

20th GiESCO International Meeting

Mendoza, Argentina
November 5th – 10th 2017

20^{ma} Reunión Internacional de GiESCO

*Mendoza, Argentina
5 -10 de noviembre de 2017*

Book of Full Manuscripts / *Libro de Manuscritos Completos*

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SPONTANEOUS COVER-CROP CHARACTERIZATION IS RELEVANT TO DEFINE A SUSTAINABLE SOIL MANAGEMENT STRATEGY IN VINEYARD

CARACTERISER L'ENHERBEMENT SPONTANE EST PERTINENT POUR DEFINIR UNE STRATÉGIE DE GESTION DU SOL DURABLE EN VIGNOBLE

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Abstract

Spontaneous cover cropping is a common practice in Mediterranean vineyards because it is often seen as less competitive and easier to manage than sown covercrops. However, the services provided by the spontaneous flora highly depend on the species, these latter being influenced by the soil management practices. This study analyzes the specific and functional composition of the vineyard flora as influenced by three soil management strategies. To do so, weed cover was sampled at 5 dates during two years after the settlement of the experiment in a vineyard in the South of France. The three soil management treatments were: a control treatment (C) corresponding to a spontaneous cover regularly mowed, a spontaneous cover with organic amendment application each year (OF) and a green manure (*Vicia faba*) sown in autumn and incorporated at budburst (GM). 122 different species corresponding to 27 families, were identified (25 to 41 different species per treatment at a date), with only five species in more than 50% of the quadrats, while a majority of species, 85 out of 122 were present in less than 10%. The functional approach allows characterizing spontaneous vegetation according to species trait values and the ecosystem services they may provide: for example, the species being uncompetitive for vineyards while improving soil fertility are *Crepis foetida* and *Lactuca serriola*. On the contrary, species such as *Geranium rotundifolium* are more competitive and less interesting for soil fertility. This study contributes to a first identification of the soil management practices that can drive the trajectories of the spontaneous flora towards the best composition, hereby contributing to design more sustainable grapevine systems.

Keywords: cover crop, weeds, ecosystem services, organic fertilization, green manure

Résumé

L'enherbement spontané est une pratique courante dans les vignobles méditerranéens, car il est souvent considérée comme peu compétitif et plus facile à gérer que les enherbements semés. Cependant, les services fournis par la flore spontanée dépendent fortement suivant les espèces. Cette étude analyse la composition spécifique et fonctionnelle de la flore du vignoble sous l'influence de trois stratégies de gestion des sols. Pour ce faire, 5 inventaires floristiques ont été réalisés sur deux ans dans un vignoble du sud de la France. Trois stratégies de gestion des sols ont été comparées: un traitement de contrôle (C) correspondant à un couvert spontané régulièrement tondu, un couvert spontané avec amendement organique annuel (OF) et un engrais vert (*Vicia faba*) semé en automne et détruit à débourrement (GM). 122 espèces différentes correspondant à 27 familles ont été identifiées (25 à 41 espèces différentes par traitement à une date), avec seulement cinq espèces dans plus de 50% des quadrats, alors qu'une majorité d'espèces, dont 85 parmi 122 étaient présentes à moins de 10%. L'approche fonctionnelle permet de caractériser la végétation spontanée en fonction des valeurs des caractéristiques des espèces et des services écosystémiques qu'elles fournissent: par exemple, certaines espèces recensées sont identifiées comme peu compétitives pour la vigne et utiles pour l'amélioration de la fertilité du sol: *Crepis foetida* ou *Lactuca serriola* par exemple. *Vicia Faba* a une position intéressante, avec la note maximale pour la fertilité des sols et une note nulle pour la compétition avec la vigne. Au contraire, des espèces parmi les plus présentes dans la flore sont plus compétitives et moins intéressantes pour la fertilité des sols comme *Geranium Rotundifolium* par exemple. Cette étude contribue à une première identification des pratiques

de gestion des sols qui peuvent modifier la flore spontanée vers une composition plus intéressante en termes d'espèces, contribuant ainsi à concevoir des systèmes de vigne plus durables.

