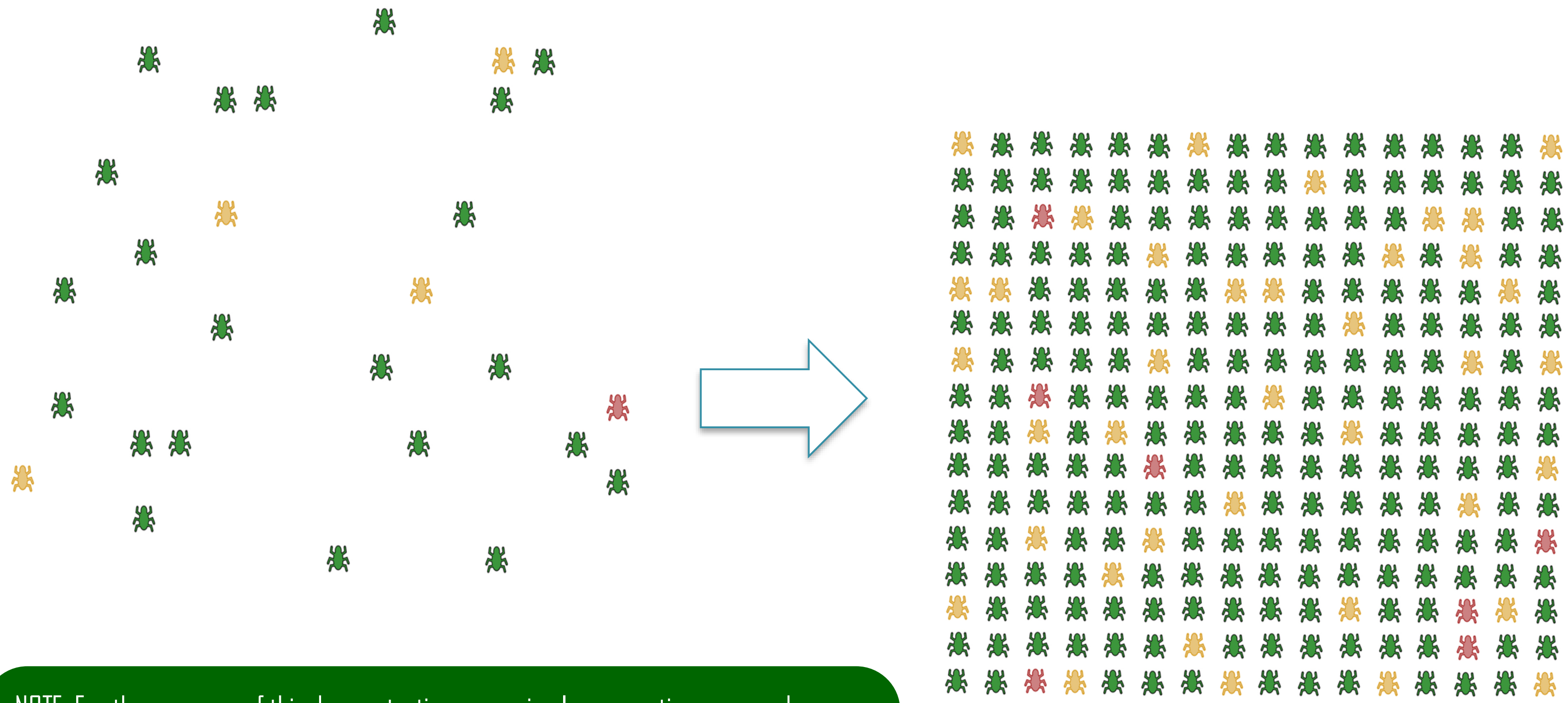
Susceptible =	250/256	=	97.7%
Mutation A =	4/256	=	1.6%
Mutation B =	2/256	=	0.8 %
Mutation C =	1/256	=	0.4 %

Frequency of insects with mutation

Susceptible =	22/26	=	84.6%
Mutation A =	4/26	=	15.4%
Mutation B =	1/26	=	3.8%
Mutation C =	0/26	=	0%

How does insecticide resistance become a problem ?

- The surviving resistant insects continue to live and breed and passing on their mutation to their offspring.
- Eventually the population may increase to a point where control will be once again necessary.



