Deliverable summary D6.1

Review of classical biological control successes and failures against forest PnPs

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1. Summary

Classical biological control (CBC), i.e. the introduction of natural enemies from the region of origin, has proven to be an efficient and cost-effective tool to control invasive pests worldwide. However, a global analysis of the trends in the CBC of insect pests by insects revealed that the success of introduced agents in completely controlling a target is only about 10% (Cock et al. 2016). About 55% of these introductions were made against pests of woody plants, for which the overall success rate tends to be higher than for pests of herbaceous plants (Kenis et al. 2017).

The relatively low success rate begs the questions (1) what are the factors affecting the success of biological control introductions and (2) what can be done to increase the success? Therefore, the main objective of this study was to review and analyse the successes and failures of previous CBC projects against invasive pests to suggest approaches for improving the success of CBC.

A literature review about the factors that can affect the success of biological control introductions identified five main aspects of CBC in which the factors can be classified. The first three concern biotic factors such as life-history traits and interactions between the three trophic levels involved in CBC, namely (1) biocontrol agents, (2) targets, and (3) target plants. Furthermore, (4) abiotic factors, such as climate, may further influence the success, as well as (5) management strategies, e.g. procedures of agent selection, rearing, release, and post-release studies. In most cases, factors within these aspects have been studied independently, for example, the comparison of the success in CBC using predators or parasitoids as agents. While this can be informative, the relative importance of these factors within the complexity of CBC programmes and its aspects remains unknown. Therefore, the analysis in this report aims at taking a more holistic view of the factors that may impact the success or failure of biological control introductions, even if it is restricted to readily available information from the literature.

The main objective of this study was to review the successes and failures of previous CBC projects against invasive pests using the BIOCAT catalogue of biological introductions (Cock et al. 2016) to suggest approaches for improving the success of biological control introductions. We decided not to restrict the analysis to forest pests because the general principles of CBC and the biological traits of agents and targets are the same for all crop systems and there is much to learn from biological control introductions against agents feeding on herbaceous plants.

To this end, we filtered the BIOCAT2010 database (Cock et al. 2016) to extract entries for the Western Palearctic ecozone and added 15 new variables that were either populated based on existing variables in the database or based on information from published peer-reviewed scientific literature or available grey literature (i.e. reports). The new variables mainly concerned traits of agents, targets, and target host plants, but also included the number of repeated introductions of a specific agent against a target species as a management aspect. Summary statistics were then calculated to describe the general trends of success in CBC in the Western Palearctic ecozone at three levels: agent establishment, impact on the target population (partial to complete control of the target), and complete control of the target (no other control methods needed). For the holistic analysis of factors significantly influencing the success, we analysed the extended BIOCAT2010 database using separate logistic regressions for the three levels of success as dependent variables and nine explanatory variables as well as four interaction terms. A separate set of three logistic regressions with three additional explanatory variables was conducted for only parasitoids as biological control agents.

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The full models were then submitted to stepwise backward model selection and the selected variables were analysed for their impact on the success of biological control introductions.

Between 1890 and 2010 a total of 780 introductions of insects for biological control were undertaken in the Western Palearctic ecozone. These introductions were conducted for 416 agent-target combinations. The majority (70%) of the targets were pests on woody plants and citrus was the most dominant crop on which targeted pests fed. The overall success of agent establishment was 31.7% and the overall success of control was 10.8%.

Establishment of introduced predators and parasitoids was only significantly influenced by one agent-related and three target-related factors: The odds of establishment decreased when agents were predators, when targets attacked reproductive plant parts, or shoots and reproductive plant parts. On the other hand, for endophagous targets, the odds of establishment increased with each repeated introduction of the same agent species against a target. The results for impact and complete control were quite similar: in both cases, univoltine targets decreased the odds of success but significantly increased them with each repeat- introduction of the same agent species against a univoltine or sap-feeding target. Additionally, oligophagous agents decreased the chances of successful complete control of a target.

For parasitoids, with each repeat-introduction of an agent species against a specific target, there was a significant increase in the odds of success of agent establishment and complete target control. Parasitoids of endophagous and sap-feeding insects established more successfully, but parasitoids of targets feeding on reproductive plant parts established less successfully. Univoltine targets significantly decreased the odds of parasitoids' impact on targets and complete target control. However, similar to predators and parasitoids together, the odds of target control increased with each repeat-introduction against univoltine targets. And also for parasitoids alone, oligophagous agents decreased the odds of complete target control.

In general, the results of the logistic regressions showed that remarkably few agent-related factors significantly influenced the success of CBC. This finding suggests that a focus on agent-related traits is not justified and should be redirected to lower trophic levels and other aspects of CBC, such as abiotic factors (i.e. climate) and management (e.g. release procedures).

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