IRRIGATION AS AN EFFECTIVE WAY TO OFFSET COMPETITION FROM A PERMANENT COVER CROP IN A MEDITERRANEAN VINEYARD

L'IRRIGATION, UN LEVIER EFFICACE POUR COMPENSER LA CONCURRENCE D'UN ENHERBEMENT PERMANENT DANS UN VIGNOBLE MÉDITERRANÉEN

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Abstract

Environmental benefits of permanent cover crop in vineyard are well known. Nevertheless, permanent cover cropping is quite rare in French Mediterranean vineyards, because there is a risk of severe drought during summer, and consequently yield losses. Over the past few years, irrigation has developed in this area, offering new possibilities for better control of grapevine water status in cover cropped vineyards. The aim of this experiment was to study the effects of irrigation, combined or not with nitrate fertilization, in order to compensate for the competition of a permanent cover crop in the inter-row. The experiment was carried out in a Shiraz commercial vineyard, located near Nîmes (Southern France). The experiment was designed to compare cover cropped grapevines with these different treatments: (i) no inputs, (ii) with irrigation, (iii) with nitrate fertilization, (iv) with both irrigation and nitrate fertilization, and (v) a reference on bare soil. Monitoring (water and nitrogen status of grapevine, yield components) took place from 2010 to 2013. Since 2011, cover crops have led to significant yield losses compared to bare soil treatment (-29% on average). Nitrate fertilization used alone did not improve grapevine yields. Irrigation increased grapevine yields by +10% for irrigation alone and by +19% for both irrigated and fertilized treatment. Despite these improvements, yields from cover cropped grapevine remained below yields from bare soils. Water availability seems to be the main parameter to monitor for managing the competition with permanent cover crops in Mediterranean vineyards.

Keywords : *Cover crop, irrigation, nitrogen fertilization, competition, Mediterranean climate*

Résumé

L'enherbement des vignes est reconnu pour ses nombreux effets positifs sur le milieu. Cette technique reste toutefois peu répandue dans les vignobles méditerranéens français par crainte d'une concurrence excessive, en particulier sur le plan hydrique, et des risques de pertes de rendement. Depuis quelques années, l'irrigation se développe dans ces vignobles, ouvrant de nouvelles perspectives pour réguler la contrainte hydrique en vigne enherbée. L'objectif de cette expérimentation a été d'étudier l'intérêt des apports d'irrigation combinés ou non à des apports d'azote minéral pour compenser la concurrence d'un enherbement permanent spontané de l'inter-rang. Une parcelle expérimentale a été mise en place sur un vignoble commercial planté en Syrah de la région de Nîmes (Gard, France). Le dispositif expérimental a comparé sur vigne enherbée les modalités (i) sans aucun apport, (ii) avec apport d'irrigation, (iii) avec apport d'azote, (iv) avec apports combinés irrigation et azote et (v) une modalité de référence en sol nu. Le suivi (statut hydrique et azoté de la vigne, composantes du rendement) a été réalisé de 2010 à 2013. À partir de 2011, l'enherbement a entrainé une perte de rendement significative par rapport au sol nu (-29% en moyenne). Dans ces conditions, l'apport d'azote seul n'a pas eu d'effet sur le rendement. Les modalités irriguées ont permis de compenser la perte de rendements en vigne enherbée, de +10% pour l'irrigation seule et de +19% pour les apports combinés irrigation-azote. Les rendements des modalités enherbées sont toutefois restés inférieurs à la modalité de référence en sol nu. La disponibilité en eau semble ainsi être le levier principal pour gérer la concurrence de l'enherbement en climat méditerranéen.

Mots-clés : Enherbement, irrigation, fertilisation azotée, compétition, climat méditerranéen

1. Introduction

French viticulture is committed to reducing the use of inputs such as pesticides for more environmentally friendly practices. For soil management, this means reducing the use of herbicides, which have been in widespread use since the Second World War. Permanent cover cropping is an alternative of high interest with regards to the positive impacts on grapevines and their environment. Therefore, permanent cover cropping has become now a common practice in cool climate areas of France such as in Bordeaux region or Alsace. On the opposite, permanent cover cropping represents less than 17 percent of the vineyards in the Mediterranean area (Agreste, 2012). Winegrowers in Mediterranean area mostly avoid permanent cover cropping because of the risk of severe drought during spring and summer (Gaudel, 2002). Indeed, permanent cover cropping induces a competition for soil resources (Celette et al., 2009; Celette et al., 2005) *i.e.* water and minerals consumption. This competition can affect grapevine performance, reducing vegetative development and yields (Chantelot et al., 2004; Monteiro & Lopes, 2007; Lopes et al., 2011). In the French Mediterranean vineyards, the irrigated area increased by 88% between 2000 and 2010, up to 25 298 ha (RGA 2000, 2010) and today represents 8% of the total vineyard area in the region. Therefore, there are new opportunities for managing competition of cover crop thanks to irrigation. The aim of this experiment was to assess the efficiency of irrigation combined or not with nitrate fertilization to reduce the negative impacts of a cover crop on grapevine yield in a Mediterranean climate.