NOTE: For the purposes of this demonstration some simple assumptions are made:

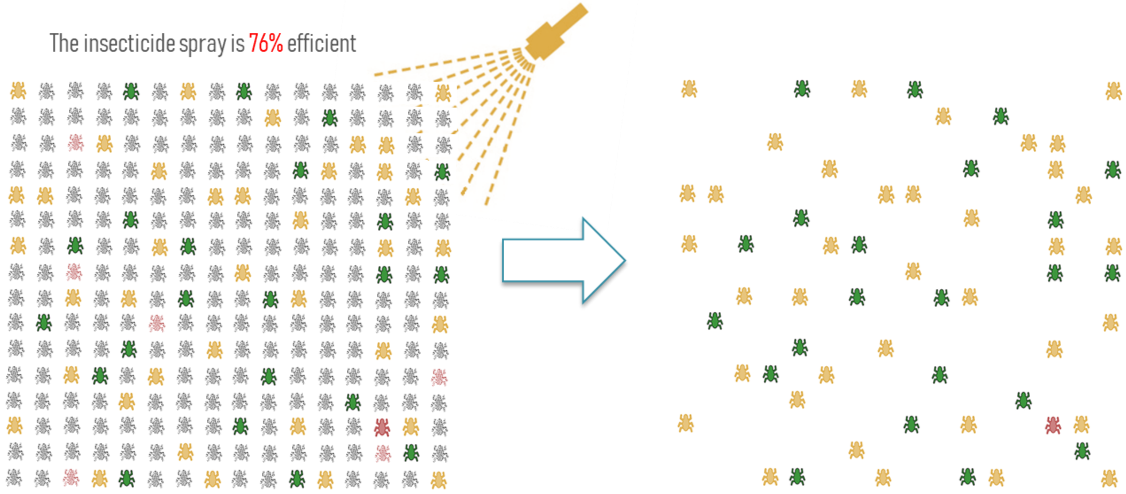
1. The insecticide has no effects on the resistant insects.
2. The resistance is always inherited by the insects offspring (dominant inheritance).
3. Resistant insects live and reproduce normally (no fitness costs).

This is not always the case and these topics will be covered in other IRAC modules.

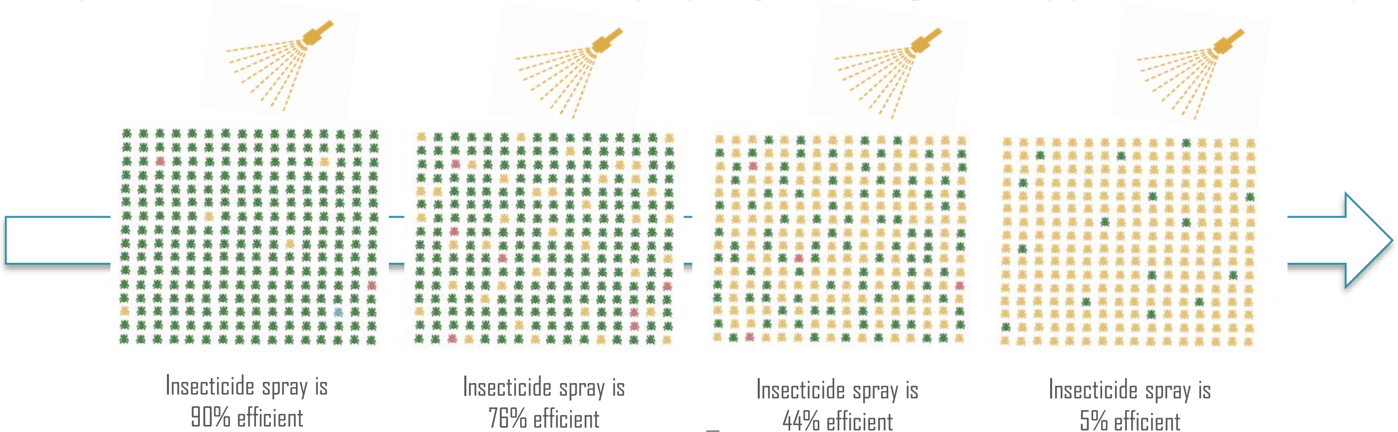
IRAC

How does insecticide resistance become a problem ?

