Influence of cover crops in a Tempranillo vineyard grown under the edaphoclimatic conditions of the Appellation of Origin Rueda

Influence d'une couverture végétale dans un vignoble de Tempranillo situé dans l' A.O.C Rueda

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Abstract

The way to manage the vineyard soils has certainly changed in Spain during the last years. Traditionally, the vineyards were tilled, but this growing technique has been replaced in some vineyards by the bare soil with herbicide. Also, soil cover crops have started to be applied in some vineyards. The competition between the roots systems of the vines and the cover crop can influence on the capacity and the conditions of the plants for water absorption, transport of photosynthesized products to the roots, etc. Consequently, the cover crop can affect the water supply to the vine. The objective of this trial has been to study the behaviour of the Tempranillo variety under different alternatives of soil management, analysing the vegetative-productive vine balance and its influence on the grape quality, as well as the soil water content and the dry matter produced by the cover crop species. The trial has been carried out along 2006 and 2007 on a Tempranillo/110R vineyard, vertical trellis trained with Royat cordon pruning, with 3.00 m x 1.25 m vine spacing. The soil has homogeneus sandy-loam structure from the surface to the 110 cm depth, where there is a ground water table. The experimental treatments have been the following: TIL, traditional tillage (2006 and 2007); BAR, barley (*Hordeum vulgare)* (2006 and 2007); LEG, *Vicia monanthos* (2006) and vetch *(Vicia sativa)* (2007); PER, resident vegetation (2006) and or perennial vegetation, fescue *(Festuca orundinacea)* and ryegrass (*Lolium perenne)* combination at 50% (2007). The use of cover crop species in the inter-row space has provoked highly significant differences among treatments in yield, depending on the cover crop species and the annual climatic conditions. Legume and perennial species have shown to be more water competitive towards the vines than the rest of cover crops applied, which has reduced yield and vegetative development and has increased the dry matter produced by this species with respect to the others. The influence of the soil management on grape quality has not been determinant, in such a way that it has depended on the annual conditions and the level of yield, as well as on the cover crop species.

Key words: quality, vigor, water, yield.

Introduction

The way to manage the vineyard soils has certainly changed in Spain during the last years. Traditionally, the vineyards were tilled, but this growing technique has been replaced in some vineyards by the bare soil with herbicide. However, since some years ago, problems of inversion and resistance of weeds, as well as the ecologist matter pressure, question the use of chemical herbicides (Morlat *et al*. 1993). On the other hand, the excess of vigour and yield in some vineyards, which are two of the main problems in present viticulture, certainly increases with this soil maintenance technique based on the use of herbicides. The use of a cover crop can contribute to solve important viticulture problems, as the excess of vigour and yield or the environment protection. The benefits of cover crops on vineyard soils on grapevines and wines can only be obtained through the optimum competence between the grass and the vine (Prichard 1998). This means to adapt the level of competence to the conditions of the plot (vine spacing, variety and rootstock, type of soil and subsoil, climate). Thus, the widespread use of cover crops in vineyards requires the study on each soil plot of its characteristic elements as well as its space variation.

Permanent cover crops are more and more used by grapegrowers (Morlat and Jacquet 2003) due to its beneficial effects (Ludvigsen 2002, Santesteban *et al*. 2007), which include the improvement of the soil characteristics, the reduction of erosion (Coulon y Prud'homme 2003, Jiménez del Río *et al*. 2007, Murisier 1986), the reduction of vigour and yield, the decrease of botrytis infection and the improvement of vineyard microclimate (Lopes et al. 2004), which indirectly improves the quality and increase the biodiversity. As Daane y Costello said (1998), the increase of the biodiversity can favour the control of some pests and the use of cover crops allows the machine labour at any time of the cycle, the reduction of soil flattening due to machine traffic, the enrichment of organic matter, the activation of microbial life and the control of certain weeds.

