Vegetative, productive and qualitative performance of grapevine "Cabernet Sauvignon" according to the use of winter cover crops [1]

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ABSTRACT

To study the effect of winter cover crops on the vegetative, productive and qualitative behavior of "Cabernet Sauvignon" grapevines, an experiment was conducted in two wine harvests by sowing different species of winter cover crops and additional treatments with manual weeding and mechanical mowing in an experimental vineyard located at the Experimental Station of Epagri in Videira, state of Santa Catarina, Brazil. Plant attributes of the grapevine, such as number of rods and weight of pruned material and number of branches per plant. At the time of skin color change, petioles of recently matured leaves were collected for analysis of the levels of N, P, K, Ca, Mg, Fe, Mn, Zn and B. Moments before harvest, 100 grape berries were collected randomly to determine the total soluble solids, titratable acidity and pH. At harvest, the number of bunches per branch, the number and mass of clusters per plant and the average mass of clusters per plot were determined. Fresh and dry matter yields of the cover crop and weed plants were also determined when coverage reached full bloom. The winter cover crops did not alter the yield and quality of "Cabernet Sauvignon" grapes and showed no differences from each other for the management of spontaneous vegetation by hand weeding or mechanical mowing. Rye and ryegrass are effective alternatives for weed control alternatives. The species of white and red clover present difficulty in initial establishment, producing a small amount of biomass.

Key words: green manure; production systems; soil management; *Vitis* sp.

RESUMO

Comportamento vegetativo, produtivo e qualitativo de videiras 'Cabernet Sauvignon' em função do uso de plantas de cobertura de inverno

Para estudar o efeito das plantas de cobertura de inverno sobre o comportamento vegetativo, produtivo e qualitativo de videiras 'Cabernet Sauvignon', foi conduzido um experimento em duas safras vitícolas, com semeadura de diferentes espécies de plantas de cobertura de inverno e tratamentos adicionais com capina manual ou roçada mecânica, em um vinhedo experimental localizado na Estação Experimental da Epagri em Videira, SC. Foram avaliados atributos vegetativos da videira, tais como número de varas e peso do material podado e o número de ramos por planta. No momento da mudança de cor da casca, foram coletados pecíolos de folhas recém-maduras para análise dos teores de N, P, K, Ca, Mg, Fe, Mn, Zn e B. Momentos antes da colheita, foram coletadas aleatoriamente 100 bagas para determinação do teor de sólidos solúveis totais, acidez titulável e pH. Na colheita, foram determinados o número de cachos por ramo, o número e a massa de cachos por planta e a massa média de cachos por parcela. Também foram determinadas a produção de massa verde e seca das plantas de cobertura e das plantas daninhas quando as plantas de cobertura atingiram a floração plena.

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As plantas de cobertura de inverno não alteraram a produtividade e a qualidade de uvas ‘Cabernet Sauvignon’ e não se diferenciam do manejo da vegetação espontânea através de capinas manuais ou roçadas mecânicas. O centeio e o azevém são alternativas eficazes para o controle de plantas daninhas. As espécies de trevo branco e vermelho apresentam dificuldade de estabelecimento inicial, produzindo baixa quantidade de fitomassa.

Palavras-chave: adubo verde; sistemas de produção; manejo do solo; *Vitis* sp.

INTRODUCTION

Cover crops play fundamental roles in agricultural ecosystems by preserving and enhancing physical, chemical and biological structures of the soil. These are long term structural changes with the least possible impact on natural resources. Among the most significant effects of cover crops are the weed control, erosion reduction and the increase in the content of organic matter in the topsoil. The first works carried out in the South of Brazil to stimulate the cultivation of cover crops in vineyard soils were developed in the mid-1980s, in the municipality of Bento Gonçalves, state of Rio Grande do Sul (Pancotto *et al*., 2004). Since then, the use of this practice has been intensified, although today most of the orchards are planted in completely bare soil, through routine application of herbicides.

