Carboxylic Acid Amides (CAA) Working Group

Annual Meeting Season 2025 on March 24th, 2026

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

Participants

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Venue:
Meeting at Lindner Hotel, Frankfurt (Höchst)

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, benthiavalicarb, iprovalicarb, valifenalate and mandipropamid.

All 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 (**C**arboxylic **a**cid **a**mides)	cinnamic acid amides	dimethomorph flumorph pyrimorph	Low to medium risk. Resistance management required.
40	Cellulose synthesis	**CAA**-fungicides (**C**arboxylic **a**cid **a**mides)	valinamide carbamates	benthiavalicarb iprovalicarb valifenalate	Low to medium risk. Resistance management required.
40	Cellulose synthesis	**CAA**-fungicides (**C**arboxylic **a**cid **a**mides)	mandelic acid amides	mandipropamid	Low to medium risk. Resistance management required.

As shown in the table, the group name **C**arboxylic **A**cid **A**mides (**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.* 2010a, b).

Uptake studies with ^{14}C labeled mandipropamid (MPD) showed that this Oomycete control agent acts on the cell wall and does not enter the cell. Furthermore, ^{14}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.

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, benthiavalicarb 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 (in comparison to high-risk phenylamides).

In populations of the grape downy mildew pathogen, *Plasmopara viticola*, resistant isolates could be found in many grape growing regions in Europe several seasons after market introduction. Main mechanism is the target site mutation G1105S and less frequently found, the G1105V in the CesA3 gene.

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. In monitoring studies from 2021 first suspicious cases were identified and in the following seasons CAA resistance in this species was confirmed. Resistance mechanism is the target site mutation G1105S in the CesA3 gene (Torriani *et al*. 2026; Derpmann *et al*. 2026)

There is cross-resistance between all CAA fungicides.

References

Blum, M., Waldner, M. and Gisi, U. (2010a) A single point mutation in the novel PvCesA3 gene confers resistance to the carboxylic acid amide fungicide mandipropamid in *Plasmopara viticola*. Fungal Genetics and Biology 47, 499–510.

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Derpmann, J., Leonard, S., Böhm, J.W. and Mehl, A. (2026) Characterization of CAA-, OSBPI- and double resistant field isolates of *Phytophthora infestans* and their impact on Late Blight control in potatoes. Potato Research 69, https://doi.org/10.1007/s11540-026-10008-z

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, https://doi.org/10.1111/j.1365-3059.2006.01512.x

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2. CAA – Resistance Monitoring

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

Disease incidence

In 2025, disease pressure was different in European regions.

Monitoring results

(BASF, Bayer, Certis Belchim, and 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 latest assessments for each country are provided. Regions of interest which are not listed here may be found in previous meeting minutes.

Countries with monitoring data from 2025:

France

As in the years before, CAA resistant isolates have been detected consistently in most areas. High frequencies of resistance were detected in Armagnac, Champagne, Val de Loire; moderate to high frequencies in Bordeaux Bourgogne and Beaujolais, Cognac, Languedoc, Sud-Est, and Valle du Rhone.

Germany

High frequencies of resistance were found in the Mosel area.

Switzerland

Samples from Wallis showed high frequencies of CAA resistance.

Italy

High frequencies of CAA resistance were found in Lazio, Marche, Piemonte, Toscana and Trentino. Moderate to high frequencies of resistance were observed in Emilia Romagna, Friuli and Vento, while moderate values were found in Lombardia.

Spain:

Monitoring in Basque, Galicia, and Rioja resulted in moderate to high frequency of CAA resistance.

Portugal

CAA resistance was heterogenous in Portugal with moderate to high frequencies of CAA resistance in the populations.

Hungary

Samples from Hungary were heterogenous and contained low to high frequencies of CAA resistance.

Greece
No CAA resistance has been detected in the Peloponnese area.

Croatia
Samples from Croatia showed moderate to high frequency of CAA resistance.

Countries with monitoring data before 2025:

Austria
Samples from 2024 from Wachau and Weinviertel showed moderate to high frequencies and samples from Burgenland and Steiermark showed moderate frequencies of CAA resistance.

Czech Republic
Samples from Czech Republic from 2024 showed low frequency of CAA resistance.

Slovenia
Samples from 2022 showed overall moderate values of CAA resistance.

Turkey
As in the seasons before, samples from 2024 from the regions Dogu Marmara and Ege were fully sensitive to CAAs.

Romania:
In 2023, monitoring of samples across Romania showed a heterogenous situation with no to high values of CAA resistance.

Bulgaria
Samples from 2022 were fully sensitive.

Slovakia
The sites, which were analysed in a limited CAA monitoring in 2020 were fully sensitive.