Mots-clés: cultures de couverture, adventices, services écosystémiques, fertilisation organique, engrais vert

Introduction

The challenge of managing agrosystems, particularly vineyards, is to increase production and restore ecological functions by increasing biodiversity in all its components (Zhang *et al.*, 2007). Cover cropping in the vineyard consists in maintaining a spontaneous or sown plant cover between the rows of the vines and / or in the intercepts (ITAB, 2003). Covercrops in vineyards may contribute to essential services such as water infiltration nutrient supply and retention, carbon sequestration and reduction of soil erosion (Ruiz-Colmenero *et al.*, 2013; Salomé *et al.*, 2016; Steenwerth and Belina, 2008). Recently (Salomé *et al.*, 2016) demonstrated that the presence of a cover crop, even temporary, in the inter row, benefits soil functioning whatever the soil type whereas organic fertilization for example exhibits contrasting results on soil functioning. Wine growers in Mediterranean regions are nevertheless reluctant to use covercrops, due to concerns about water competition between covercrops and grapevines (Celette and Gary, 2013) even if, during the last years, the use of cover cropping has increased in Mediterranean vineyards (Mercenaro *et al.*, 2014). Trade-offs between competition for resources and services provided by cover crops have to be reduced (Guilpart and Gary, 2017) through adapted cover crop management. Several strategies of cover cropping are possible: temporary or permanent, total or partial, sown or spontaneous, depending on the soil and climate conditions and the grapevine yield objectives. Spontaneous cover cropping consists in allowing the natural flora to develop in the inter-rows and / or in the rows of the vineyard, during the winter period or throughout the year: consequently, spontaneous cover treatment can be chosen as a costless trade-off for the winegrowers between improving soil properties, limiting mechanical work and maintaining vine production (Kazakou *et al.*, 2016). In the Mediterranean region, where competition for water and nutrients are often feared by the winegrowers, this strategy seems to be more adapted. A recent regional survey in the Languedoc Roussillon region in the South of France (Frey, 2016) showed that in 2015, 40% (of the 334 interviewed winegrowers) left spontaneous covercrops grow in their vineyard during winter. However, the spontaneous flora is very diverse and control of weed populations is essential in order to optimize the supply of ecosystem services, while minimizing competition with the vine. Indeed, a limitation of using plant cover (spontaneous or sown) is the competition for resources, including water, soil nutrients and light, which can compromise vineyard vigor, at least over the short term before possible accommodation (Kazakou *et al.*, 2016). In this study, we analyze the flora composition and functioning in response to three soil management treatments in vineyards. We combine a classical flora inventory approach and an original method based on functional traits values to assess the potential effect of the flora on the grapevine.

Material and Methods

The experiment was carried out on a vineyard located near Montpellier (Domaine du Chapitre) in the south of France (43°32'_N; 3°50'_E). The climate was Mediterranean with a mean annual rainfall of 700–750 mm. Grapevines (*Vitis vinifera* L. cv. Mourvèdre) were planted in 2008, at a density of 3300 stocks per hectare (2.5 m × 1.2 m). Soil was a deep, calcareous (mean total CaCO₃: 10%) fluvisol (FAO classification) with a clay loam (30% clay, 40% silt and 30% sand) texture, containing less than 5% of coarse elements. Mean organic matter content was about 1.5% and total nitrogen was 0,8 g kg⁻¹ over the top soil layer (0–30 cm). In June 2015, three different soil management strategies in the inter-rows were designed as part of the European project FertilCrop (www.fertilcrop.net) so as to evaluate different levers for building fertility in soils and to assess consequences on the flora: spontaneous cover crops with regular mowing after budburst considered as the Control (C) treatment, spontaneous flora with organic amendment (OF) applied to the soil once a year (2,1 Mg ha⁻¹, Orgaveg 65 fermented plant based pulp and composted sheep manure) and a green manure (GM) treatment. The green manure treatment consisted in sowing *Vicia faba* in the inter-rows after grapevine harvest and mowing it at budburst.