- The decision on what to do next is critical for both the management of the pest insects and in managing resistance.
- If the same insecticide is used on the next generation of pest insects, then the effectiveness of the insecticide is likely to be reduced and even more resistant pests will survive.

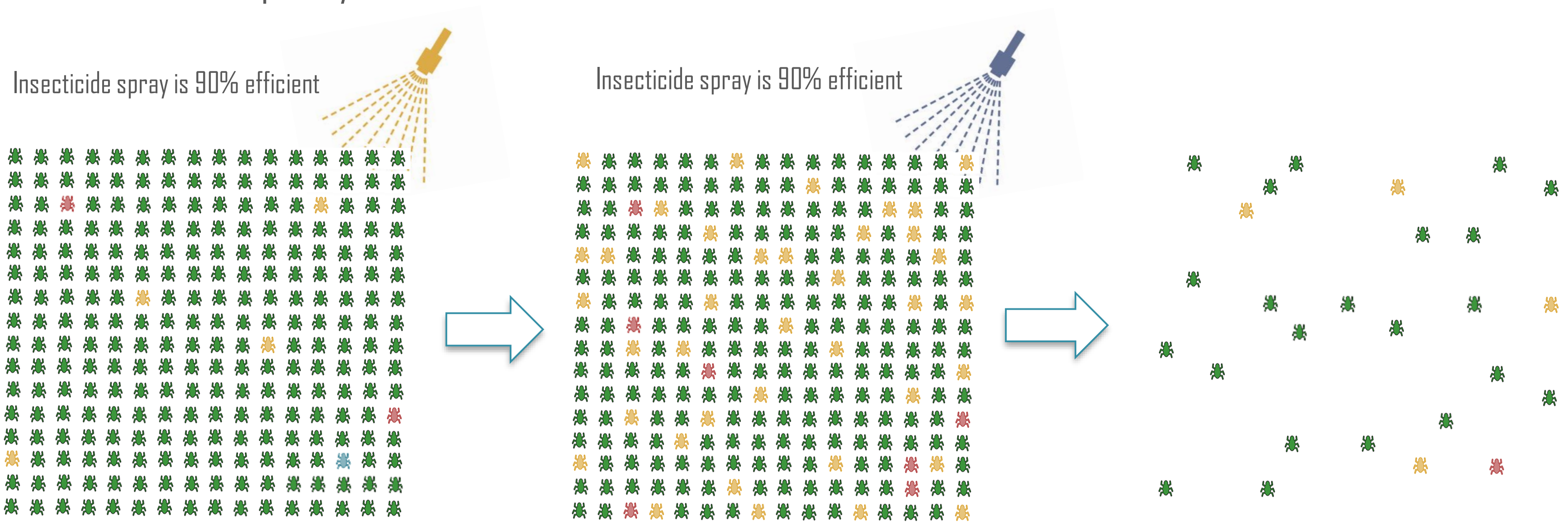


A control program with repeated use of the same insecticide mode of action can quickly change a once manageable insect population into one that is very difficult to control



How can we prevent insecticide resistance becoming a problem ?

- In order to prevent insect pests with a resistance mutation from becoming too dominant in a population, insecticides with different modes of action should be used in sequence or rotation across insect generations.
- This method of pest management slows the selection process and delays resistant insects from increasing in frequency.
- The more frequently the same insecticide is used the faster the resistance mutation is selected.