Although the G1105S/V mutation occurs often in many regions, CAAs continue to play a role in managing the disease. The mutation frequency tends to be low early in the year, rises due to CAA selection pressure, and then decreases later in the season.

2.2. CAA – *Phytophthora infestans* – Late blight

Disease incidence

In 2025, disease pressure was low in the main potato growing areas of Europe.

Monitoring results

(Certis Belchim and Syngenta)

Europe

In 2025, samples were taken from potatoes and tomatoes from Austria, Belgium, Denmark, Estonia, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Spain, Switzerland, Sweden, and United Kingdom. As in the previous years, analysis was done with sensitivity tests using isolates or populations from leaf samples and/or with genetic analysis from these samples. Complementary studies were conducted to quantify target-site mutation G1105S.

Potatoes: In countries where CAA resistance was detected in the last years, the frequency of CAA resistance stabilized or even decreased. This indicates that resistance management strategies are effective.
An expansion to other countries has been detected (Switzerland and United Kingdom). In 2025, resistance has been detected in Austria, Denmark, France, Germany, Poland, Portugal, Sweden, Switzerland, the Netherlands, and United Kingdom.

All samples analysed from Ireland, Estonia, Greece, Latvia, Lithuania, and Spain were sensitive and mutation G1105S was not detected.

Low frequencies of mutation G1105S, but no resistant phenotypes have been detected in Finland, Norway, and Italy.

Tomatoes: All samples from France, Spain, Greece, Italy, and Poland were sensitive.

Late blight is classified according to SSR (Short Sequence Repeats) types by Euroblight (https://agro.au.dk/forskning/internationale-platforme/euroblight). These genotypes could express variable aggressiveness, **but are not linked to fungicide resistance, although associations can occur.** SSR types and fungicide resistance mechanisms are genetically independent. CAA resistance has meanwhile been found in multiple Euroblight genotypes.

Vietnam

Tomatoes: Single cases of high frequency of the G1105S mutation have been detected in Lam Dong. All other areas were sensitive.

Historic background

In 2024, samples were taken from potatoes and tomatoes from Austria, Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Ireland, Italy, Latvia, Lithuania, Netherlands, Norway, Poland, Portugal, Slovenia, Spain, Switzerland, Sweden, and UK.

As in 2023, analysis was done with sensitivity tests using isolates or populations from leaf samples and/or with genetic analysis from these samples. Complementary studies were conducted to quantify target-site mutation G1105S.

Potatoes: In countries where CAA resistance was detected in the last years, the frequency of CAA resistance stabilized or even decreased. This indicates that resistance management strategies are effective.
However, an expansion to other countries has been detected (Austria, Poland, France).
A full sensitive situation was observed in UK, Ireland, Italy, Latvia, Lithuania, Spain, Greece, Switzerland, Czech Republic, Croatia, Slovenia, Finland.

Tomatoes: All samples from France, Spain, Greece, Poland, Croatia were sensitive. Only one sample from Italy was CAA-resistant.

In 2023, samples were taken from potatoes and tomatoes from Belgium, Croatia, France, Germany, Greece, Hungary, Ireland, Italy, Latvia, Netherlands, Poland, Portugal, Romania, Slovakia, Spain, Sweden, and UK. Analysis was done with sensitivity tests using isolates or populations from leaf samples and/or with genetic analysis from these samples. Complementary studies were conducted to elucidate the SSR genotype and target-site mutation (G1105S) presence using FTA cards.
Extensive monitoring showed full sensitivity in most European countries.
Resistance was found in potato samples in Belgium, Germany, Netherlands, and Portugal; preliminary data from Denmark showed lower frequency of resistance compared to 2022; further studies are still ongoing.
All samples from tomatoes (France, Portugal, Italy, Croatia, and Romania) were sensitive. A single sample from Slovakia was resistant.
In 2023, the G1105S mutation in CesA3 in homozygous stage was found as the responsible resistance mechanism as in the years before. All resistant isolates were characterized as the genotype EU_43_A1, but also sensitive isolates with this genotype have been identified (Genotypes are classified by Euroblight (https://agro.au.dk/forskning/internationale-platforme/euroblight). These genotypes could express variable aggressiveness, but are not necessarily linked to fungicide resistance, which is genetically independent).
For the first time in 2023, heterozygous strains were detected and phenotyped as sensitive, confirming the recessive inheritance of CAA resistance as reported for *Plasmopara viticola* (Gisi et al. 2007, Plant Pathology 56, 199-208)

In 2022 and 2023, monitoring studies were conducted with samples from tomatoes from Vietnam using FTA cards for molecular analysis of the presence of the G1105S mutation. In 2022, all samples were sensitive (homozygous wildtype). In 2023, most samples were sensitive (homozygous wildtype), while single samples were heterozygous (sensitive) or homozygous (resistant) for the G1105S mutation.