The use of soil cover in the orchards reduces and even eliminates the use of herbicides. The effect of cover plants on weeds may be suppressant by means of plant mass deposition and even allopathic effect with the release of allele chemical that inhibit the growth of weeds (Bettoni *et al*., 2011; 2012).

The benefits of soil cover use are shown in studies demonstrating increases in the grape crop yield (Dalbó and Becker 1994; Zalamena *et al*., 2013a). The effects of vegetation cover in the increase of yield are observed when coverage is carried out in the dormant period of the vines. On the other hand, whether the soil is permanently covered, the effect starts competing with the vine for nutrients, and especially for water (Murisier & Calame, 1987; Dalbó and Becker, 1994). Under certain conditions, the cultivation of perennial cover crops may be an interesting alternative, especially in soils with high content of organic matter. By proving this statement, Zalamena *et al*. (2013a) and Zalamena *et al*. (2013b) observed in soils with high levels of organic matter that the cultivation of tall fescue (*Festuca arundinacea*) may be a viable alternative to reduce the vigor of the vine, producing wines with higher content of anthocyanins and total polyphenols.

Another interesting effect of the use of cover crops was observed by Botton *et al*. (2010), who found a lower infestation of *urhizococcus brasiliensis* in areas maintained with vegetation cover than in areas without coverage, which can be attributed to the ease of to plague to locate the vine plants, as they are the only hosts in the area with no plant protection.

A large number of plant species has potential for being used as a soil cover plant. However, for the selection of the most suitable species for cultivation in a given local, the adaptability capacity of each species to the existing conditions in the vineyard should be considered, as some unfitted species may produce less biomass than the typical weed in the cultivation area (Bugg *et al*., 1996). According to Agostinetto *et al*. (2000), the plant mass of the aerial part produced by plants and their soil covering capacity are important parameters that should be used to evaluate the suitability of species.

The growing of soil cover crops in vineyards is a practice that has been increasingly adopted in southern Brazil in the winter period. However, due to the limited availability of experimental results with species of plants suitable for this purpose, it is necessary to carry out studies to verify their effects on vegetative, productive and qualitative behavior of “Cabernet Sauvignon” grapevines.

MATERIAL AND METHODS

This work was carried out in 2009/10 and 2010/11 crops in experimental orchard at Estação Experimental da Epagri de Videira, located in the city of Videira, in the Upper Valley region of Rio do Peixe, state of Santa Catarina (geographic coordinates, 27º 02’04" S and 51º08’05"W at 834 m above sea level). The vineyard was established in 1999 on UDULT class soil (Embrapa, 2013) whose area is in a region with climate characterized as Cbf, according to Köppen classification (Pandolfo *et al*., 2002).

For the formation of the orchard, seedlings of “Cabernet Sauvignon” grafted on Paulsen 1103 rootstock were planted in the spacing of 1.5 x 3.0 m and plants conducted in trellis system. Before orchard implementation, fertilization and liming were carried out, based on the chemical analysis of the soil (Table 1). After the implementation of the orchard, crop management consisted of manual weeding on the planting rows and mechanical mowing between rows without the application of herbicides.

Orchard fertilization, which until the beginning of the experiment was done in the row of the crop, was the application in total area of 150 kg ha^{-1} N as urea, 100 kg ha^{-1} P_2O_5 as triple superphosphate and 120 kg ha^{-1} K_2O in the form of potassium chloride. About 50% of the phosphorus amount and 25% of potassium dose was applied at sowing of cover crops, associated with the application of 1.5 t ha^{-1} of dolomitic limestone. The rest of the rates of the fertilizers was split and applied during the vegetative cycle of the grapevine, starting about 15 days after sprouting and extending until the color change of the berries.