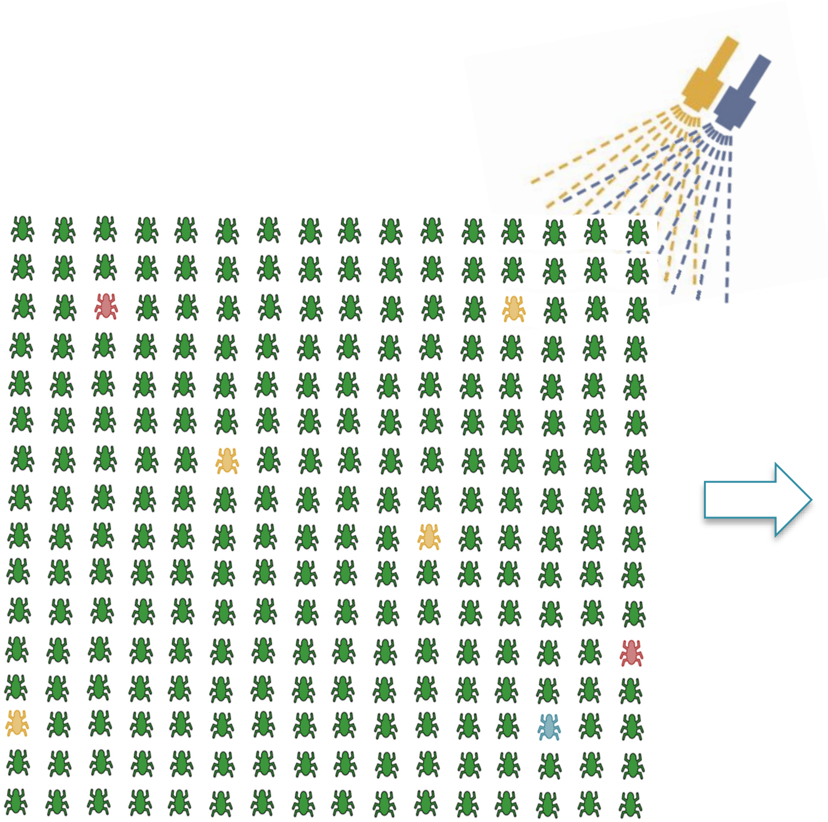


- Using insecticides with different modes of action, relies upon the insects being susceptible to at least one or more of the insecticides being used in the program.

How can we prevent insecticide resistance becoming a problem ?

- Rotations of insecticides are not the only way to manage resistance development.
- Insecticide mixtures can also be effective.

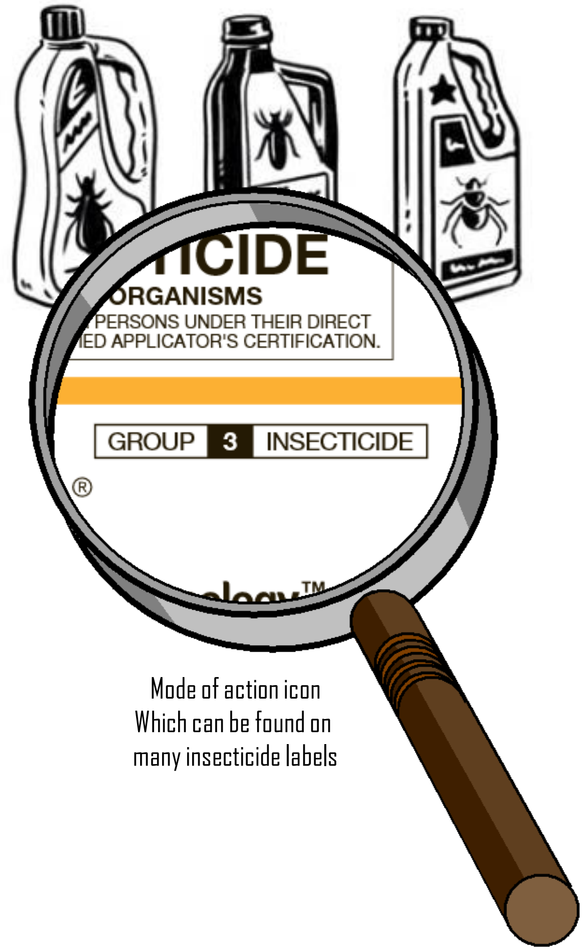
For more information on the use of insecticide mixtures to manage resistance visit www.irac-online.org



Insecticide spray is 90% efficient
But both susceptible and insect with resistant mutations are controlled

Insecticide modes of action

- In this presentation we have talked about insecticide modes of action.
- Most insecticides registered for use to control insects, work through an identified biochemical pathway or interact with a specific target site in insects. This is called the **mode of action (MoA)**.
- All insecticides which work in the same way are grouped together in the internationally recognized IRAC mode of action classification scheme.
- Each group is represented by a number code and in many countries this number is displayed on product labels to help users to differentiate between products with the same and different modes of action.



