



## 1. Introduction

The FRAC CAA Working Group was set up in 2005 to generate common resistance management recommendations for the Oomycete fungicides dimethomorph, flumorph, iprovalicarb, bentiavalicarb, mandipropamid and valifenalate.

All of the above-mentioned fungicides exhibit cross resistance and are grouped under the FRAC Code No. 40 in the FRAC Code List.

| CODE | TARGET SITE OF ACTION | GROUP NAME                              | CHEMICAL GROUP        | COMMON NAME                                    | COMMENTS  |
|------|-----------------------|---|-----------------------|--|---|
| 40   | Cellulose synthesis   | CAA-fungicides (Carboxylic acid amides) | cinnamic acid amides  | dimethomorph<br>flumorph                       | Low to medium risk. Resistance management required. |
|      |                       |   | valinamide carbamates | bentiavalicarb<br>iprovalicarb<br>valifenalate |   |
|      |                       |   | mandelic acid amides  | mandipropamid                                  |   |

As shown in the table, the group name **Carboxylic Acid Amides (CAA)** has been chosen. This name best represents compounds from three different chemical groups.

The mode of action of CAA compounds is directly linked to the inhibition of cellulose synthesis in the Oomycete plant pathogen (Blum et al., 2010).

Uptake studies with <sup>14</sup>C labelled Mandipropamid (MPD) showed that this Oomycete control agent acts on the cell wall and does not enter the cell. Furthermore, <sup>14</sup>C glucose incorporation into cellulose was perturbed in the presence of MPD. Gene sequence analysis of cellulose synthase genes in laboratory mutants, insensitive to MPD, revealed two point mutations in the *PiCesA3* gene, known to be involved in cellulose synthesis. Both mutations in the *PiCesA3* gene result in a change to the same amino acid (Glycine-1105) in the protein.

Sensitivity monitoring studies over several years revealed that in populations of the late blight pathogen, *Phytophthora infestans*, all isolates were fully sensitive to CAA fungicides. However, in populations of the grape downy mildew pathogen, *Plasmopara viticola*, isolates can be found in certain regions, which are resistant to all CAA fungicides.

Inheritance studies (Gisi et al., 2007) showed that sexual crosses between sensitive and CAA resistant isolates of *Plasmopara viticola* lead to a co-segregation of resistance to dimethomorph, iprovalicarb, bentiavalicarb and mandipropamid, but not to the phenylamide, mefenoxam, which was tested in parallel as an independent marker.

Further, the inheritance studies showed that the gene(s) for resistance to CAA fungicides are inherited in a recessive manner. Therefore, the entire F1 generation of crosses between sensitive and CAA resistant isolates was sensitive, and only in the F2 progeny did CAA resistance reappear in some isolates. These results suggest that the resistance risk can be classified as moderate (as compared to high for phenylamide and QoI fungicides) and that it can be managed by appropriate product use strategies (see below).

## 2. Resistance Monitoring 2011

### 2.1. *Plasmopara viticola* – Grape downy mildew

#### Disease incidence

In 2011, disease pressure was low to moderate in the main grape growing areas of Europe.

#### Monitoring results

(Results generated by BASF, Bayer, Isagro, KI-Chemical, Makhteshim, Syngenta)

##### France

As in the years before, CAA resistant isolates have been detected consistently in all areas. High frequency of resistance was detected in Western France (Cognac, Armagnac, Gascogne, Bordeaux, Val de Loire). In other areas the frequency of resistance was moderate (Champagne, Bourgogne, Sud Est) or low (Alsace).

##### Germany

High frequency of resistance was observed in Mosel, Rheinhessen, Pfalz, Franken and Württemberg and moderate levels in Baden.

##### Italy

High resistance levels were observed in Alto Adige, Trentino, Veneto and Piemonte. Low levels have been found in Lombardia and Toscana. No resistance was detected in Emilia Romagna and Marche.

##### Spain, Portugal

No resistance was detected in Galicia, Basque, Valencia and Portugal.

##### Switzerland

A high level of resistance was observed in Buendner Herrschaft, moderate in Lake of Geneva and low levels in Valais. No resistance was detected in Tessin.

##### Austria

No resistance was detected in Weinviertel, Wachau and low levels in Burgenland.

##### Slovakia, Czech Republic, Hungary

No resistance was detected.

#### Field performance

Field performance of registered products was good in 2011. No resistance-related complaints have been received.

### 2.2. *Phytophthora infestans* – Late blight of potatoes and tomatoes

#### Monitoring results

(Results generated by BASF, KI Chemical, Makhteshim and Syngenta)

Sensitivity monitoring programs in 2011 did not detect less sensitive strains of *Phytophthora infestans* in Europe. These studies document that populations of *Phytophthora infestans* are fully sensitive to CAA fungicides and confirm the observations of previous years.