The treatments consisted of sowing eight species of winter cover crops (white clover, red clover, vetch, wild radish, gorga, black oat, rye and ryegrass) and additional treatments with manual weeding or mechanical mowing of weeds. The seeding rate of white clover, red clover, vetch, wild radish, gorga, black oat, rye and ryegrass were 4, 6, 40, 20, 10, 80, 50 and 25 kg ha^{-1} seed , respectively, adjusted to 100% germination.

Cover crops were sown by throwing all over the plot area in June of each year, with mild incorporation by using hoe and managed by mowing at their full bloom. Each plot consisted of an area of 45 m^2 of vegetation, made up of five grapevine plants, where one plant of each end was borders, evaluating the three central plants. The experimental design was a randomized block design with four replications.

At the time of fruiting pruning, the number of rods and the mass of the pruned material per plant were determined. After bud sprouting, the number of branches per plant was determined. Before harvest, 100 berries were collected randomly on the useful area of each plot, located in the apical, median and basal areas of different clusters on both sides of the plant to determine the total soluble solids, titratable acidity and pH, using methods described in Rizzon (2010). At harvest, which occurred in April of each wine harvest, the number of bunches per branch, the number and weight of bunches per plant and the average weight of bunches per plot were determined.

The nutrient content in the leaf tissue of grapevines was determined on samples collected at the time of color change of the skin, consisting of 50 petioles of newly matured leaves per plot for analysis of N, P, K, Ca, Mg, Fe, Mn, Zn and B, according to the methodology described in Tedesco *et al*. (1995). Fresh and dry mass yields of cover crops and weeds were determined at the time of full bloom. The samples were collected 1.0 x 1.0-m square by cutting the plant material close to the ground, collecting three subsamples per plot, one in the row and two in between the rows. After collection, cover plants were separated from weeds and weighing of the fresh mass of both (FM t.ha^{-1}) was carried out. Subsequently, the samples were dried in an oven at 60°C, until constant weight to determine dry matter (DM t.ha^{-1}).

Data were submitted to analysis of variance, and when significance was tested by the F test, the averages were compared by the test of Tukey at 5% of error , using the statistical program SISVAR 5.0 (Ferreira, 2011).

RESULTS AND DISCUSSION

Biomass yield differed among winter cover crops, where lower yield was found in productions of red and white clover, which produced insignificant quantities in the first harvest (Table 2). The highest biomass yield (FM t.ha^{-1}) in the first year was achieved in vetch crop, followed by ryegrass and turnip, with production of 30.0; 22.9 and 19.7 t ha^{-1}, respectively. However, when comparing the dry matter production, which ultimately is what really remains on the ground, no statistical difference between the cultivated species was found, except for the clovers. In the second harvest, the production of biomass (FM t.ha^{-1}) followed the same trend of the previous harvest; however, when dry matter production (DM t.ha^{-1}) was compared, ryegrass stood out, with 5.25 t ha^{-1}, followed by rye, vetch and black oat. The smallest yield of biomass (FM t.ha^{-1}) was found in wild turnip and gorga, with 2.63 and 1.92 t ha^{-1}, respectively. Similar to the previous harvest, the insignificant biomass yield of clovers was evident due to low capacity of establishment, which associated with the slow initial growth of this species is muffled by the spontaneous vegetation.

Regarding the percentage of dry mass of cover crops, rye showed the highest index in the two evaluated harvests, indicating lower water content in plant tissue when compared with other species (Table 2). The great potential of plant mass of rye was also found in a study carried out in the state of Paraná by Derpsch *et al*. (1987) and in Santa Catarina by Wildner and Dadalto (1992). This larger yield of rye biomass, associated with its high C/N ratio (Doneda *et al*., 2012;Wildner and Dadalto, 1992), makes this species an interesting option for land cover in vineyards, especially in soils with low content of organic matter as it promotes

Table 1: Soil chemical characteristics of sample colected in the 0-20 cm layer in a 'Cabernet Sauvignon'cultivar vineyard, Videira, state of Santa Catarina

Soil	pH[1]	O.M.	P	K	Ca	Mg	Al	H + Al
Layer cm		g kg^{-1}	mg dm^{-3}		cmol$_c$ dm^{-3}			
0-20	5.48	41.25	16.10	173.25	5.30	3.23	0.82	5,63

[1] pH in water.

accumulation of persistent dry matter on the soil surface in addition to reducing the harmful effect of water runoff and reduces the impact of rain water drops on the ground, promoting nutrient cycling and maintaining water infiltration in the soil profile.

