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Exploit biodiversity in viticultural systems to reduce pest damage and pesticide use, and increase ecosystem services provision – BIOVINE

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Abstract: Organic vineyards still rely on large external inputs to control harmful organisms (i. e., pests). The BIOVINE project is developing natural solutions based on plant diversity to control pests and reduce pesticide dependence. The capability of plants of increasing the ecosystem resistance to pests and invasive species is a well-known ecosystem service. However, monocultures (including vineyards) do not exploit the potential of plant diversity. BIOVINE aims to develop new viticultural systems based on increased plant diversity within (e. g., cover crops) and/or around (e. g., hedges, vegetation spots, edgings) vineyards by planting selected plant species for the control of arthropods, soil-borne pests (oomycetes, fungi, nematodes), and foliar pathogens. Candidate plants were identified by literature review, and the selected ones were tested in controlled environment or small-scale experiments. The ability of the selected plants to: i) attract or repel target arthropod pests; ii) conserve/promote beneficials; iii) control soil-borne pests by mean of biofumigation; iv) carry mycorrhizal fungi to vine root system to increase plant health (growth and resistance); v) control foliar pathogens by reducing the inoculum spread from soil, were investigated. New viticultural systems able to exploit plant diversity were then designed following a design-assessment-adjustment cycle, which are under testing in in-vineyard experiments in France, Italy, Romania, Spain and Switzerland for a 2-year period. Innovative viticultural systems should represent an improved way for pest control in organic viticulture, meanwhile they should positively affect functional biodiversity and ecosystem services. New control strategies may provide financial opportunities to vine growers and lower their reliance on pesticides. Preliminary results of the first round of *on-farm* vineyard experiments are presented and discussed.

Key words: viticulture, cover crops, innovative, fungi, pests, beneficials

Introduction

Functional diversity (FD) is a component of biodiversity that specifies the roles that organisms play in communities and ecosystems (Petchey and Gaston, 2006). FD studies have mainly focused on how species influence ecosystem functioning and respond to environmental changes (Hooper et al., 2000). FD is important in maintaining or increasing ecosystems services (ESs) (Hooper et al., 2005), defined as the benefits that the ecosystems provide to humans (Millenium Ecosystem Assessment, 2005). Balvanera et al. (2006) conducted a meta-analysis of the literature over a 50-year period, analysing 446 measures of biodiversity effects on ecosystem functioning, provision of ESs, and human well-being. The same study showed that biodiversity has positive effects on most ESs, including ecosystem resistance to pests (greater diversity of plants results in lower damage to plants) and invasive species (plant biodiversity reduces success of invaders). Plant diversity has also potential of naturally controlling arthropod pests and plant pathogens.

Natural control of pests in agro-ecosystems is a well-known ES. Non-crop habitats provide the habitat and diverse food resources required for natural enemies of agricultural pests (arthropod predators and parasitoids, insectivorous birds and bats), and provide biological control services (Tscharntke et al., 2005). Evidence suggests that management systems emphasizing crop diversity through the use of polycultures, cover crops, crop rotations and agroforestry, around or within the crop, can often reduce the abundance of insect pests that are specialized on a particular crop, while providing refuge and alternative prey for natural enemies (Andow, 1991). In contrast, monocultures provide abundant food to specialized pests and have a negative impact on their natural enemies because of the lack in adequate food sources (Balmer et al., 2013). A sustainable use of FD by providing habitats to conserve these functions is therefore needed (Bianchi et al., 2013).

FD can also play a role in the control of soil-borne pathogens and nematodes, by two mechanisms: biofumigation and reduction of inoculum load. Different cultivars or plant parts of commonly used biofumigant plants (e. g., mustards, radishes and rocket species) contain different glucosinolates, which hydrolysis results in different toxic isothiocyanate compounds (Potter et al., 2000). There are various reports of soil-borne plant disease suppression with biofumigant plants (Matthiessen and Kirkegaard 2006; Motisi et al., 2010). Important groups of pathogens were fungi and species of endoparasitic and semi-endoparasitic nematodes, whereas there was less emphasis regarding the effect of biofumigation on free-living nematode species.