Mode of action icon
Which can be found on
many insecticide labels

There are some registered insecticides where the exact biochemical mode of action is unknown. These are classified by IRAC as UN (Unknown) until a time that the mode of action can be determined.

To learn more about IRAC mode of action classification follow the link
IRAC MoA Video

- There are over 30 different mode of action groups registered, but not all groups are available in every country.
  - There are also sub-groups which are denoted by a letter after the number, but these will be covered in another module.

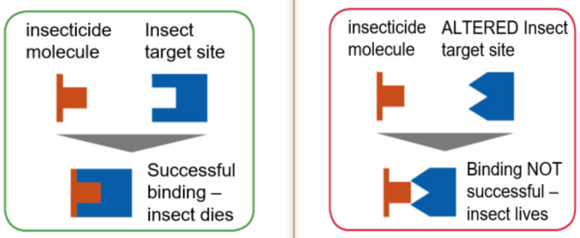
Mechanisms of resistance

- Earlier in this presentation we referred to changes in the genetic make-up of the insect as mutations.
- Mutations can take different forms and result in different types of resistance.

Susceptible | Resistant

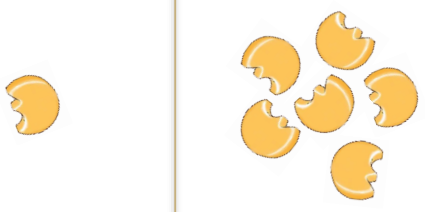
Target Site Resistance

Insecticides generally have a specific site of action within an insect, this is usually a receptor protein. When a mutation occurs in the genetic code for the receptor protein, it can modify the shape of the protein and prevent the insecticide from interacting at the site of action and thus confers resistance. This type of mutation is called target site resistance.



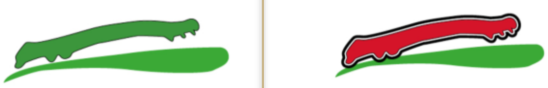
Metabolic resistance

Insects can become resistant to insecticides, when the enzymes which break down unwanted molecules are either significantly increased in amount or modified to be come more efficient at breaking down the insecticide.



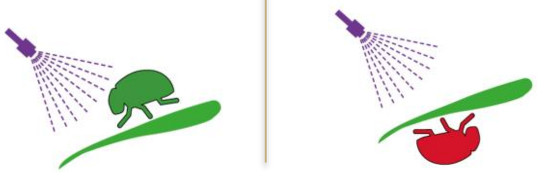
Physical adaptation

A mutation may cause a physical adaptation of the insect which helps it to protect against the insecticide, such as a thicker cuticle, extra waxy covering, or faster excretion of waste. Alone these adaptations don't offer much protection, but can often be combined with other mechanisms to be more effective.



Behavioural adaptation

Although not common, there are examples where mutations have altered the natural behaviours of the insect, reducing exposure of the insect to the insecticide and allowing it to survive.



Cross-resistance & multiple-resistance

- The mode of action classification is designed to help growers identify different modes of action in order to avoid repeated use of similar insecticide products and select for resistance.
- It is based on the most common observation, which is that there is **cross-resistance within a mode of action** group, but **not between mode of action groups.**

- Cross-resistance
  - Cross resistance is defined as resistance to two or more insecticides via a single mechanism of resistance.
- Cross-resistance within a mode of action group.
  - In most cases resistance to an insecticide also confers resistance to insecticides from the same group.
  - However, there can be differences in the level of resistance between insecticides even within the same group. This is called **partial cross-resistance**.
  - In very rare cases there may be no cross-resistance within a group, but this is often only restricted to a single pest.
- Cross-resistance between mode of action groups.
  - In rare cases insecticides which don't have the same mode of action, but have similar molecular structural components may be metabolised by a single enzyme.
  - Insects which over-express that enzyme may therefore be resistant to all the insecticides metabolised by the enzyme.
- Multiple resistance
  - Multiple resistance is defined as resistance to two or more insecticides via multiple mechanisms of resistance in a single insect. It is often confused for cross-resistance.