The reflection of adaptability capacity and establishment of cover crop species is shown in Figure 1. The rye, among the evaluated species, presents more dominance in relation to the weeds, around 90% of dry matter produced in the winter cycle followed by ryegrass, black oats, wild radish, vetch, gorga and clovers. The effect of cover crops on weeds is normally suppressive due to the rapid establishment and initial growth, characteristic not presented by species of clover. In addition to the dominance of cover crops on weeds in dormant stage of the grapevine, there is also the effect of the remaining mulch after the management of green mass on the growth of weeds (Bordelon & Weller, 1997), as well as nitrogen fractionation (Brunetto *et al*., 2011), increase in the content of organic matter in the soil (Faria *et al*., 2007) and grape productivity (Dalla Rosa *et al*., 2009), with no effect on their quality.

The production of grapes and its income components were not affected by treatments in the two evaluated crops (Table 3). However, in the second harvest, grape production was 9.55 t ha^{-1}, in the average of treatments, 56.4% higher than in the previous harvest, possibly associated to climatic conditions that favor the production in this season. Similar results were found by Zalamena *et al*. (2013b) when evaluating a “Cabernet Sauvignon” vineyard in the Santa Catarina Plateau region, where no increase in the productivity of grapes was found using land cover plants during two evaluation crops. Even in the cultivation of nitrogen-fixing species such as vetch or clovers, increase in plant vigor was not found, probably due to the high content of organic matter found in natural conditions in soils of the Upper Valley of Rio do Peixe and that already meets the requirements of the crop for this nutrient.

Table 2: Plant mass and dry matter percentage of winter cover plants in ‘Cabernet Sauvignon’cultivar vineyard,in two harvests. Epagri, Videira, state of Santa Catarina

Species	DM	FM	% DM	FM	FM	% DM
	2009/2010 (Harvest 1)			2010/2011 (Harvest 2)		
	t ha^{-1}		%	t ha^{-1}		%
Rye	4.18 a	13.90 b	30.00 a	4.64 ab	11.70 a	40.20 a
Rye grass	4.16 a	22.90 ab	18.50 b	5.25 a	18.80 a	28.00 b
Vetch	3.35 a	30.00 a	11.20 bc	4.13 abc	20.50 a	20.20 c
Gorga	2.72 a	13.20 b	16.00 bc	1.92 de	9.52 a	19.20 c
Black oat	2.59 a	15.20 b	17.20 bcd	3.52 abcd	17.90 a	19.70 c
Wild turnip	2.52 a	19.70 ab	12.70 bcd	2.63 bcde	15.00 a	17.50 c
Red clover	0.03 b	0.23 c	12.20 bcd	0.31 f	1.43 b	20.70 c
White clover	0.01 c	0.09 d	7.70 d	0.26 f	1.91 c	16.70 c
C.V (%)	15.61	20.12	36.42	29.14	42.12	28.54

DM (dry mass); FM (fresh mass); % DM (dry mass /fresh mass x 100). Means followed by the same leeter in the column do not differ significantly from each other ($p < 0.05$).