2. Material and methods

Experimental site and design

The experiment was carried out in a vineyard located near Nîmes (Southern France, 43°74 N–4°43 E) from 2010 to 2013. Vines (*Vitis vinifera* L. cv. Shiraz clone 877 grafted on SO4) were planted in 1998 in rows orientated E-W (2.5× 0.8 m i.e. 5000 vines/ha). The grapevines were trained using a unilateral cordon system. Vines were spur pruned to 8 x 2 nodes per vine on average. The soil had a loam texture class with rare coarse elements, and low organic matter content. A strongly cemented carbonate root restrictive layer was found at about 0.7m deep.

Five treatments were monitored. In one treatment, the soil was kept bare by chemical weeding (BS: Bare Soil). Others treatments were established with a 1.5m wide grass strip in the inter row. Irrigation and nitrate fertilization were applied or not on these grapevines in order to create the following treatments: ground cover without inputs (GC: Ground Cover), with irrigation (GCi), with nitrate fertilization (GCn) and with both irrigation and nitrate fertilization (GCin). Drip irrigation was applied under the row. From 2010 to 2012, irrigation was started a few days after flowering, about 1 $mm.day^{-1}$, and was stopped at veraison or earlier if rains occurred as in 2011. In 2013, irrigation was anticipated before flowering in early soil drying. Around 55mm were applied each year, but only 16mm in 2011 which was a wetter year (Figure 1). Fertilization was provided with ammonitrate 50-50% applied under the vine row around budburst. 40 $kgN.ha^{-1}$ were applied in 2010 and 2011, and 60 $kgN.ha^{-1}$ in 2012. No fertilization was applied in the last year of the experiment. The experiment started in 2009, with a cover crop already established, using a randomized block design of 3 sub-plots of 10 grapevines. Treatments were monitored over 4 years from 2010 to 2013, and in 2014 for bud fertility measurements in BS, GC and GCi treatments.

Measurements

The grape yield and its components were measured once at harvest time. Yield and bunch number per vine were recorded on sub-plot at harvest. In addition, a sample of 200 berries, 2 berries per cluster randomly harvested, was collected at harvest per sub-plot, weighed with a high precision electronic balance (Sartorius, model BP4100). Grapevine bud fertility was calculated as the ratio of bunch number to shoot number per vine. The grapevine nitrogen status was monitored using a N-Tester® (Yara France), that gave one value from 30 measurements made in the terminal part of adult leaves at flowering. Soil volumetric water content was measured manually using a portable capacitance soil moisture monitoring sensor (Diviner® 2000, Sentek, Australia) through PVC access tubes. Depth of PVC tubes was limited by the cemented calcaric layer. Tubes were set under the grapevine row, on each subplot of treatments BS, GC and GCi. The fraction of transpirable soil water (FTSW) was calculated as described in Pellegrino et al., 2004. Thermal time was calculated by daily integration of mean air temperature minus a base temperature of 10°C from budburst and was expressed in degrees-days (°Cd), with using weather data from Météo-France. Mean of FTSW was calculated between the 500°Cd and 600°Cd after budburst (FTSWc), which is identified as a critical period in Mediterranean area, because inflorescence formation is highly sensitive to water and nitrogen stress (Guilpart et al., 2014).

Data analysis

Statistical analysis were performed with R software (R Development Core Team 2007, version 2.15.1). Kruskal-walis tests were performed using package agricolae.

3. Results and discussion

Dynamics of soil water content

FTSW showed a decreasing pattern from spring to the beginning of the rainy period in autumn (Figure 1). Cover crop reduced FTSW in spring, especially when dry winter and spring occurred as in 2011 and 2012. In 2013, which was a wet year, FTSW dynamics followed the same pattern in GC and BS. From the beginning, irrigation was efficient for maintaining higher levels of FTSW in GCi compared to GC.

Yield components

No differences between treatments were found on yield and its components in 2010, but berry weight was significantly higher in GCin than in GCn (Table 1).

Since 2011, yield was always significantly higher in BS compared to GC and GCn. Grapevine yield was also higher in BS compared to GCi in 2011 and 2012, and higher compared to GCin only in 2012. On average over the 4 years, GC treatment reduced grapevine yield by 29% compared to BS treatment. These losses were linked to lower bunch number per vine (-12%) combined with lower bunch weight (-18%). Compared to GC, grapevine yield on irrigated treatments were significantly improved by 19% for GCin. This increase was linked to higher bunch number per vine, and significantly higher bunch weight. Nitrate fertilization used alone showed no yield improvement, bunch weights were even significantly lower in GCn compared to GC.