Flora sampling strategy

The flora of the inter-rows of each treatment were identified 5 times during autumn (2) and spring (3): June 2015, at the settlement of the experimentation (last time the C treatment was tilled), November 2015, March 2016, June 2016 and early December 2016. Each time, the same 10 fully randomized quadrats (1m²) per treatment were characterized: the species were identified and their respective cover rate estimated visually.

Trait and species analysis

To assess the effect of the flora on the grapevine and, particularly, the soil fertility building and the risk of competition, we chose traits reflecting species morphology, phenology and reproduction: mean height, specific leaf area, flowering starting month, flowering duration and leaf dry matter content, as explained in Table 1. Trait values were obtained in standardized international traits database: TRY (Kattge *et al.*, 2011). Due to the large number of species (see Results), we chose to focus on the 25 most frequent species found in the inter-rows of the vineyard. Based on these trait values, we built two indicators: a fertility index and a competitiveness index. On the one hand, we assumed that mean height, specific leaf area, flowering starting date and flowering duration are traits relevant to explain the level of competitiveness of a species relative to the vine. On the other hand, we hypothesized that LDMC and LNC which are related to the rate of decomposition of the litter and thus the rate of release of mineral elements, explain the service of short term fertility building of the soils. Thus, two scores were assigned to each species, with each grade depending on the functional trait values: a competitiveness score corresponding to the sum of the scores for mean height, leaf area, flowering time and date (the higher the value, the lower the competition for the vine), and a Fertility score, related to leaf dry matter and nitrogen content values (the higher the value, the bigger the effect of fertility building) (Table 1). Before plotting the scores of the most frequent species, we normalized the score S_i (as follows: $S_{i,norm} = (S_i - \text{mean}(S)) / \text{Standard deviation}(S)$).

Results and Discussion

The composition of the flora in the vineyard's inter-rows, throughout the experiment, is summarized in Table 1: for the 150 quadrats observed, we identified 122 sp. in 27 families. The most frequent families are Asteraceae, Poaceae and Fabaceae in terms of number of species, and Asteraceae, Poaceae and Euphorbiaceae in frequency of observations. The Asteraceae family clearly dominates the flora, with 43 species identified, and a mean cover rate of 5% of the soil surface (from 1 up to 60% of the soil surface). The most frequent species are *Galium parisiense*, *Euphorbia segetalis*, *Erigeron sumatrensis*, *Carduus pycnocephalus*, and *Convolvulus arvensis* which are present in 93%, 79%, 71%, 63% and 57% of the 150 quadrats respectively. Regarding the abundance, *Vicia faba*, when present in the GM treatment, represents a mean cover rate of 50% (with high heterogeneity from 10% to 90% due to difficult conditions of emergence in 2016) while *Erigeron sumatrensis* and *Galium parisiense*, which are very widespread, only stand for 12 and 10 % of the soil coverage respectively. As expected, most of the species we identified are frequent in vineyards, particularly in the Mediterranean (Gaviglio, 2013).

Dynamics analysis of the composition: the five flora samplings allow analyzing the dynamics of the flora composition during the first two years after the introduction of the treatments (Table 3). We notice that the specific richness (number of species) is always higher all through the 5 sampling dates for GM and OF treatments in comparison with the Control. This result is contradictory with some recent studies (Steenwerth *et al.*, 2016) proving the strong filter effect of sown species on weed communities, decreasing all components of diversity. We may assume it is due to the low development of *Vicia faba* in 2016 and the duration of the experiment.

A complementary analysis (Durocher, 2016) on the June 2016 database, to identify the “indicator species” that is to say the species characteristic of a group of ecological sites (Dufrêne and Legendre, 1997) showed that even after one year, in June 2016, the treatments had already a filter effect on the plant community. For example, *Sonchus oleaceus* was found to be significantly associated to the GM treatment, while *Aster squamatus*, *Centranthus calcitrapae* and *Crepis foetida* were significantly associated to the OF treatment, the most common species, *Galium parisiense* and *Erigeron sumatrensis* being still undifferentiated. But these conclusions have to be taken cautiously for they may reflect local soil effects and consequences on seed banks or previous cropping systems' effect.