Permanent cover crops can also influence on the vine root system, although its long term effects are not known enough, due to the fact that roots depth is conditioned by soil type. An increase of vine spacing, a lack of infiltration and the acidity of the soil provoke the decrease of the number of roots per vine. Many authors say that the soil water content has a strong effect on the rooting of the vine. Thus, Morlat and Jacquet (2003) observed a positive effect of the soil water content on the root system. The competence between the cover crop roots and the vine roots influences on the capacity and conditions for water absorption, the transport of photosynthetic substances to the roots, the rooting depth and distribution of the roots, as well as on the quality of the root system colonization (Van Zyl 1988).

Consequently, permanent cover crops can affect vine water supply, especially in the soil surface. The interaction between cover crops and vines in relation with the water and nitrogen demand are not well known yet and there is a quantitative lack of data about the amount of water is used by any growing cover crop species and any weed under field conditions (Lopes *et al*. 2004). There are not available data comparing the amount of water consumed by vines, cover crop species or weeds.

The use of cover crops can also have disadvantages. Gulick *et al*. (2004) observed that the increase of water infiltration due to the continuous cover crop growing increased the water use of water around 46 % against the bare soil. Cover crop species can compete for water and nutrients with the vines, decreasing the vine development, and can also prevent the development of roots close to the soil surface (Van Huyssteen & Weber 1980, Morlat & Venin 1981). Also, cover crops can reduce yield if there is not crop rotation, especially in young vineyards under non irrigation conditions (Saayman & Van Huyssteen 1983).

Depending on the context, the use of cover crops could be very useful (Chantelot *et al*. 2003). The comprehension of the competition mechanisms is an essential way for research, which could make viable the establishment of different techniques adapted to each viticulture.

The objective of this work has been to study the behaviour of Tempranillo variety under different alternatives of soil management, particularly, the aim of the trial is to analyze the variation on the vegetative-productive vine balance and its influence on the quality of grape, as well as the soil water content and the dry matter produced by each cover crop species.

Material and methods

The trial has been located in Nieva (Segovia province, Spain), which belong to the Appellation of Origin Rueda. It has been carried out with Tempranillo/110R vines planted in 2000. The vine spacing is 3.00 m x 1.25 m. The vines were growing under non irrigation conditions with a rainfall from April to September of 169 mm (443 mm, annual) in 2006 and 258 mm (469 mm, annual). The soil has a homogeneous sandy-loam structure from the surface to 110 cm depth, where there is a ground water table. The vine training is VSP, with Royat cordon pruning and all vines having a load of 1 shoot per 10 cm of cordon.

The experimental treatments have been the following: TIL, traditional tillage (2006 and 2007); BAR, barley (*Hordeum vulgare)* (2006 and 2007); LEG, *Vicia monanthos* (2006) and vetch *(Vicia sativa)* (2007); PER, resident vegetation (2006) or perennial vegetation, fescue *(Festuca orundinacea)* and ryegrass (*Lolium perenne)* combination at 50% (2007). The trial was carried out in 2006 and 2007. The cover crop species were sown in October 2005 and 2006 for getting all treatments available to study the following years. The soil management under the vines has been with mechanical labour. The width of field sown in each cover crop treatment has been 2 m. The 2nd of May and the 1st of June 2006, and the 18th of April 2007, the species were mowed in order to reduce the risk of frozen. The

