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Adapting cover crop soil coverage to soil depth to limit competition for water in a Mediterranean vineyard

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ABSTRACT

Cover crops could provide many interesting environmental services for vineyards, but French Mediterranean winegrowers mostly avoid permanent cover cropping because they fear too much competition and consequently a reduction in grapevine yield. To better understand the effect of cover cropping management on vine growth and yield, we carried out our study in a vineyard of Shiraz (*Vitis vinifera* L.) in the Mediterranean region of France over three consecutive years. Three cover crop strategies were monitored (30CC, 60CC and 100CC corresponding respectively to 30%, 60% and 100% of cover crop soil coverage) on two types of soils (shallow and deep), and compared with bare soil (0CC corresponding to 0% cover crop, controlled with chemical weeding). Grapevine growth, yield and soil moisture were measured and the fraction of transpirable soil water (FTSW) was simulated using a water balance model. Grapevine yields decreased as the cover crop soil coverage increased, and these yield reductions were found to be more severe in the shallow soil. Nevertheless, the 30CC treatment appeared to be both feasible and useful for ecosystem services such as soil protection whatever the soil depth. Moreover, FTSW was found to be relevant as an early yield indicator that could be useful to adapt the cover crop strategy to seasonal climate characteristics. The findings support the feasibility of a cover crop-based strategy, even in the Mediterranean region, as an effective measure to reduce the use of herbicides and fossil fuels without significantly decreasing the grape yield, provided that the winegrowers adapt their strategy to the soil depth and to the seasonal climatic conditions.

1. Introduction

Nowadays, vineyard cover cropping is widely used in the world's winegrowing regions, mainly in areas with summer rainfall or with irrigation (Monteiro and Lopes, 2007). Cover cropping is a practical way to increase biodiversity in the fields (Teasdale, 1996) and is a frequent option for weed management (Moonen and Barberi, 2008). Cover crops generate various environmental services such as, for example, mitigation of soil erosion (Kort et al., 1998), increase in carbon and nitrogen content of the soil and improvement of soil biological activity with higher levels of microbial biomass (Ramos et al., 2010) and earthworms (Doledec et al., 2003). Permanent cover cropping significantly reduces the risk of compaction (Polge de Combret-Champart et al., 2013) and improves soil trafficability. Cover crops may also increase infiltration rates, especially during winter (Gaudin et al., 2010) therefore increasing water storage in soil and decreasing runoff. Less runoff means less soil erosion and less pesticide flux towards watersheds (Andrieux et al., 2007). Nevertheless, a permanent cover crop can compete with grapevines for soil resources (Celette et al., 2005; Celette et al., 2008; Celette and Gary, 2013), and can consequently affect grapevine performance, by reducing vegetative development and yield (Monteiro and Lopes, 2007). Reduction in the grapevine vegetative development could have positive effects, such as decreased sensitivity to diseases such as grey mould (*Botrytis cinerea* Pers.) (Valdés-Gómez et al., 2008; Jacometti et al., 2010) and powdery mildew (*Erysiphe necator* [Schw.] Burr.) (Valdés-Gómez et al., 2011) which in turn could lead to a reduction in use of fungicide. However, yield reduction can be a problem for vineyards with reduced profitability.

In spite of these many environmental benefits, cover cropping is observed in only 30% of the vineyards in the French Mediterranean area, with equal use of temporary cover crops and permanent grass cover crops (Ambiaud, 2012). Mediterranean winegrowers mostly avoid permanent cover cropping because they fear the risk competition for water during the periods of severe drought which are possible during spring and summer (Frey, 2016; Gaudel, 2002). Indeed, impacts of permanent cover cropping on grapevines were found to be more severe in warm dry climates (Monteiro and Lopes, 2007; Tesic et al., 2007). Experiments in the Mediterranean climate area (Languedoc,

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Table 1
Soil type characteristics in the two zones of the field.

Soil type	Soil depth (cm)	Position in the field	Horizon	[1]Organic matter $g\,kg^{-1}$	[2]pH (water)	[3]Clay content $g\,kg^{-1}$	[4]Sand content $g\,kg^{-1}$	[5]P_2O_5 $mg\,kg^{-1}$	[6]K_2O $mg\,kg^{-1}$	[7]MgO $mg\,kg^{-1}$	[8]CaO $mg\,kg^{-1}$
Shallow	70	upper part	0–30 cm	10	8.0	140	535	126	135	120	3310
			30–60 cm	8	8.0	188	467	62	105	148	2789
Deep	Above 200	lower part	0–30 cm	6	7.4	108	515	48	90	120	1706
			30–60 cm	12	7.6	140	452	77	102	142	2845

Analytical norms: [1] NF ISO 10694, [2] NF ISO 10390; [3] and [4] NF X 31–107; [5] oxalate ammonium extraction (method of Joret-Hébert, NF X31-161); [6,7] and [8] ammonium acetate extraction (NF X31-108).

