State and development of tools for the Flavescence dorée management in Switzerland

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Abstract: In Switzerland, *Scaphoideus titanus* was recorded first in Canton of Ticino (Swiss canton in the South of the Alps) in the 1967 and only in 1996 in the Canton Geneva, from where it began to colonize the vineyards along the Leman Lake, reaching today the vineyards of the Valais Canton. Flavescence dorée (FD) was first recorded in 2004 in Ticino. In 2015, the disease was found for the first time in the Canton of Vaud and in 2016 in the Canton of Wallis. The vineyards of the North site of the Leman Lake and in the West part of Switzerland are still free of *S. titanus* and FD.
FD complex is high in uncertainties and to solve this complexity we applied an Adaptive Management (AM) framework, which is appropriate for complex problems high in uncertainties. This approach allows to increase the knowledge for *S. titanus* management and to learn how a system works and it permitted to develop the necessary tools for *S. titanus* management and for the landscape analysis.
The tools consisted in: i) sampling plans for estimating nymph densities of *S. titanus* in the canopy and improving techniques and methodology in population system study and management. ii) a phenology model, based on time-varying distributed delays, integrated in a Decision Support System (DSS) called PreDiVine. The model is the entry point into the AM system for improving its explanatory and predictive capabilities. It operates at the interface between research and pest management, establishes a close-loop between monitoring, management and analysis of systems and automatically improves the reliability of pest control relevant predictions as soon as additional information becomes available, iii) an age-structured multigenerational model of *S. titanus* populations to increase the knowledge into the dynamic of its populations. This model is useful to organize monitoring activities, to follow the stability of multi-annual occupancy of the vineyard, to control the colonization potential and to develop control strategies, iv) a landscape analysis tool to quantify alternative host plant and vectors as basis for the development of a risk analysis system.
PreDiVine has proved to be a robust DSS able to provide accurate predictions already starting from a zero-knowledge condition of the site and, at the same time, being flexible by re-using the data collected every year to self-improve the system calibration for future real-time predictions (see abstract and poster of Prevostini *et al.*).
The development of the multigenerational model of *S. titanus* has showed how many aspects of its biology are still poorly known. The first step was to quantify the longevity, fecundity, egg oviposition duration and rate of females. The results suggest that *S. titanus* prefers relatively mild climates and they could contribute to explain its distribution area in Europe (see abstract and poster of Rigamonti *et al*.).
The landscape analysis associated with a molecular epidemiology approach has shown that the FD complex could be considered as an open system. In such a situation, we have the

necessity to develop a risk analysis system and to move from a concept of eradication of *S. titanus* to one of sustainability (see abstract of Jermini *et al*.).
In conclusion, the AM framework was adequate to deal with high uncertainties associated with the complexities of the FD system. It permitted a continuous improvement of techniques and methodologies, improved the insight into the dynamics of infestation patterns, rationalized control operations and prepared the ground for further activities aiming at the study and management of populations and vector(s)-host plants-FD disease systems. In particular, the results obtained show that AM actively generated information and appears as management with a plan for learning.

Highlights: The Flavescence dorée complex is high in uncertainties and to solve this complexity we applied an Adaptive Management (AM) framework. The AM framework has permitted to develop tools for the management of Scaphoideus titanus and the basis for a landscape analysis. The knowledge of the landscape composition and the leafhopper population present is the basis the study and management of populations and vector(s)-host plants-FD disease systems.