**Nematode Working Group**

## Nematicide Mode of Action Classification

There are no substantiated examples in the scientific literature from the last century documenting cases of significant tolerance shifts or suspected resistance leading to failure of commercial agricultural nematocides against plant parasitic nematodes (PPN) under natural field conditions. Instances of these phenomena occurring have only been reported for some products under controlled laboratory conditions. Product usage approaches and nematode ecology also reduce the potential that sustained selection pressure on PPN populations may evolve under natural field conditions. Thus overall, it can be considered that the development of resistance in PPN species to nematicides under natural field conditions is currently unconfirmed, theoretically unlikely, and poses a low risk.

The reasons underpinning this conclusion are explained below.

Unlike other plant protection products (e.g. herbicides, fungicides and insecticides), several factors limit the potential for nematicides to create high and sustained selection pressure on plant parasitic nematode (PPN) populations under field conditions. These factors include the:

- relatively low frequency of nematicide use in a single cropping cycle, as a proportion of the duration of the crop and the number of PPN generations. Typically, one nematicide application is made per growing season, and occasionally move in long-season or perennial crops;
- primary application methods used for nematicides in the field often target a small soil volume (e.g. crop not zone, crop beds or rows, or seed only), leaving untreated areas and host plants (weeds) that can act as refuge or source of reclamation for unexposed PPNs;
- various nematicide species have life stages (dormant or living) in host plants (e.g. crop or crop weeds) that may remain in the field and not be exposed to or affected by nematicide treatments. It is noteworthy to mention that very few nematicides are effective systemically in the plant against nematode populations;
- complexity of the soil environment and chemical interactions with nematicides frequently reduces product persistence, mobility and/or bioavailability, thus minimizing the likelihood of a chemical product to reach a high percentage of the plant parasitic nematode population present in the field, e.g. at different soil depths or distances from the point of application, or causing exposure to multiple generations;
- large diversity of naturally occurring organisms that may attack surviving life stages of PPNs in soil, reducing the overall selection pressure from a single nematicide application.

Plant parasitic nematodes occur in a variety of pressures (soil population density levels) under field conditions. In some countries, and in some species, local threshold levels may be available to assess the risk of economic crop loss. Nematode management programs should be used in cases where populations of PPNs are deemed high or very high, employing multiple tactics to provide effective control and population reduction. These programs may include cultural practices, e.g. crop rotations or fallow periods, solarization, nematicide resistant or tolerant varieties and the application of nematicides. In cropping systems which require multiple nematicide applications within one cropping cycle or on the same field over several cycles, rotation to a nematicide with a different mode of action is recommended to reduce the risk of sustained selection pressure on PPN populations.

Nematicidal products with fungidal or insecticidal activity require additional resistance management considerations and labelling according to FRAC or IRAC guidelines.

Reduced performance of chemical nematicides can be caused by the phenomenon of Enhanced Microbial Biodegradation (EMB). This is well documented in the scientific literature and EMB should not be confused with resistance development in plant parasitic nematodes. EMB affects the level of product availability and duration of exposure to PPN to the product, thus reducing the apparent efficacy of a nematicide application. Rotation of nematicides from different chemical classes, as well as employing other control methods such as resistant varieties and cultural methods (e.g. crop rotations) should be considered.

(1) Tolerance shifts or resistance development in PPN under laboratory conditions.

(2) Reduced if the same chemical class or the same microbial metabolite in the same field soil may lead to an apparent reduction in PPN kill.

(3) Enhanced microbial biodegradation (EMB): Reduced in frequent use of the same nematicide in the same field soil may lead to an apparent reduction in PPN kill. Application of nematicides with different microbial metabolites that break down a particular product, therefore changing the amount of product available and/or duration of exposure to PPN. The minimum responsible for EMB in soil may be different to different chemical classes or products, thus rotation of different nematicide types, or a reduction in the frequency of application may lessen the likelihood of EMB occurrence.
Colour key:

- Nerve and muscle (Carbamates, Organophosphates and Avermectins)
- Pyridinylmethyl-benzamides
- Tetronic and Tetramic acid derivatives
- Unknown
- Biologicals