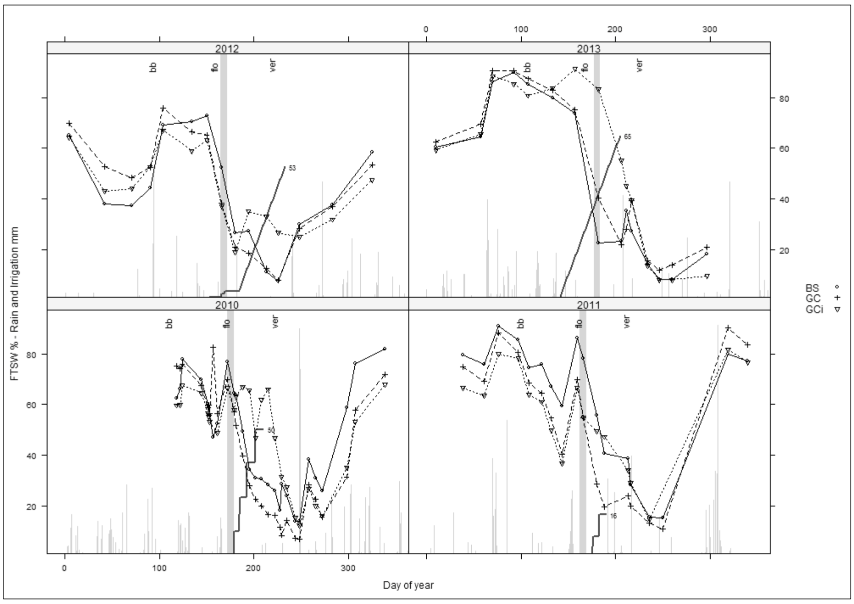

Figure 1. *Dynamics of Fraction of Transpirable Soil Water (FTSW) for BS, GC and GCi treatments (mean of the 3 subplots) for each year. Vertical bars represent rain events in mm. Blue line represents cumulative irrigation in mm. bb,flo and ver are for budburst, flowering and veraison stages. The grey shaded polygons represent the critical period of 500°Cd to 600°Cd after budburst.*

Figure 1. Dynamiques annuelles de la fraction en eau transpirable du sol (FTSW) pour les traitements BS, GC et GCi (moyenne des 3 placettes). Les barres verticales représentent les pluies en mm. La ligne épaisse représente l'irrigation cumulée en mm. Bb, flo et ver indiquent les stades débourrement, floraison et véraison. Les polygones gris représentent la période critique de 500 à 600 degrés jours après débourrement.

Table 1*. Yield components for each season monitored. Letters refer to Kruskal-Walis tests.*

Tableau 1. Composante du rendement sur les années de suivis. Les lettres réfèrent aux tests de Kruskal-Walis.

Year	Variables	GC	GCi	GCin	GCn	BS
2010	Yield per vine (kg)	2.4a	2.3a	2.6a	2.3a	2.2a
	Bunch per vine	13.3a	13.7a	14.2a	13.9a	12.9a
	Bunch weight (g)	182.4a	165.0a	178.1a	171.0a	166.0a
	Berry weight (g)	1.6ab	1.7ab	1.7a	1.5b	1.6ab
2011	Yield per vine (kg)	2.8c	3.0bc	3.7ab	3.0bc	4.2a
	Bunch per vine	16.3a	17.1a	18.7a	18.2a	16.0a
	Bunch weight (g)	175bc	177.4bc	199.4b	169.4c	257.6a
	Berry weight (g)	1.6ab	1.6b	1.6ab	1.5b	1.9a
2012	Yield per vine (kg)	1.5bc	1.9b	1.9b	1.1c	2.8a
	Bunch per vine	11.8b	12.8ab	12.6ab	12.5ab	16.0a
	Bunch weight (g)	129.1b	148.8ab	154.3ab	90.8c	184.3a
	Berry weight (g)	1.3a	1.5a	1.5a	1.1a	1.4a
2013	Yield per vine (kg)	1.6bc	1.9ab	1.7ab	1.2c	2.5a
	Bunch per vine	9.2ab	9.8ab	9.2ab	8.2b	12.9a
	Bunch weight (g)	173.6a	198.9a	179.0a	139.2b	194.9a
	Berry weight (g)	2.0abc	2.1ab	2.2a	1.9bc	1.7c
All	Yield per vine (kg)	2.1cd	2.3bc	2.5b	1.9d	2.9a
	Bunch per vine	12.7b	13.3b	13.7ab	13.2ab	14.5a
	Bunch weight (g)	164.9c	172.5bc	177.7b	142.6d	200.8a
	Berry weight (g)	1.7ab	1.7ab	1.8a	1.5b	1.6ab