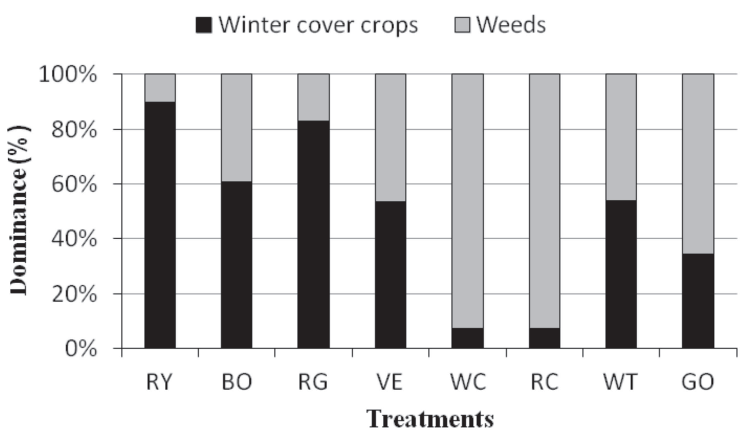

Figure 1: Dominance of cover crops over the weeds, in two wine harvests of soil management with winter cover crops on a grapevine orchard ‘Cabernet Sauvignon’. RY: rye grass; BO: black oat; RG: rye grass; VE: vetch; WC: white clover; RC: red clover; WT: wild turnip; GO: gorga.

The total soluble solids content and pH in both harvests and the total acidity in the second crop were not influenced by cover crops, manual weeding and mechanical mowing (Table 4). In the first harvest, total acidity showed a significant difference among treatments with manual weeding and cover with vetch. However, the magnitude of the difference is very small, so that it does not affect substantially the quality of the wine. This similarity of the wort characteristics of the evaluated crops may be related to the absence of treatment effects on plant vigor and increase in the yield of grapes.

The species of cover crops and management of its biomass with manual weeding or mechanical mowing influenced the accumulation of nitrogen (N), phosphorus (P) and boron (B) on the petioles of the leaves at "Cabernet Sauvignon" grapes color change state (Table 5). A higher N content in the petioles of the leaves in the plots with vetch in relation to the ones in the oat plot, which presented N accumulation similar to other crop cover species and also to the management with hoeing or mowing. The higher N content observed on the cover with vetch, however, did not result in productivity gains and vegetative vigor as also observed by Dalbó and Becker (1994) in a study with using this species as cover crops in vineyard for four years. Thus, it can be inferred that gains in vegetative vigor, and even in grapevine productivity with vetch cover can be achieved in the long term only.

Higher levels of accumulated P and B in the petioles of the grapevine leaves were found when using the turnip as land cover plant, significantly differing from management with manual weeding and cover with vetch (Table 5). There are studies that report the rapid release of P and N in the decomposition of wild turnip (Ohland *et al*., 2005), with higher release rate up to fifteen days after plant mass management (Heinz *et al*., 2011).

Land cover is essential for the sustainability of the production system and the effects are likely to be more apparent over the years of using this practice. As the evaluation was conducted during two growing seasons, the effects of cover crops were not found in the increase of productivity and quality of the grapes produced; however, in the short term, it was possible to observe the suppressive effect on the weeds in vineyards grown with species of cover crops in the winter period, which can lead to a reduction in the use of chemical control, thus reducing the cost of grape production.

Table 3: Rods, branches and clusters per platn and cluster weight per plant, production, cluster average weight and cluster per branch of 'Cabernet Sauvignon' grapevine in two wine harvests. Epagri, Videira, state of Santa Catarina