The position of the 25 most frequent species on the 2-axis figure 1 represents a simple but easy-reading functional approach of the species and allows characterizing spontaneous vegetation according to species trait values and the ecosystem services they may provide. This figure may help to identify the species which meet the trade-off between low competition for the vine, and high fertility building potential. For example, the species being uncompetitive for vineyards while improving soil fertility found in our plots are *Crepis foetida*, *Lactuca serriola*. *Vicia Faba* has an interesting position in the figure showing high fertility building index and close to 0 competitiveness index. On the contrary, species such as *Veronica persica* or *Geranium rotundifolium* seem to be more competitive and less interesting for soil fertility building. A further step would consist in (i) testing the sensitivity of these indicators to the services they are supposed to be related with and maybe revising the scoring method, and (ii) using this approach at the community scale level, using the Community Weight Mean, CWM)

(Garnier *et al.*, 2004). This method may help to situate the community, resulting from the soil management practices on this 2-axis figure so as to identify which communities are potentially more favorable to the vine.

Conclusion

This study contributes to a first identification of the soil management practices that can drive the trajectories of the spontaneous flora towards the best composition, hereby contributing to design more sustainable grapevine systems. After two years of differentiation between treatments, we note an evolution of the flora of inter-rows of the vineyard with some species significantly associated to green manure or organic fertilizer treatments. This experiment must be continued in order to evaluate the effects of inter-row maintenance on the flora on the long term. Then, the positioning of the species in the trade-off space proposed in this study allows identifying the species that are the most interesting in terms of soil fertility building and the least competitive in the vine.

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Table 1: Traits obtained in TRY (Kattge *et al.*, 2011) and relating score attribution, considering its effect on soil building fertility and competitiveness with the grapevine.

Traits	Score depending on the value of the trait	Relevance to assess the effect on the vine
Mean height (m)	<0,20 : 3; 0,20-0,40 : 2,3; 0,40-0,60 : 1,6; >60 : 1	high: competition for light (Westoby <i>et al.</i> , 2002) positively correlated to root length (Schenk and Jackson, 2002)
Specific leaf area (mm ² mg ⁻¹)	<20 : 3; 20-30 : 2; > 30 : 1	Competitive growth (Damour <i>et al.</i> , 2015)
Flowering starting month (month)	before may : 1; may : 2 after may : 3	Early flowering before grapevine flowering (june) may create competition for water and nutrients (Celette and Gary, 2013; Spring and Delabays, 2006)
Flowering timelapse (months)	< 3 months : 3; 4-5 months : 2; > 6 months : 1	Hypothesis: Long-lasting flowering may create long-term competition
Leaf Dry Matter Content (LDMC) (g/g)	< 0,15 : 3; 0,15-0,20 : 2;> 0,20 : 1	Negatively correlated with decomposition rate (Fortunel <i>et al.</i> , 2009) High LDMC : nutrient immobilization (Lavorel and Grigulis, 2012)
Leaf Nitrogen Content (LNC) (mg/g)	< 20 : 1; 20-30 : 2; > 30 : 3	High LNC : high nutrient restitution to the soil (de Bello <i>et al.</i> , 2010)

Table 2: Flora overview: total number of species observed, total number of families and relative proportions of families (in number of species and abundance)

Main families in number of sp. (10 first)	% number of species	Main families in presence frequency (10 first)	% presence
Asteraceae	35,0%	Asteraceae	34,3%
Poaceae	13,0%	Poaceae	9,3%
Fabaceae	7,3%	Euphorbiaceae	8,6%
Geraniaceae	4,9%	Rubiaceae	8,2%
Brassicaceae	3,3%	Geraniaceae	5,8%
Caryophyllaceae	3,3%	Convolvulaceae	5,1%
Euphorbiaceae	3,3%	Apiaceae	4,0%
Plantaginaceae	3,3%	Caryophyllaceae	3,3%
Caprifoliaceae	2,4%	Malvaceae	2,8%
Papaveraceae	2,4%	Papaveraceae	2,7%