Further analysis of suspicious isolates from 2021 confirmed resistance to CAAs. The mechanism is the G1105S mutation in the CesA3 gene. All isolates having CesA3 G1105S mutation were genotype EU_43_A1.

Monitoring studies were conducted in 2022 in potatoes in Belgium, Denmark, Germany, France, Hungary, Ireland, Latvia, Norway, Netherlands, Poland, Portugal, Sweden, and United Kingdom. Single resistant isolates have been detected in Germany, Netherlands, Sweden, Norway and with higher frequency in Denmark. Full sensitivity was monitored in Belgium, France, Hungary, Ireland, Latvia, Poland, Portugal, and United Kingdom.

All samples from tomatoes from Europe (Croatia, Italy, Poland) and Vietnam were fully sensitive.

Sensitivity monitoring programs in 2021 showed a full sensitive picture over Europe. Samples were taken from tomatoes and potatoes originating from Belgium, Czech Republic, Denmark, Germany, France, Spain, Greece, Italy, Portugal, Slovakia, Netherlands, Poland, Romania, United Kingdom. However, few suspicious isolates with higher EC_{50} values have been detected. Further molecular analysis conducted in 2022 identified the mechanism of resistance, which is related to the G1105S mutation in the CesA3 gene.

Sensitivity monitoring programs in previous years showed full sensitivity for *Phytophthora infestans* collected from potatoes and tomatoes in Europe (Belgium, Croatia, Denmark, Finland, France, Germany, Greece, Hungary, Ireland, Italy, Lithuania, Latvia, Netherlands, Poland, Portugal, Slovakia, Spain, Sweden, UK).

2.3. CAA – *Pseudoperonospora cubensis* – Downy mildew of cucurbits
(Syngenta)

Monitoring in 2025 in Vietnam showed low frequency of the G1105W mutation in An Giang, Hai Duong, Lam Dong, Long An and Tien Giang, and high frequency of V1109L in Son La, Long An, Lam Dong, Hai Duong, Ha Nam in cucumber.
High frequency of G1105W has been detected in Guatemala in melon.

In 2024, genetic monitoring was conducted with samples from Vietnam. Low frequency of the mutation V1109L in a heterozygous state was detected in Ha Nam, Hai Duong and Son La. This indicates a full sensitive situation in 2024 in Vietnam.
In 2022 and 2023, genetic monitoring was conducted with samples from Vietnam. Low frequency of resistance (responsible mutation was V1109L) was detected in Ha Nam. Southern regions showed full sensitivity.

In 2020 and 2021, full sensitivity was monitored in samples collected from cucumber, melon and zucchini in Croatia, Germany, Hungary, France, Greece, Poland, and Switzerland. Single strains showing CAA resistance were detected in Italy in 2020 and in Spain in 2021, however, most of the samples from both countries were sensitive.

All samples collected from China (6 provinces) between 2019 and 2020 confirmed full sensitivity based on molecular analysis.

Two trial sites from US (South Carolina and Florida) confirmed the presence of the previously published mutation G1105W in the cesA3 associated to CAA resistance (Blum *et al.* 2011, *Pest Management Science* 67, 1211-1214).

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

(Syngenta, BASF)

Full sensitivity was monitored in 2020 and 2021 from samples collected in Belgium, Germany, Spain, Greece, Croatia, Hungary, and Italy.

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

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

(BASF, Syngenta)

Genetic analysis conducted in 2025 on samples from Belgium, Germany, France, Italy, the Netherlands, Poland, and Spain indicated the absence of any known mutations in the CesA3 gene, thereby suggesting complete sensitivity.

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 three 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 CAA fungicides is one that provides satisfactory disease control when used alone at the mixture rate.
- Alternation of 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

CAA were introduced into the market in 1993. No resistant isolates from field populations have been found until 2021.

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, appropriate use strategies should 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.
- Apply CAA fungicides always at recommended dose rates.
- Apply CAA fungicides using not more than 2 consecutive applications.
- Apply CAA fungicides preferably in mixtures with effective partners belonging to different modes of action.

- An effective partner for CAA fungicides 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.
- Good agricultural practices must be considered to reduce sources of inoculum, disease pressure and resistance risk, *e.g.,* consider planting resistant varieties and referring to disease prediction models

In countries with reported cases of resistance:

- CAA fungicides must be used in mixtures, with no more than two consecutive applications.
- In case mixtures cannot be applied for regulatory reasons, apply CAA fungicide in strict alternation.

For more detailed product recommendations refer to the 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 CAA fungicides 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 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*). Despite 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 must 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 guidelines published by the respective CAA manufacturers.

4. Next Meeting

Next annual meeting is scheduled for 16th March 2027.