cover crops were ploughed the second fortnight of June in 2006 and 2007 (with the exception of the permanent cover, PER).
The experimental design has consisted of randomized blocks with 4 replications per treatment, with 150 vines elemental plot and 50 control vines per replication. The experimental determinations were focused on vegetative measurements (through pruning weight, vigour and number of shoots), grape yield (number of clusters, yield per vine and berry weight), grape quality (sugar concentration, acidity, pH and total poliphenols), dry matter of cover crops (1 m^2 of soil vegetal material of each species was sown, weighed and dried in stove at 110 ºC until the weight was constant), soil water content and leaf water potential at solar midday. The soil water content was determined through fortnight volumetric measurements by the Time Domain Reflectometry (TDR), with a commercial Trase System Model 6050X1 (Soil Moisture corp. California, USA). The probes for electromagnetic transmission were 0.3 cm diameter and 20 cm length, compound by 3 small sticks buried at 30, 60 and 90 cm, 30 cm apart from the line of vines. One probe site per replication was installed. For leaf water potential measurements it was removed one single leaf of 8 vines per treatment and measured its sap tension with a Scholander pressure chamber since June to September. The control harvest took place on September 19th in 2006 and on October 18th in 2007. Previously a sampling was done to analyze the basic components of must. Total poliphenols were determined through spectrophotometric analysis measuring absorbance at 280 nm after obtaining the must from grapes without any skin maceration, with the aim of simplifying the operation an establishing of an adequate and standardized comparison between treatments.

Results

Vegetative development

The total shoots amount of treatments TIL, BAR and PER have been similar due to the number of water shoots developed by TIL treatment in 2006, whereas treatment LEG showed the lowest number of total shoots in 2006 due mainly to the low counted budbreak ratio. Anyway, the differences on the total shoots number have not been statistically significant. The number of bud counted shoots per vine has been similar for all studied treatments, even though in 2007 the budbreak percentage has been lower than in 2006, without reaching the budbreak of the 12 counted buds left per vine. In 2006, TIL and LEG treatments had about one shoot less than the established counted buds per vine, whereas PER and BAR treatments maintained the same number of shoots as the number of counted buds left at pruning.
The pruning weight has been higher for treatments TIL and BAR than for LAB and PER, with statistically significant differences both years. There was observed a more clear tendency for the vigour of the shoot the first year, with superiority of LAB treatment with respect to the others. However, in 2007, the shoot vigour of TIL and BAR treatments were similar, whereas the treatment PER obtained the smallest shoots, which shows the biggest competence between this cover crop species and the vines. The differences were statistically significant in 2006 and 2007 (table 1).
Taking into account these results, LEG and PER treatments have reached less vegetative development derived from the high competence established between the legume and permanent cover crop species and the vines.

Year	Treatment	Pruning w.	Shoots	Count. Shoots	Water Shoots	Shoot Weight
2006	**TIL**	0.909	14.6	11.2	3.4	62.4
	BAR	0.699	15.0	12.1	2.9	46.7
	LEG	0.524	13.6	11.1	2.5	38.5
	PER	0.575	14.9	12.2	2.7	38.5
	S.L.	**	-	-	-	*
2007	**TIL**	1.160	12.8	10.6	2.2	91.2
	BAR	1.204	12.7	10.9	1.8	94.6
	LEG	1.047	12.5	10.6	1.9	84.0
	PER	0.905	12.8	10.7	2.2	70.5
	S.L.	*	-	-	-	*

Table 1 Pruning weight (kg/vine), total shoots number per vine, counted shoots per vine, water shoots per vine and shoot weight (g) of treatments: TIL (tillage), BAR (barley), LEG (legume, vetch) and PER (resident perennial vegetation), in 2006 and 2007. Statis

Yield

The use of cover crop species in the work row has provoked highly significant differences among treatments in yield, in such a way that the vines with higher yield were those growing with traditional tillage in the work row (TIL), in 2006 and 2007, followed closer by BAR treatment than the two other treatments. TIL treatment obtained 14,5%, 36,7% and 46,7% higher yield than treatments BAR, PER and LEG respectively in 2006. In 2007, TIL obtained 4,5%, 29,9% and 27,6% higher yield than BAR, PER and LEG respectively. This increase was caused by the number of clusters and the cluster weight, with statistically significant differences mainly in 2007, because in 2006 the differences were not statistically significant for the number of clusters per vine. The cluster weight was superior in TIL and BAR than in PER and LEG treatments, with statistically significant differences in both years. The berry size reached by TIL and BAR was superior than that of LEG and PER treatments in both years, although the differences were only statistically significant in 2006. In relationship with fertility, expressed as number of clusters per vine, LEG had the lowest fertility in both years whereas BAR and TIL had the highest quantity of clusters (table 2), although the differences were statistically significant only in 2007.
To summarize, the use of any cover crop in the inter-row space, compared with bare soil, has provoked a decrease in yield more evident with the legume species. The cereal species has provoked slighter reduction of yield than the other species with respect to the bare soil.

