Cite as: Fritsch, E., Undorf-Spahn, K., Kienzle, J., Zimmer, J., Benduhn, B., Adolphi, C., Zebitz, C.P.W., Jehle, J.A. (2022) Virulence management of codling moth resistance to Cydia pomonella granulovirus (CpGV) in organic fruit growing in Germany. *Proceedings of the 20th International Conference on Organic Fruit-Growing*, online 2022.02.21-23. Ed. FOEKO e.V. 2022: 159-161

Virulence management of codling moth resistance to Cydia pomonella granulovirus (CpGV) in organic fruit growing in Germany

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Abstract

*Cydia pomonella granulovirus (CpGV) products are an important tool for the biological control of codling moth (*Cydia pomonella*) in organic pome fruit production. It is crucial to maintain their efficacy and to include them in existing and future strategies of pest and disease control applications. After field resistance against commercial CpGV products was identified in organic apple orchards, novel resistance-breaking CpGV isolates have been identified and eventually registered to overcome this problem. A virulence management strategy was established for organic growers. This strategy relies on efficacy monitoring of CpGV isolates in the field and isolate adaptation if signs of resistance are determined. A total of 64 cases of field resistance could be verified in Germany since 2004. After switching to resistance-breaking CpGV isolates damage can be stably reduced.*

Keywords: Codling moth, granulovirus, resistance, inheritance, resistance testing

Introduction

The application of Cydia pomonella granulovirus (CpGV) is a corner stone of biological control of codling moth (*Cydia pomonella*, CM) larvae in organic pome fruit production. After first CM populations with resistance to commercial CpGV products were recorded in 2004 from Southern Germany (Fritsch et al., 2005), methods for resistance monitoring were developed and systematically applied in different apple growing regions in Germany and other European countries (Schulze-Bopp and Jehle 2013; Schmitt et al., 2013; Fritsch et al., 2020).

Until now, resistance testing from field collections from more than 110 orchards were carried out in Germany. Genetic analyses revealed three different types of resistance (type I-III) differing in their mode of inheritance and the resistance mechanism (Asser-Kaiser et al., 2007; Jehle et al., 2017; Sauer et al., 2017ab, Sauer et al., 2021). More recently, evidence of additional types of resistance were reported from France and Italy (Siegwart et al., 2020). Intensive research on the genetic diversity of CpGV revealed seven phylogenetic lines of CpGV isolates (genome groups A-G), many of them are able to overcome type I and type II resistance (Gueli-Alletti et al., 2017; Fan et al., 2021). This contribution provides an update of the resistance monitoring and reports the reduction of infestation pressure and damage caused by resistant CMs after switching to the resistant-breaking isolate ABC V14.

Material and Methods

For resistance testing, living L2-L4 larvae were extracted from infested apples and exposed to CpGV-S at a diagnostic concentration of 2×10^5 OB/ml (for details see Schulze-Bopp and Jehle (2013). In the orchards with CM populations resistant against type II ABC V14 was applied with 100 ml/ha each 7-10 days during the hatching periods of the codling moth

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larvae. The CpGV application was combined with mating disruption. In June or in the first days of July (B1) and in August (B2) 1000 casually selected fruits per orchard were assessed for injuries by codling moth larvae. The injured apples were sliced and it was controlled if there were living larvae and if the galleries reached the core and the kernels were attacked. If the gallery was stopped before the core and no living larva was found, this damage was considered “stopped”. Living larvae or galleries that reached the core with kernel attack were considered as “active” damage.

Results and Discussion

Monitoring of Field Resistance: Resistance monitoring of 10 suspect orchards with increased CM damage was carried out from 2020-2021. Larvae were collected from infested apples and exposed to CpGV-S (genome group E) in the laboratory. Populations from nine orchards were found to show decreased susceptibility to the virus, increasing the number of verified cases of field resistance in Germany to a total of 64 (Table 1). About two-third of the cases are assumed to be type II resistance as they were not susceptible to CpGV from genome group E.

Table: Occurrence of CpGV resistance in organic apple growing in Germany 2004 – 2021, verified in laboratory bioassays with L1 larvae by LC_{50} estimation or resistance testing (exposure to 5.8 x 10^4 OB/ml) and/or direct testing of L2-L4 larvae extracted from apples (exposure to 2 x 10^5 OB/ml).

Year		**Verified Resistance**		**Total**
		Type I	**Type II**	
2004 - 2009		22	2	24
2010 - 2016		-	14	14
2017 - 2019		-	17	17
2020 - 2021			9	9
2004 - 2021		**22**	**42**	**64**

Successful control of type II resistance using ABC V14: Fig. 1 shows the results of fruit damage reduction in an organic orchard which was regularly sprayed with CpGV products but exhibited high fruit damage and resistance to CpGV products containing viruses from genome group A and E.

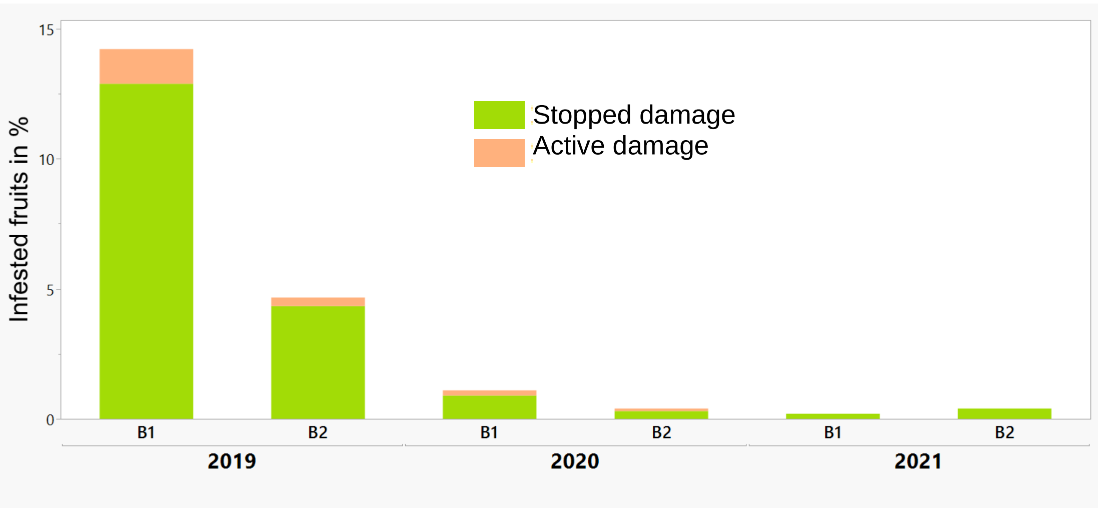

Fig. 1: Stopped and active infestation of apples in an orchard where type II resistance was detected in 2018 and treatment with ABC V14 was initiated in 2019. B1 and B2 refer to fruit evaluation in early and late summer.

After resistance to genome group E was verified in 2018 (in 2018 CpGV was applied in combination with mating disruption), CM control was continued from spring 2019 on with regular sprays of ABC V14 (containing genome group B) in combination with mating disruption. If ABC V14 was applied, in the first generation after the change of product (B1/2019) the damage was still high (up to 14%), though in most injured apples no living larvae were found. In the following generations, the infestation was considerably reduced and the damage remained at low level (<1%). Most of the damage found was “stopped” and the infestation remained at a low level (Fig 1).

Acknowledgements

We acknowledge financial support of BMEL (2809OE097).

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