Examinations on the pupae of the fruit fly *Rhagoletis batava* Hering 1958 (Diptera: Tephritidae) and the role of applied scientific research in a "bottom-up" approach to control this pest

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Abstract: In Germany, considerable damage of the sea buckthorn fly *Rhagoletis batava* Hering 1958 in fruits of sea buckthorn *Hippophae rhamnoides* L. is fairly new. Up to 100 % of the harvest can be lost and methods available for controlling the pest are limited both in organic and in integrated production systems. In response to this, growers, institutions, companies and scientists connected with this issue joined forces. They collected existing data about the pest, coordinated and carried out monitoring and tested first control measures. This comprehensive body of preliminary work was the origin of the MoPlaSa project, which is funded by the European Innovation Partnership (EIP-agri). The project was launched on 1st October 2018 to develop a control strategy against *R. batava* consisting of several non-chemically based control modules. In general, EIP-agri finances projects which combine a "bottom-up" principle in the identification of solutions to problems in agricultural through the application of directed scientific research. The aim is to achieve quick, sustainable and practicable results in the project. First findings of the MoPlaSa project revealed the importance of gaining a deeper understanding of the phenological, ecological and biological characteristics of the pest. Accordingly, the scope of applied research was expanded with further experiments and the monitoring of additional parameters. Flexibility regarding the scope of scientific work is crucial in order to adapt quickly to findings which may emerge in the course of a project.

Key Words: Sea buckthorn, Sea buckthorn fruit fly, *Rhagoletis batava* Her., EIP-agri, MoPlaSa, non-chemically based control

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Introduction

Severe damage to fruit of sea buckthorn *Hippophae rhamnoides* L. by the fruit fly *Rhagoletis batava* Her. was reported for the first time in Germany in 2013. As yield losses of important varieties regularly exceed 80 %, the entire cultivation of sea buckthorn in North-East Germany is endangered. The fact that the growing area of sea buckthorn in Brandenburg is the third largest after apples and sweet cherries emphasizes the urgency of a strategy to control this pest.

Damage is caused by larvae of the pest. Like other species of *Rhagoletis*, flies of *R. batava* emerge after hibernating as pupae in the soil. After mating, female flies pierce the fruit with their ovipositor and insert their eggs into the fruit of sea buckthorn. Here the larvae develop through three stages before leaving the fruit to pupate and hibernate in the soil. It is known, that some *R. batava* pupae do not develop into flies in the following year but one season later.

In 2014, the Plant Protection Service Brandenburg (LELF) and the Mecklenburg-Vorpommern Research Centre for Agriculture and Fisheries, Centre of Horticultural Crop Production (LFA) invited growers, institutions, companies and scientists connected with the issue to discuss possible strategies and to coordinate and carry out monitoring and first control measures. During the meetings the participants decided to create a project outline taking into consideration the demands of the growers for a practicable, efficient, and reliable control method which could be adapted to their different needs. As 90 % of sea buckthorn in Brandenburg is cultivated according to organic guidelines, measures should comply strictly with the requirements of this production system.

With funding of the MoPlaSa project provided by the European Innovation Partnership (EIP-agri), the European Agricultural Fund for Rural Development (EAFRD) and the state Brandenburg, it was possible to cover all the necessary fields of expertise. The program provides a framework for the joint identification of the control strategies by growers and scientists and for a quick exchange of information amongst its participants. It connects the following specialists from different fields:

- Four sea buckthorn growers:
  - Werderfrucht GmbH
  - Forst Schneebecke
  - Gut Schmerwitz GmbH & Co. KG
  - Biohof Glindow GbR
- Plant Protection Service Brandenburg, LELF (plant protection)
- e-nema GmbH (plant protection with nematodes)
- Four research institutes:
  - Leibniz Centre for Agricultural Research, ZALF e. V. (lead partner and plant protection with entomopathogenic microorganisms)
  - Mecklenburg-Vorpommern Research Centre for Agriculture and Fisheries, Centre of Horticultural Crop Production, LFA (sea buckthorn cultivation)
  - Humboldt-University of Berlin, Albrecht Daniel Thaer-Institute of Agricultural and Horticultural Sciences (technical aspects, cultivation and plant protection)
  - Julius Kühn-Institute (plant protection with entomopathogenic fungi)
- agrathaer GmbH (project coordination)
- International Geotextil GmbH (geosynthetics, hydroseeding)
- German Society for Seabuckthorn and Wild Fruits – Sanddorn e.V. (stakeholder)

The MoPlaSa project group aims to develop a plant protection strategy which will provide all sea buckthorn growers with a modular concept for non-chemical control by the end of 2022. Both, the production conditions (ecological, integrated) and the method of cultivation (extensive, intensive) will be taken into account. The spectrum of modules comprises the following measures:

- Traps
- Mechanical tillage
- Permanent barriers (foil, nets) or temporary coverage of the soil (curing liquid)
- Macro-organisms (nematodes, beneficial insects)
- Microorganisms (entomopathogenic fungi, bacteria)
- Influence of sea buckthorn varieties
- Mobile poultry keeping

A handbook and short videos will summarize the recommendations in a practical way.

First investigations and findings

Since the start of the project on 1st October 2018, the project group has been working in close consultation. From early on in the project, the planned program of work had to be altered in response to unexpected first results concerning the variability of *R. batava* pupae and resulting questions about their influence on the life cycle.

For the MoPlaSa project, the pupae of the sea buckthorn fly are considered to be an important developmental stage to target for control measures. Additionally, they are suitable for setting up experimental designs for assessing effects on adult emergence. Consequently, since the start of the project in autumn 2018, a huge amount of work has been invested into obtaining pupae for the 2019 trial season, by sieving soil collected from under infested sea buckthorn plants. Comparison of thousands of pupae revealed considerable differences in their colour and size and led to the following questions:

- Are the observed different colours of the pupae (yellowish to brown) indicators for parasitism or delayed hatching of the flies (carry-over for two or more winters)?
- Do the considerable differences in size of the pupae affect their fitness and their ability to survive through the dormant stage?
- Why do we find up to 30 % of empty pupae in the winter, with clear signs of hatching but without an indication of decay, suggesting fly emergence outside of the usual season (June – August)?

To answer these questions an additional experiment was started. The length and width of one thousand pupae was measured and their colour was recorded. The pupae were then placed in individual cages, allowing them to rest in the soil and hatch under field conditions. These cages will be monitored over the next two years. This is just one example of steps being taken to better understand important biological, ecological and phenological parameters of *R. batava.* Besides this trial, experiments have to be carried out pursuant to the guidelines of the MoPlaSa project. In order to improve the reliability of the data, the large number of 80 pupae per repetition was fixed for all experiments. Another adaptation was to increase the number of experiments conducted in controlled environment conditions. The aim of the project team members was to achieve reproducible test results under controlled climatic conditions to improve chances for a successful transfer of control strategies to field conditions.

In 2019 field season, experiments on the control of pupae and hatching flies through traps, barriers, nematodes and entomopathogenic fungi are set to begin.

Conclusion

It is crucial that experienced scientists with a horticultural or agricultural background accompany projects like MoPlaSa. Unexpected findings, which are not unusual in a project dealing with a so far little investigated pest, have to be identified and assessed. In this case, phenological and biological parameters of *R. batava* are being investigated closely and further tests will have to be adapted in the light of these studies. Implementation of the planned module-based measures through field tests alone is not sufficient as underlying variability of the pupae can greatly impact the results of a given control measure taken. Additional experiments conducted under controlled environmental conditions therefore have to be carried out e. g. identifying visible attributes for fitness of the pupae can help improve the reliability and reproducibility of field results. It is thus crucial that projects like MoPlaSa are open to early and short-term adjustments when the first generated data reveal findings which demand a new or modified approach.

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