## **Field performance**

Field performance of CAA fungicides against late blight was very good.

### **2.3. *Pseudoperonospora cubensis* – Downy mildew of cucurbits**

(Results generated by Syngenta)

Sensitivity monitoring was carried out in France, Spain, Bulgaria, Czech Republic, Israel, China, Taiwan, Japan and USA. Data from 2011 show the occurrence of a few resistant isolates in Spain, Israel and USA.

### **2.4. Other Oomycete pathogens**

No sensitivity monitoring studies were conducted in 2011.

## **3. Use Recommendations**

### **3.1. *Plasmopara viticola* – Grape downy mildew**

*Plasmopara viticola* is classified by FRAC as a high risk pathogen. Long-term experience with CAA fungicides demonstrates that the resistance risk of *Plasmopara viticola* to this fungicide group is moderate and can be managed through appropriate use strategies.

#### **Use Recommendations:**

- Apply CAA fungicides preferably in a preventive manner
- Apply a maximum of 50% of the total number of applications not exceeding a total of 4 CAA fungicide sprays during one crop cycle
- Always apply CAA fungicides in mixture with effective partners such as multi-site or other non cross resistant fungicides
- An effective partner for a CAA fungicide is one that provides satisfactory disease control when used alone at the mixture rate
- Alternation with fungicides having other modes of action is recommended in spray programs

For more detailed product recommendations refer to the use guidelines published by the respective CAA manufacturers.

### **3.2. *Phytophthora infestans* – Late blight of potato and tomato**

No resistant isolates from field populations have been found since the introduction of CAA fungicides over 15 years ago.

*Phytophthora infestans* is classified by FRAC as a medium risk pathogen. Long-term experience with CAA fungicides demonstrates that the resistance risk of *Phytophthora infestans* to this fungicide group is low to moderate. For effective resistance management a precautionary strategy has to be implemented.

### **Use Recommendations:**

- Apply CAA fungicides preferably in a preventive manner
- Maximum 50 % of the total number of intended applications for late blight control
- Alternation with fungicides having other modes of action is recommended in spray programs

For more detailed product recommendations refer to the use guidelines published by the respective CAA manufacturers.

### **3.3. *Pseudoperonospora cubensis* – Downy mildew of cucurbits**

*Pseudoperonospora cubensis* is classified by FRAC as a high risk pathogen.

### **Use Recommendations:**

- Apply CAA fungicides preferably in a preventive manner
- Maximum 50 % of the total number of intended applications for disease control
- Alternation with fungicides having other modes of action is recommended in spray programs; do not use more than 2 consecutive applications of CAA fungicides
- In areas where resistant strains have been detected in commercial fields, apply CAA fungicides only in mixture with effective partners such as multi-site or other non cross resistant fungicides
- An effective partner for a CAA fungicide is one that provides satisfactory disease control when used alone at the mixture rate

For product recommendations refer to the use guidelines published by the respective CAA manufacturers.

### **3.4. Other Oomycete pathogens**

Some of the downy mildew pathogens are classified by FRAC as moderate risk pathogens (e.g. *Bremia lactucae*). In spite of the use of CAA fungicides for more than 15 years against a range of such Oomycete pathogens, no reports on the occurrence of less sensitive field populations are available.

For effective resistance management a precautionary strategy has to be implemented.

### **Use Recommendations:**

- Apply CAA fungicides preferably in a preventive manner
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- Maximum 50 % of the total number of intended applications for disease control
- Alternation with fungicides having other modes of action is recommended in spray programs

For more detailed product recommendations refer to the use guidelines published by the respective CAA manufacturers.

#### **4. References**

Blum, M., Boehler, M., Randall, E., Young, V., Csukai, M., Kraus, S., Moulin, F., Scalliet, G., Avrova, A.O., Whisson, S.C. and Fonne-Pfister, R. (2010). Mandipropamid targets the cellulose synthase-like PiCesA3 to inhibit cell wall biosynthesis in the Oomycete plant pathogen, *Phytophthora infestans*. *Mol. Plant Pathol.* 11, 227–243.

Gisi, U., Waldner, M., Kraus, N., Dubuis, P.H. and Sierotzki, H. (2007). Inheritance of resistance to carboxylic acid amide (CAA) fungicides in *Plasmopara viticola*. *Plant Pathology* 56, 199-208.

#### **5. Next Meeting**

The next annual meeting is planned for December 4th, 2012.