



Carboxylic Acid Amides (CAA) Working Group

Annual Meeting Season 2019 on January 21st, 2020

Protocol of the discussions and recommendations of the CAA Working Group of the Fungicide Resistance Action Committee (FRAC)

Participants

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Venue:

Lindner Congress Hotel, Frankfurt am Main, Germany

Anti-trust guidelines (from FRAC constitution) were shown at the start of the meeting

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1. Introduction

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

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 flumorph pyrimorph	Low to medium risk. Resistance management required.
			valinamide carbamates	bentiavalicarb iprovalicarb 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, Molecular Plant Pathology 11, 227-243).

Uptake studies with ¹⁴C labeled mandipropamid (MPD) showed that this Oomycete control agent acts on the cell wall and does not enter the cell. Furthermore, ¹⁴C 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, Plant Pathology 56, 199-208) 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 CAA fungicides) and that it can be managed by appropriate product use strategies (see below).

2. CAA – Resistance Monitoring 2018

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

Disease incidence

In 2019, disease pressure occurred late in the season with a moderate disease pressure in most European countries.

Monitoring results

(BASF, Bayer, Belchim, Syngenta)

The following estimations are based on the data provided by the different companies. These data were generated by different laboratories including external service providers. Different methods such as *in vivo* tests, zoospore germination tests and molecular genetic analysis were used for sensitivity assessment. The assessments are from 2019 studies, besides another year is mentioned.

France

As in the years before, CAA resistant isolates have been detected consistently in most areas. High frequencies of resistance were detected in Cognac and Savoie, moderate to high frequencies in Armagnac, Champagne and Sud-Est. Moderate frequencies were detected in Bordeaux, Bourgogne and Beaujolais and Val de Loire, low to moderate frequencies in Languedoc, Val du Rhone and no to low frequency of CAA resistance in Alsace/Lorraine.

Germany

High frequencies of resistance were found in Mosel, Main, Württemberg, Baden. Moderate to high frequencies were observed in Pfalz and Rheinhessen.

Switzerland

High frequency values of CAA resistance were detected in Northern Switzerland, moderate to high values in Ticino and Vaud.

Austria

Moderate to high values were detected in Wachau and Steiermark, low values in Weinviertel and no resistance in Burgenland.

Italy

High frequencies of resistance were observed in Alto Adige, Friuli, Lazio, Piemonte, Trentino and Veneto, moderate to high values in Campania, Emilia Romagna and Toscana, moderate values in Marche and low values in Lombardia.

Spain:

Moderate to high frequencies of resistance were found in Basque region and low frequency of CAA resistance was detected in Galicia.

Portugal

Most samples from Portugal were fully sensitive, some samples contained low frequencies of CAA resistance.

Greece

No CAA resistance was detected in Peleponnes area and low frequencies of CAA resistance in Makedonia.

Croatia

Samples from Croatia from the 2019 monitoring were heterogenous, with no CAA resistance to high frequencies of CAA resistance.

Hungary

Samples from Hungary contained no to moderate frequency values of CAA resistance.

Romania

Samples from Romania were fully sensitive or showed low values of CAA resistance.

Bulgaria

Sensitivity monitoring from 2019 season showed no CAA resistance.

Slovenia

The frequency of CAA resistance in 2019 samples from Slovenia was moderate to high.

Czech Republic

No monitoring data were presented for 2019 season. In 2016, sensitivity monitoring showed low frequencies of CAA resistance.

Slovakia

No monitoring data were presented for 2019 season. In 2016, sensitivity monitoring showed low frequency of CAA resistance.

Field performance

Field performance of registered products was good when applied in spray programmes using timely preventive applications, according to the FRAC recommendations.

2.2. CAA – *Phytophthora infestans* – Late blight

Disease incidence

In 2019, disease pressure was moderate in the main growing areas of Europe.

Monitoring results

(Belchim, KI-Chemicals and Syngenta)

Sensitivity monitoring programs in 2018 showed full sensitivity for *Phytophthora infestans* collected from potatoes and tomatoes in Europe (Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, UK). These data are in line with findings from previous monitoring studies. From China, data are available from 2016 (Hebei, Inner Mongolia) and all samples were sensitive. These studies document that populations of *Phytophthora infestans* are fully sensitive to CAA fungicides and confirm the observations of previous years.

Genotypes of *Phytophthora infestans* are classified by Euroblight. These genotypes could express variable aggressiveness but are not necessarily linked to fungicide resistance, which is genetically independent.

Field performance

Field performance of registered products in potatoes and tomatoes was good when applied in spray programmes using timely preventive applications.

2.3. CAA – *Pseudoperonospora cubensis* - Downy mildew of cucurbits

(Syngenta)

Sensitivity monitoring programs were carried out in Europe since 2015. Preliminary results from 2019 indicate no resistance in Spain, France, Greece, Italy and Poland. Samples were collected from cucumber and melon. Monitoring studies are ongoing.

2.4 CAA – *Bremia lactucae* – Downy mildew of lettuce

(Syngenta, BASF)

Sensitivity studies were done with samples from 2013-2015 from France, Italy, Germany and Spain. All samples tested were sensitive.

In 2016, genetic analysis of the *cesA3* gene showed that all samples from Spain, Germany and UK did not contain any known mutation potentially causing CAA resistance and were therefore classified as sensitive.

In 2018 and 2019 samples collected from France, Greece, Germany, Netherlands and Italy were sensitive. Monitoring is still ongoing.

2.5 CAA – *Peronospora destructor* - Downy mildew of onions

(BASF)

Genetic analysis of the *cesA3* gene in 2016 showed that all samples from Germany did not contain any known mutation potentially causing CAA resistance and were therefore classified as sensitive.

3. CAA – Use Recommendations

3.1. CAA – *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.

CAA – Use Recommendations:

- Apply CAA fungicides preferably in a preventive manner
- Apply a maximum of 50% of the total number of intended applications for disease control not exceeding a total of 4 CAA fungicide sprays during one crop cycle. In areas of high resistance, the total number should not exceed a maximum of 3 applications 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. CAA – *Phytophthora infestans* – Late blight of potato and tomato

No resistant isolates from field populations have been found since the introduction of CAA fungicides in 1993.

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
- Apply a maximum of 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. CAA – *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
- Apply a maximum of 50% of the total number of intended applications for disease control not exceeding a total of 4 CAA fungicide sprays during one crop cycle. In areas of high resistance, the total number should not exceed a maximum of 3 applications 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 product recommendations refer to the use guidelines published by the respective CAA manufacturers.

3.4. CAA – 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 20 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
- Apply a maximum of 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. Next Meeting

Next annual meeting is planned for January 19th, 2021.