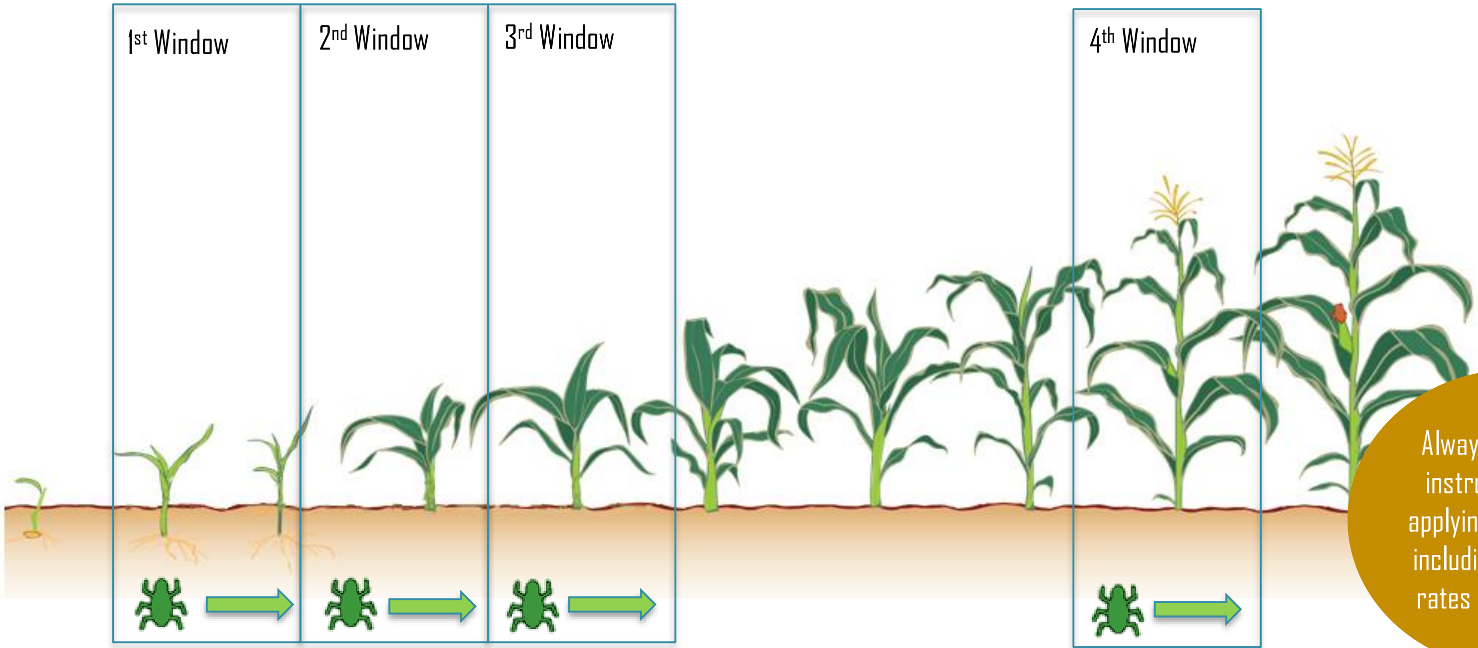
Cross-resistance:
Protection from two or more insecticides through a single mechanism

Multiple-resistance:
Protection from two or more insecticides through multiple mechanisms

IRAC

Managing insect pest resistance

- Insects may occur at different times within a crop environment.
- When designing a strategy to control the insect pests it is important to consider resistance management.
- IRAC recommends segregating the crop cycle into 'windows of application'.
- Each window of application should be as long as it takes for the pest to go through one generation (egg/juvenile to adult) or the duration of effect of a single application of the insecticide used (whichever is longest).
- It's not always easy to determine the generation time of an insect, so in the absence of this information, IRAC recommends using a 30 day window for most pests, but a 15 day window for aphids and mites.



Always follow label instructions when applying insecticides, including application rates and intervals.