Relevant fungal pathogens of grapevine produce inoculum (spores) on plant debris present on the soil surface of vineyards. These spores reach plant surfaces through rain splashes and/or air currents. Ground cover has therefore been indicated as an efficient way to limit splash dispersal in several crops (e. g., *Septoria tritici* on wheat crops, Bannon and Cooke, 1998; *Colletotrichum acutatum* on strawberry, Ntahimpera et al., 1998), but these preventive practices have never been explored in detail for the management of key fungal pathogens in viticulture.

The majority of cultivated plants have developed the ability to establish a mutualistic symbiosis with AMF by developing a very thin and branched mycelial network. This kind of network strongly increases the plant's nutrient prospecting area and the mobilization of immobile nutrients in soil, consequently having a beneficial effect on plant production. In viticulture, AMF increases grapevine growth and nutrition, improves soil structure and stability, improves the tolerance to abiotic stresses and protects the roots against soil pathogens or root diseases, which is considered as a beneficial ES. However, studies on the diversity of AMF able to connect grapevine to plants covering the vineyard soils and their role in the transfer of signaling and plant defense molecules in vineyards are not available. Thus, the effect of plant diversity could also be explored in its relation to arbuscular mycorrhizal fungi (AMF), belonging to the phylum of Glomeromycota.

All these considered, the BIOVINE project was organized and funded in order to develop new viticultural systems based on increasing plant and functional diversity within (e. g., cover crops) and around (e. g. hedges, vegetation spots, edgings) the vineyards by planting plant species. The main hypotheses underpinning the project suggests that these species should be able to contribute in: i) controlling the pest populations (pest = any organism harmful to plants and plant products, including oomycetes, fungi, bacteria, nematodes and arthropods), ii) reducing the pest damages, iii) reducing the pesticide use, and iv) increasing the ecosystem services provided.

Material and methods

The project involves six Partners from different Countries (Italy, France, Romania, Spain, Slovenia and Switzerland), which account for more than 90 % of the EU28 total surface of organic viticulture (FiBL 2016, www.fibl.org). BIOVINE project is organized in 7 work packages (WPs), closely related together (Figure1), and each led by a competent partner: UCSC (Italy), INRA (France), SCV (Romania), UPV (Spain), KIS (Slovenia) and Agroscope (Switzerland).