Table 3: Total number of species observed per treatment for each sampling date. GM: Green Manure treatment (*Vicia Faba*), OF: Organic Fertilizer treatment; C: Control treatment

Treatment	Total number of species observed per treatment observed at each date				
	Jun-2015	Nov-2015	Mar-2016	Jun-2016	Dec-2016
C	25	25	34	25	32
GM	35	37	38	35	41
OF	26	41	41	34	34

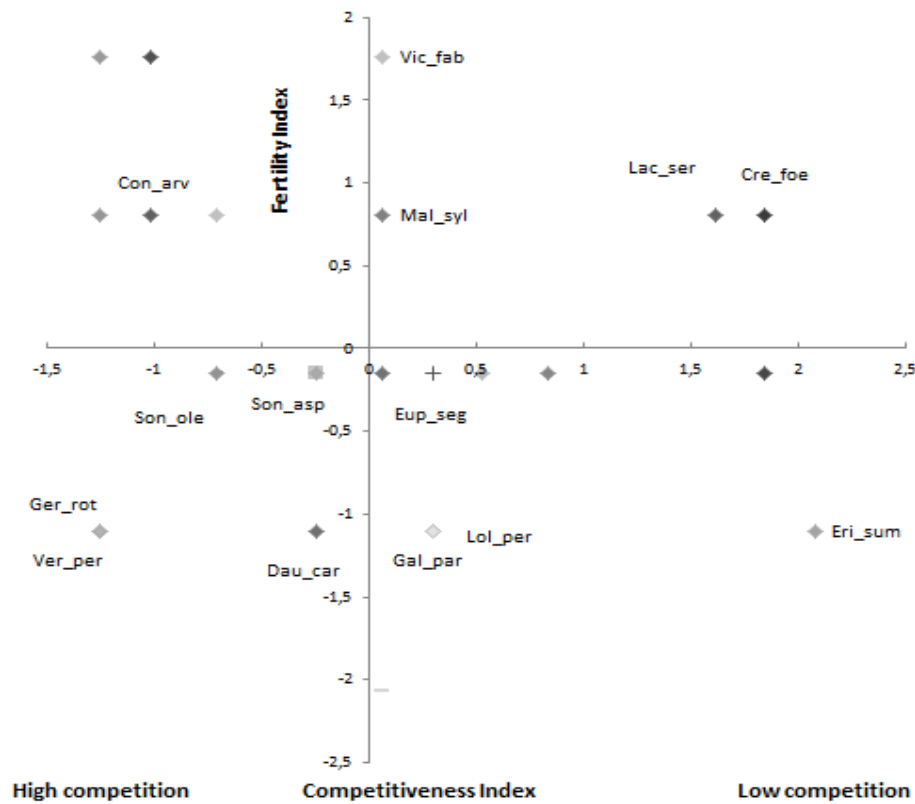


Figure 1: Competitiveness index and Fertility index for the 25 most frequent species. A high competitiveness index means low competition for the vine. To keep the figure readable, only the most frequent or the most discriminate species on the figure have captions. Con_arv: *Convolvulus arvensis*; Cre_foe: *Crepis foetida*; Dau_car: *Daucus carota*; Eri_sum: *Erigeron sumatrensis*; Eup_seg: *Euphorbia segetalis*; Gal_par: *Galium pariense*; Ger_rot: *Geranium rotundifolium*; Lac_ser: *Lactuca serriola*; Mal_syl: *Malva sylvestris*; Son_asp: *Sonchus asper*; Son_ole: *Sonchus olerraceus*; Ver_per: *Veronica persica*; Vic_fa: *Vicia faba*