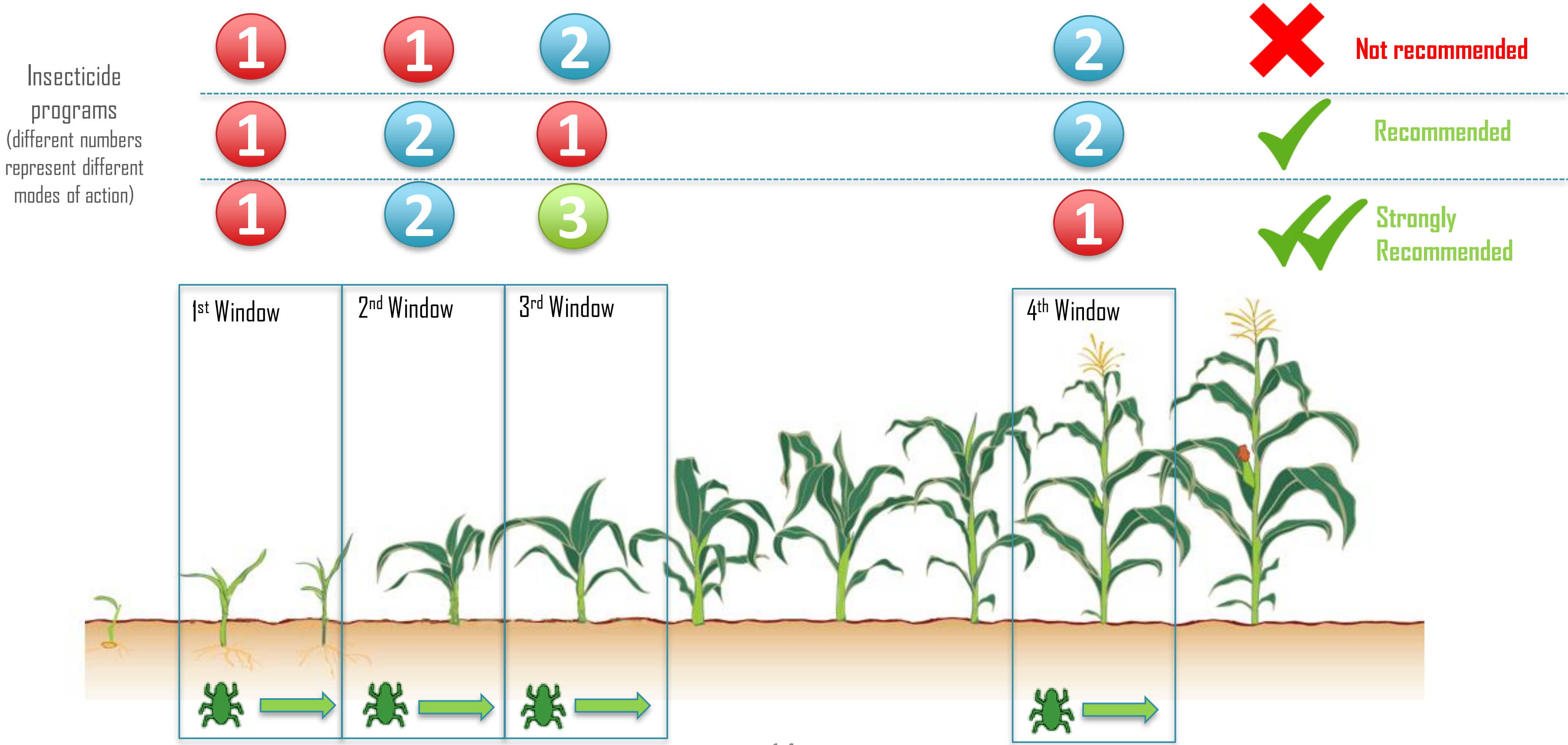
IRAC

Managing insect pest resistance: Single Pest

- It is recommended that insecticides with the same mode of action or with cross-resistance are not used in adjacent or sequential windows.
- However the same mode of action can be used in alternate windows.
- For best resistance management practice multiple effective modes of action should be utilised in a program.

NOTE: The term 'modes of action' is based on the IRAC mode of action classification. This includes, synthetic chemical, non-synthetic chemical and biological insecticides.