Year	Treatment	Yield	N. Clusters	Cluster W.	Berry weight
2006	**TIL**	16.9	21.7	294	1.67
	BAR	14.4	22.0	245	1.53
	LEG	9.0	18.1	187	1.42
	PER	10.7	19.9	201	1.40
	S.L.	**	-	*	**
2007	**TIL**	10.6	19.2	206	1.85
	BAR	10.1	18.1	213	1.87
	LEG	7.7	14.5	199	1.77
	PER	7.4	15.7	177	1.67
	S.L.	**	**	**	-

Table 2 Yield (t/ha), number of clusters per vine, cluster weight (g) and berry size (g) of treatments: TIL (tillage), BAR (barley), LEG (legume, vetch) and PER (resident perennial vegetation), in 2006 and 2007. Statistical signification level (S.L.): - = no si

Soil water content

In 2006, the measurement of soil water content in the first 100 cm of soil depth showed that all 4 treatments started the vegetative cycle with a quantity of water close to 20% (v/v) approximately, but later when the demand is highest and the water availability is lowest in the season (August and September) the water content decreased below 10% (v/v). PER and BAR treatments seem to have consumed less soil water because they showed lightly higher soil water content than the other 2 treatments in some part of the vegetative cycle. The legume cover crop (LEG) seem to have consumed more water than the other cover crops, because its soil water content was the lowest of all 4 treatments. From the month of June, when the cover crops of BAR and LEG were ploughed, a lower soil water content was detected in LEG treatment than in the others due to a lower capacity of the cover crop to retain the rain water at that period, although the observed differences were not statistically significant, in general.

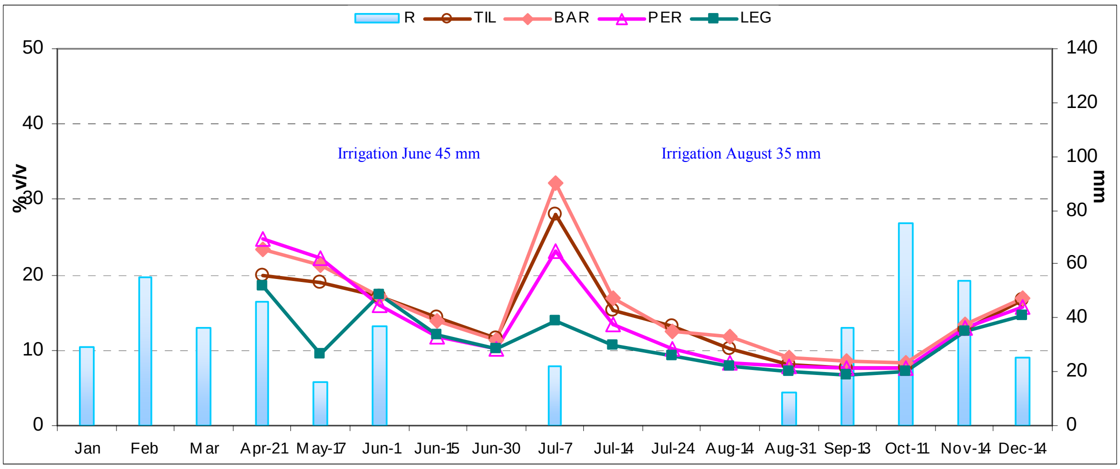

Figure 1 Soil water content of first 100 cm soil depth (% v/v) in 2006.