Effects of water and nitrogen status on grapevine bud fertility

Yield per vine was mainly linked to bunch number per vine (R^2=0.68), and at a lower level with bunch weight (R^2=0.60). Grapevine bud fertility was thus a key yield component. In a previous study (Guilpart et al.,2014), grapevine bud fertility was found determined by water and nitrogen stress around flowering in the previous year. In BS, grapevine bud fertility correlated well with FTSWc calculated the previous year (Figure 2).

This is consistent with results obtained by Guilpart et al., even if intercept and slope of regression line are quite different. In GC, correlation was still statistically significant. In GCi no correlation was observed between FTSWc and grapevine bud fertility. FTSWc was calculated from soil water contents measured under the row, and drip irrigation may led to an overestimation of FTSWc in GCi. Nitrogen status measured at flowering in the previous year (N-Tester measurements) showed no correlation with grapevine bud fertility (data not shown). Irrigation patterns applied during this experiment poorly improved FTSWc, which may explain the low efficiency of irrigation to increase grapevine yields in GCi and GCin. Further investigations should be made to test irrigation strategies designed to recover yield in cover cropped vineyards.

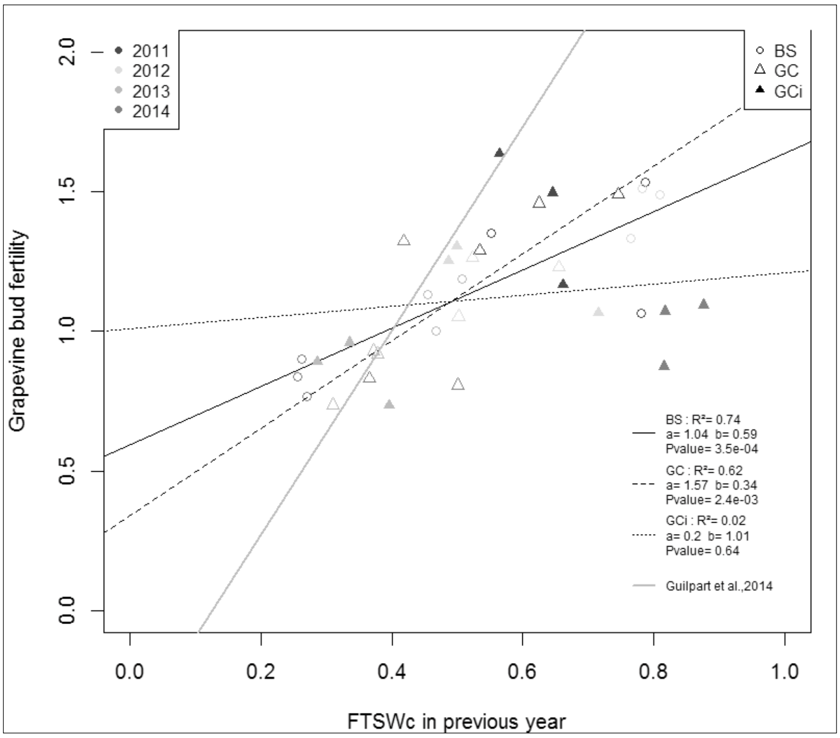

Figure 2. *Relationships between FTSWc in previous year and grapevine bud fertility. R^2 and Pvalue were computed using linear regression (y=a.x+b) for each treatment. FTSWc: Fraction of Transpirable Soil Water calculated between the 500°Cd and 600°Cd after budburst.*

Figure 2. Relations entre la FTSWc de l'année précédente et la fertilité des bourgeons de la vigne. R^2 et Pvalue ont été calculés par régression linéaire (y=a.x+b) sur chaque modalité. FTSWc : Fraction en eau transpirable du sol calculée entre 500°Cd et 600°Cd après débourrement.

4. Conclusion

Soil water content decreased early at spring due to cover crop consumption. After the second season of experiment, cover crop induced a significant decrease in grapevine yields. Irrigation in cover cropped grapevines was effective in improving yields. A synergetic effect was observed when irrigation was combined with nitrate fertilization. Despite this improvement, yields from cover cropped grapevine remained below yields from bare soils. Soil water content in the critical period of 500°Cd to 600°Cd after budburst correlated well with bunch number per vine the following season. This result underlines the need for further investigations on irrigation strategies focused on this critical period in order to carefully manage the degree of water competition in Mediterranean cover cropped vineyards.

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