France) also quantified the most severe impacts of a permanent cover crop (*Festuca arundinacea* cv. Centurion) on soils with low water holding capacity (Chantelot et al., 2004). This was confirmed by results from Val de Loire (France), where impacts of a permanent cover crop were seen to be less severe in a plot with deeper soil compared to shallower soil after 4 years of cover cropping (Le Goff-Guillou et al., 2000). These authors suggested that in a deep soil, the grapevine root system is able to explore the deeper layers, therefore avoiding competition with the cover crop root system. Furthermore, the reduction of grapevine growth and yield due to cover cropping has been shown to increase with the level of soil coverage by a permanent cover crop (Morlat and Jacquet, 2003; Tesic et al., 2007; Giese et al., 2014). Finally, as grapevine fruit formation extends over two consecutive years, the effect of cover crop strategy has to be considered over several consecutive years. Only a few studies have focused on interactions between soil and cover cropping (Ingels et al., 2005; Monteiro and Lopes, 2007; Steenwerth and Belina, 2008; Salomé et al., 2015), and even less have assessed how this interaction could affect grapevine performance over a three-year period with contrasting climatic conditions. The formation of inflorescences (around flowering in season 1) is particularly crucial as this determines both the bunch number per vine and the berry number per bunch in season 2, which accounts for about 60% and 30% of year-to-year grapevine yield variation respectively (Guilpart et al., 2014, Dry, 2000; Clingeleffer and Krstic, 2001; Clingeleffer, 2010). During the formation of inflorescences, light, temperature, and particularly water and nitrogen availability modified by the presence of a cover crop could affect inflorescence formation and therefore the bunch number per vine and yields in the following year (Guilpart et al., 2014; Ripoche et al., 2011; Tesic et al., 2007). As a result, the intensity of competition between cover crop and grapevine is complex and driven by different factors, mainly: climate, soil depth, the percentage of soil covered by cover crop, the cover crop biomass and the duration of cover cropping.

The objectives of the present study were to determine the influence of a permanent cover crop on water use, grapevine vegetative vigor and yield in a non-irrigated Mediterranean vineyard, and to assess to what extent cover crop soil coverage affects the grapevine performance taking into consideration soil depth. We focused our study on early indicators of water and mineral constraints influenced by the climatic conditions and the presence of a cover crop, because these early indicators are known to determine the number of bunches in the following year. This is of economic importance as the number of bunches is generally the major determinant of grapevine yield. We hypothesize that this approach may be helpful to adapt cover crop and soil management strategies within the vineyard over the years (Ripoche et al., 2011) and we assume such results may provide early yield indicators and tools to better manage the cover crop in the case of water deficit.

2. Material and methods

2.1. Experimental site and design

2.1.1. Location

The experiment was carried out in a 4 ha non-irrigated and unfertilized vineyard located near Nîmes (Southern France, 43°74′ N–4°43′ E) from 2011 to 2013. The vines (*Vitis vinifera* L. cv. Shiraz clone 877 grafted on SO4) were planted in 1998 (2.5 × 0.8 m i.e. 5000 plants/ha) in rows oriented East-West, following the direction of the main slope (around 1.5%). The grapevines have been trained by means of a unilateral cordon system to a height of 0.7 m. The vines have been spur pruned to 16 nodes per plant on average (8 spurs and 2 nodes per spur), without shoot thinning in season. The trellising system has been made of 3 wires, with an average foliar height of 1.4 m in full season.

2.1.2. Soil characteristics

The soil of the field is a sandy loam clay containing rare coarse elements with the following average characteristics: sand 49.2%, silt 36.4%, clay 14.4%, organic matter 0.9%, pH 7.8. This soil is part of the Haplic Cambisol (calcaric) soil reference group (IUSS Working Group WRB, 2006). According to soil depth and structure, two soil types were determined in the vineyard: (i) in the upper half part of the plot, the soil is characterized by a layer of strongly cemented carbonates at about 70 cm depth and (ii) in the lower half, a deep soil zone (more than 200 cm) without any cemented layer. The first soil type was therefore considered as "shallow", as opposed to the "deep" soil of the lower zone. The chemical characteristics of the soils sampled from 5 random locations for each zone using a manual gauge under the vine-row, separating layer 0–30 cm from layer 30–60 cm, were homogeneous (Table 1).

2.1.3. Cover crop management and characterization

In the vineyard, a spontaneous permanent cover crop had already been established between grapevines rows in 2009. The experimental plot was divided into two parts according to soil depth. In each part, in 2011, treatments were designed to create a gradient in proportions of permanent cover crop soil coverage and were monitored over three years. The experiment was designed in complete randomized blocks, with 3 replications per treatment. Treatments were applied as strips with no buffer rows. Blocks were imposed across rows, perpendicular to the natural slope of the field. Each replicate was made up of plots of 18 grapevines in a single row, and only the 10 central grapevines were monitored to avoid border effects. The first treatment corresponded to a soil kept bare by chemical weeding and was called 0CC for 0% cover crop soil coverage (Fig. 1a). The second treatment corresponded to a mixed-management system for the inter-row with a spontaneous permanent cover crop on one side of the grapevine row and a soil kept bare by chemical weeding on the other side. The grass strip was about 1.5 m wide, which represented a cover crop soil coverage of about 30%; this treatment was called 30CC (Fig. 1b). The third treatment was obtained by keeping and regularly mowing the spontaneous cover crop already established in each inter-row; which represented 60% cover crop soil coverage and was called 60CC (Fig. 1c).

In the vineyard with deep soil, a fourth treatment was obtained by sowing *Festuca rubra* L. ssp. *commutata* cv. Bargreen (Barenbrug) in a 1.0 m wide band under the vine row, at 50 kg ha^{-1}. The soil was therefore 100% covered by a permanent cover crop, and this treatment was called 100CC (Fig. 1d). We decided not to implement this 100CC treatment on the shallow soil as too much competition from the cover