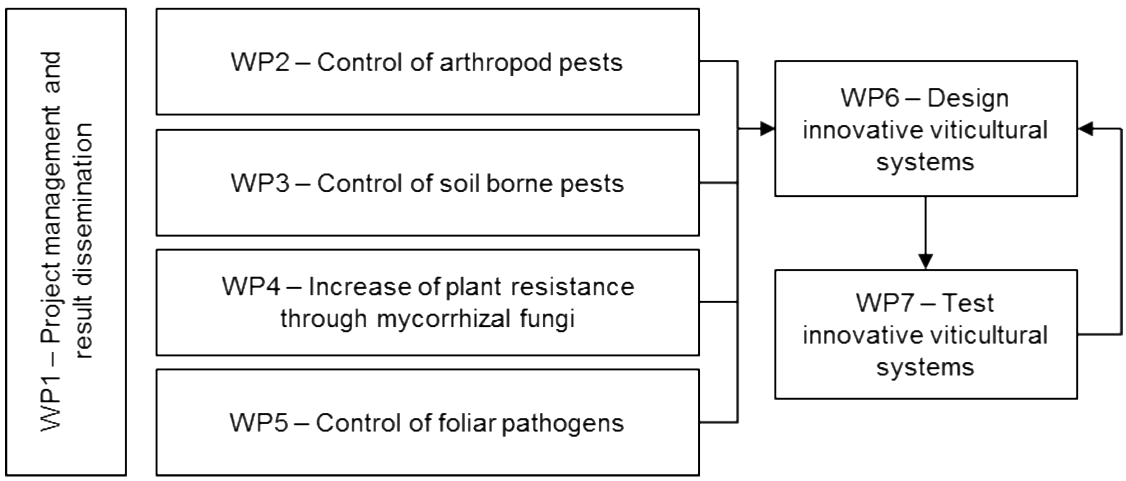

Figure 1. Pert diagram of the BIOVINE Project

Systematic literature review and meta-analysis were conducted for identification of cover crop plants able to i) repel/attract target pests (e. g., *Lobesia botrana*, *Drosophila suzukii*); conserve/promote beneficials; ii) control soil-borne pests (*Xiphinema index* nematode, the vector of the Grapevine fanleaf virus, GFLV), root and wood pathogens (*Phaeomoniella chlamydospora*, *Phaeoacremonium* spp., *Cylindrocarpon*), soil-transient pathogens (*Plasmopara viticola*); iii) carry mycorrhizal fungi to the vine through a Common Mycelial Network; iv) control pathogens producing spores on plant debris (e. g., *P. viticola*, *Botrytis cinerea*, *Guignardia bidwellii*).

Identified cover crop plants were then planted in different experimental fields for different purposes listed above. Several trapping and spraying methods were used for pest management. These experiments were conducted by Agroscope, SCV and KIS jointly. In order to assess root/wood pathogens and nematode population, soil and root samples were collected from all the fields (all partners) and analyzed by KIS and UPV. Cover crop root samples also were assessed for availability of arbuscular mycorrhizal fungi (AMF) development by INRA.

In order to evaluate spore dispersal by rain splashes and win currents, experiments were designed in small plots at UCSC (Caffi and Rossi, 2008). For instance, spore traps were set at different height and distance from pathogen inoculated wood parts and weekly collection of traps was performed. Obtained samples were sent to UPV for DNA extraction, and subsequent pathogen identification and quantification by qPCR methods developed for the target fungal species.

Innovative viticultural systems developed by all partners, were tested in on-farm experiments carried out in Italy (Piacenza), France (Bordeaux), Romania (Murfatlar), Spain (Utiel-Requena and Benitatxell), and Switzerland (Changings). Innovative systems were applied on large plots (homogeneous for variety, plant age, training system, and terroir) and compared with the current practice for organic farms. In the *on-farm* experiments, four different strategies were compared: i) an innovative strategy based on autumn sowing of the cover crop (species or mixture), ii) an innovative strategy based on spring sowing of the cover crop (species or mixture), iii) the farm practice based on the usual approach representative of the region, and iv) untreated control. Effectiveness of the different systems was evaluated during the grape-growing season. Disease progress was assessed as incidence and severity of symptoms on trunks, canes, leaves and/or bunches, depending on the disease, based on specific protocols. For assessing the growth stage of cover crops, suitable scales have been developed following the BBCH approach; for the development, the biomass of the plants or particular plant parts (e. g. flowers) have been determined by sampling and measuring and/or weighing. Physio-chemical properties of grape samples from different plots, such as sugar content, pH and titratable acidity were measured as well. During the season, vineyards were monitored periodically, and scouting was performed in each plot (conventional and innovative) at least once a week. During each visit phenological stages and incidence/severity of occurring diseases (on leaves and bunches) was recorded.

All the different experiments set up during the BIOVINE project in each Partner Country are listed in Table 1.

Table 1. Ongoing experiments measuring cover crop effects on several aspects of the viticultural ecosystem. Small scale experiments were developed in specific WP, while the vineyard experiments were set up within WP7.