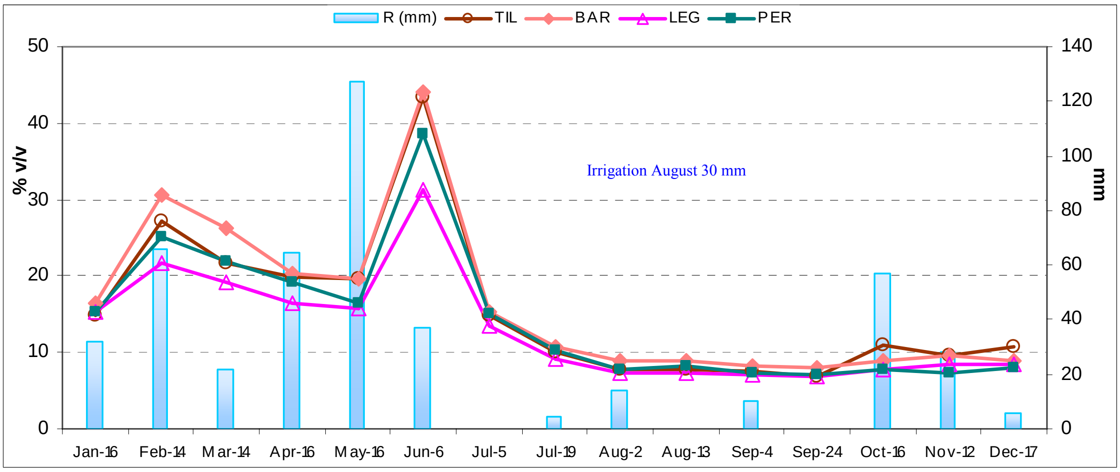

Figure 2 Soil water content of first 100 cm soil depth (% v/v) in 2007.

In 2007, more evident differences between treatments have been observed in the first 100 cm soil water content from January to July than from this month in advance. The water content values have varied from 30% (v/v) at the beginning of the year until less than 10% (v/v) from July on advance, except at the month of June. In this month the level of soil water was increased due to the intense rainfall registered, which remarked the differences between TIL and BAR with respect to LEG and PER treatments. BAR treatment has shown values slightly higher than the others, mainly during the first half of the year, meanwhile LEG cover crop showed the lowest values for some part of the same period, although the differences were not statistically significant in general, making noticeable the statistical significance in the measurement of May. since the month of July the vineyard suffered the effects of a high atmosphere water demand which led to a decrease in the soil water content to below 10% (v/v) on all treatments.

Cover crops dry matter

The productivity of the species used as cover crops has been very variable, in 2007, measured as dry matter content per square meter of soil. LEG treatment has produced around 10 times more dry matter than PER and 6 more times than BAR. The vegetal cover crop of fescue plus ryegrass (PER) has obtained a quantity of g per m^2 of soil lower than the barley cover crop (BAR). BAR was the treatment which maintained more soil water in some of the measurements. Thus, the dry matter produced by the vetch legume (LEG) has been clearly higher than that produced by the herbaceous species barley (BAR) and fescue plus ryegrass (PER), with statistically significant differences (table 3).

Midday leaf water potential

The evolution of midday leaf water potential (Ψ_{12}) along the vegetative cycle has shown a continuous decrease, more intense in July, which has been less evident in 2006 than in 2007 (August and September), to end the cycle with -1.7 MPa in 2006 and -2.0 MPa in 2007. The midday leaf water potential (Ψ_{12}) has not shown statistically significant differences among treatments at any time over the cycle, although at the end of June, when the water demand for vines was strong and it was observed a high competence due to the cover crops, the differences among some treatments could have been statistically significant with a level of probability less than 10%. Definitively, the individual leaf water status has been similar for all treatments although it has been observed that LAB treatment has shown less negative potential values than the other treatments at certain dates, as well as PER treatment has shown lower values in some dates, but not being the differences statistically significant in any case.