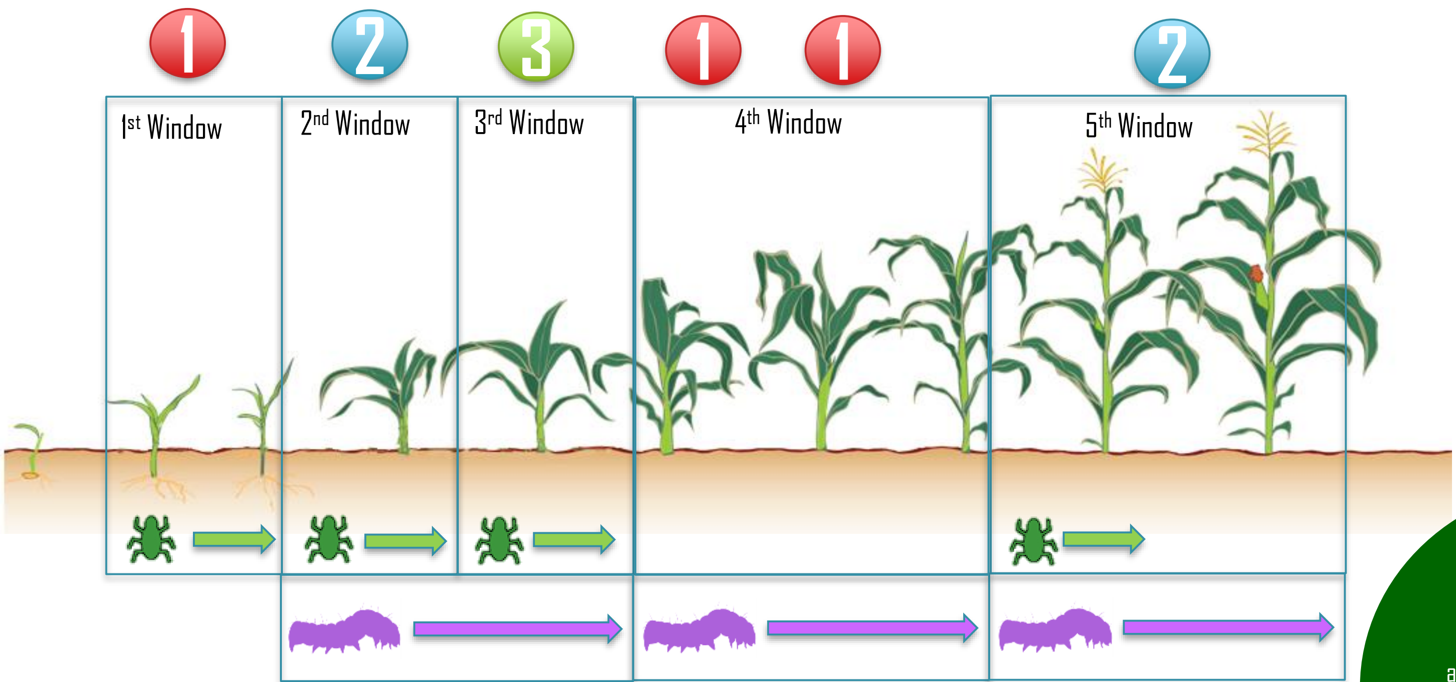
Always check insecticide product labels to determine the mode of action



IRAC

Managing insect pest resistance: Multiple Pests

- A resistance management strategy for a single pest can be easy to design and implement, but the reality is that there is often more than one pest present in a crop.
- In a multi-pest environment, application windows have to be modified to include each pest.
- It is important to note that more than one application of the same mode of action can be made within a window, as long as the residual effects of the insecticide do not exceed the length of the window.



NOTE: In cases where pest species overlap in the cropping cycle and have different generation times, The shortest generation time is used as the basis of the window.

IPM: Integrated Pest Management
Use of IPM techniques, such as crop rotation, preservation of natural predators, removal of the previous crops residues, etc.. Can also help to manage resistance.

IRAC

Why is it important to manage resistance

- Resistance management is a critical part of pest management.
- Although it may seem more cost effective or convenient to use the same product repeatedly, it leads to a loss in efficiency and the need for more repeat applications.
- Once resistance is established it is almost impossible for susceptibility to return and affected insecticides to work at previous levels. This reduces growers options and flexibility to control pests.

Resistance Management….

IRAC