	Italy (UCSC)	**Switzerland (Agroscope)**	**Spain (UPV)**	**Slovenia (KIS)**	**Romania (SCV)**	**France (INRA)**
Small scale experiments:						
Lobesia botrana (repellent effect)		✓			✓	
Drosophila suzukii (attractive sp.)		✓				
Promoting beneficials (predators and parasitoids)		✓				
Foliar pathogens (*P. viticola, B. cinerea, G. bidwelii*)	✓		✓			
Trunk pathogens (*P. chlamydospora, Phaeoacremonium* spp.)	✓		✓			
Vineyards experiments:						
Arthropods (pests and beneficials)	✓	✓	✓		✓	✓
Foliar pathogens (*P. viticola, B. cinerea, G. bidwelii*)	✓	✓	✓		✓	✓
Nematode (*X. index*)	✓	✓	✓	✓	✓	✓
Trunk pathogens (*P. chlamydospora, Phaeoacremonium* spp.)	✓	✓	✓		✓	✓
Arbuscular mycorrhizal fungi (AMF) colonization	✓	✓	✓		✓	✓
Ecosystem services	✓	✓	✓	✓	✓	✓

Results and discussion

Preliminary results from the growing season 2019 showed interesting differences between different cropping systems and also between treated and untreated plots. For instance, the effect of the different cover crops was quite visible in the case of soil-transient pathogens, like *Plasmopara viticola*. In fact, the first seasonal symptoms of downy mildew appeared from five days to two weeks later in the plots sown in autumn with cover crops compared to the other soil managements options (Figure 2). On the contrary, in the case of a pathogen like *Erysiphe necator*, which overwinters on the grape barks as chasmothecia and has less or no obstacle in its dispersal caused by the cover crops, the first symptoms are appearing more randomly during the season in the different vineyard, with no clearly differences due to the soil cover (not shown).

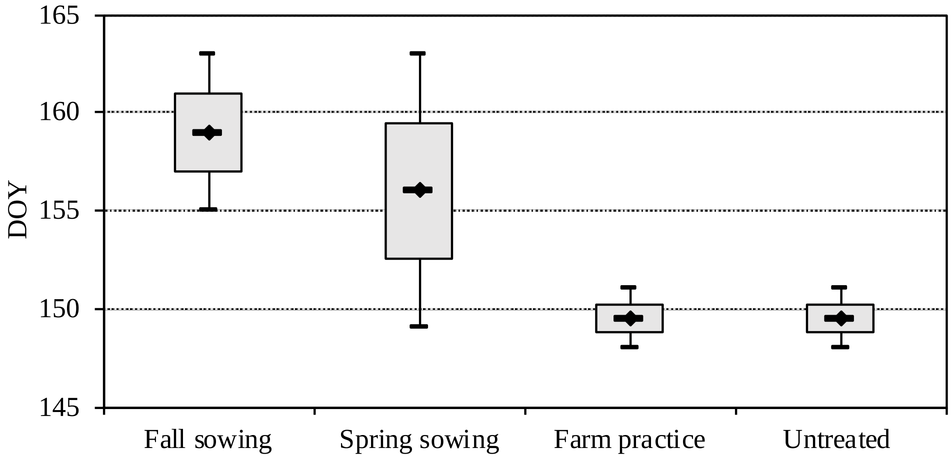

Figure 2. Box plot of the first symptoms onset of downy mildew in the different experimental vineyards: boxes contain 50 % of the observed cases, the line (—) is the median date, dot (•) is the mean, whiskers are the minimum and maximum observed. The onset dates are expressed as day of the year (DOY).

Conclusion

The preliminary results obtained during the first half of BIOVINE project show that there is a genuine potential to develop new viticultural systems based on increased plant diversity within (e. g., cover crops) and/or around (e. g., hedges, vegetation spots, edgings) vineyards by planting selected plant species. These species have potential to contribute to the control of arthropods, soil-borne pests (oomycetes, fungi, nematodes) as well as foliar pathogens and thereby increase economic, social and environmental sustainability of organic vineyards. It will subsequently lead to higher income and satisfaction of organic winegrowers. Further experiments will be conducted in the second half of project.

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