Year	Treatment	Jun 22	Jul 24	Aug 24	Aug 31	Sep 19
2006	**TIL**	-1.02	-1.27	-1.40	-1.53	-1.74
	BAR	-1.12	-1.31	-1.39	-1.53	-1.71
	LEG	-1.10	-1.31	-1.43	-1.49	-1.74
	PER	-1.11	-1.36	-1.55	-1.59	-1.64
	S.L.	-	-	-	-	-
		Jun 19	**Jul 29**	**Aug 13**	**Sep 4**	**Sep 24**
2007	**TIL**	-0.59	-1.08	-1.28	-1.57	-1.94
	BAR	-0.57	-1.13	-1.33	-1.52	-1.98
	LEG	-0.64	-1.18	-1.32	-1.57	-2.05
	PER	-0.55	-1.19	-1.35	-1.60	-1.96
	S.L.	-	-	-	-	-

Table 3 Midday leaf water potential of treatments: TIL (tillage), BAR (barley), LEG (legume, vetch) and PER (resident perennial vegetation), in 2006 and 2007. Statistical signification level (S.L.): - = no significant; * = p < 5%, ** = p < 1%.

Grape quality

Sugar concentration has been lightly affected by the way of soil management. The tendency has been different in 2006 than in 2007 probably due to the environmental conditions, as well as to the annual yield. In 2006, LEG obtained a sugar concentration higher than the other 3 treatments (1.5 ºBrix more than PER and BAR, and 2.7 ºBrix more than BAR), being the differences statistically significant. In 2007, sugar concentration was very similar for all 4 applied treatments, although TIL obtained a slightly higher concentration than the others without statistically significant differences. On the other hand, the titratable acidity has shown the same tendency in both years, showing TIL treatment higher values than the rest with statistically significant differences between treatments. Similar results were observed in pH than in the acidity parameter, but with the inverse tendency in such a way that LEG obtained the highest values in both years, which corresponded to statistically significant differences with respect to the other treatments. The total poliphenols index has not shown significant differences between treatments, although treatment LEG had a lower value than the others in 2006, whereas treatment PER had it higher than the rest of treatments in 2007.

Year	Treatment	Sugar C.	Total Acidity	pH	Poliphenols	Dry matter
2006	**TIL**	20.8	4.5	3.79	13.5	
	BAR	21.9	4.1	3.80	16.5	
	LEG	23.5	4.0	3.94	17.8	
	PER	21.9	3.9	3.80	17.3	
	S.L.	**	**	**	-	
2007	**TIL**	21.4	6.2	3.46	28.1	
	BAR	21.0	6.0	3.47	28.1	336
	LEG	20.8	5.7	3.56	28.6	2129
	PER	21.0	5.5	3.51	30.7	206
	S.L.	-	**	**	-	**

Table 4 Sugar concentration (ºBrix), total acidity (g, tartaric acid/l), pH, total polyphenols index and dry matter (g/m2) of treatments: TIL (tillage), BAR (barley), LEG (legume, vetch) and PER (resident perennial vegetation), in 2006 and 2007. Statistical sig

Conclusions

The application of cover crops in the vineyard inter-row space has provoked a more or less large variation of the final yield, depending on the species and the annual climatic conditions. The legume species has shown a higher competence with the vines than the other cover crop species, in such a way that the grape yield and the vegetative development have been lower, as well as the soil water content, which has been lower than in the others treatments. At the same time, the LEG treatment productivity, expressed as g of dry matter of cover crop per m^2 of soil, has widely passed that of PER or BAR treatments.
The influence of the kind of cover crop in the grape quality has not been determinant, thus the effect of the cover crop and its competence with respect to the vines have deeply depended on the annual conditions and the level of yield, as well as on the cover crop species.

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