Species	Rods	Brancehs	Clusters	Cluster mass	Production	Cluster mass	Clusters
	Harvest 2009/2010						
	units plant^{-1}			kg plant^{-1}	t ha^{-1}	g cluster^{-1}	un. branch^{-1}
Vetch	3.93^{ns}	33.77^{ns}	23.77^{ns}	1.93^{ns}	4.23^{ns}	91.30^{ns}	0.67^{ns}
White clover	4.17	32.37	31.83	2.93	6.50	93.77	1.00
Wild turnip	3.70	36.27	31.93	2.70	5.93	85.47	0.93
Black oat	3.70	34.87	26.77	2.25	4.98	84.80	0.77
Weeding	3.43	34.30	25.80	2.53	5.60	99.30	0.77
Rye grass	4.10	33.83	28.70	2.56	5.70	95.40	0.83
Gorga	3.27	32.93	23.50	2.26	5.03	98.10	0.68
Rye	3.83	35.60	27.50	2.43	3.37	91.00	0.77
Red clover	4.37	34.10	27.60	2.54	5.67	91.07	0.80
Mowing	4.80	32.93	36.17	3.13	6.93	86.60	1.10
C.V. (%)	30.64	15.85	31.49	24.63	24.97	19.77	26.83
Species	Harvest 2010/2011						
Vetch	5.33^{ns}	26.27^{ns}	47.60^{ns}	4.33^{ns}	9.63^{ns}	90.97^{ns}	1.87^{ns}
White clover	5.25	26.13	50.37	3.87	8.60	76.83	1.90
Wild turnip	5.00	26.87	53.53	4.20	9.33	77.40	2.00
Black oat	4.92	25.20	55.10	4.50	10.03	82.77	2.27
Weeding	5.43	25.20	49.53	4.87	10.80	96.67	1.93
Rye grass	4.50	22.30	41.60	3.63	8.10	88.13	1.90
Gorga	5.50	26.63	58.50	4.93	11.00	84.83	2.20
Rye	4.77	22.87	57.03	4.83	10.70	88.27	2.60
Red clover	3.92	21.33	48.50	3.83	8.53	78.57	2.50
Mowing	4.50	22.27	46.20	3.97	8.83	88.43	2.13
C.V. (%)	23.74	17.59	19.53	24.03	23.99	19.35	26.65

^{ns} – not significant.

Table 4: Total soluble solids content (TSS), pH and total acidity of ‘Cabernet Sauvignon’ grapevine in two wine harvests. Epagri, Videira, state of Santa Catarina

Species	TSS	pH	Total acidity	TSS	pH	Total acidity
	Harvest					
	2009/2010			2010/2011		
	°Brix		meq L^{-1}	°Brix		meq L^{-1}
Vetch	19.20^{ns}	3.52^{ns}	109.30 b	17.30^{ns}	3.71^{ns}	163.07^{ns}
White clover	19.10	3.46	110.70 ab	17.03	3.68	135.53
Wild turnip	18.83	3.46	116.00 ab	17.17	3.70	125.60
Black oat	18.60	3.47	109.43 ab	16.63	3.68	139.30
Weeding	18.53	3.45	122.63 a	16.47	3.70	135.87
Rye grass	18.47	3.40	114.77 ab	16.87	3.68	139.00
Gorga	18.40	3.43	116.07 ab	16.47	3.69	142.60
Rye	18.30	3.47	117.60 ab	17.10	3.71	139.30
Red clover	18.30	3.45	115.00 ab	16.77	3.70	135.90
Mowing	17.93	3.41	117.43 ab	16.87	3.69	146.83
C.V. (%)	3.28	1.18	3.96	5.23	1.04	12.60

^{ns} – not significant. Means followed by the same leeter in the column do not differ significantly from each other ($p < 0.05$).

Table 5: Average nutrient content on the petioles of the leaves at “Cabernet Sauvignon” grapes color change state in two wine harvests with manual weeding, mechanical mowing and winter crop cover species. Epagri, Videira, state of Santa Catarina

Species	N	P	K	Ca	Mg	Fe	Mn	Zn	B
	%					mg kg^{-1}			
Vetch	0.93 a	0.18 bc	8.38^{ns}	1.36^{ns}	0.68^{ns}	84.4^{ns}	649^{ns}	170^{ns}	26.40 b
Rye grass	0.89 ab	0.33 ab	7.57	1.39	0.68	83.2	402	169	28.80 ab
White clover	0.87 ab	0.25 abc	7.73	1.36	0.74	94.2	527	177	31.60 ab
Gorga	0.86 ab	0.28 abc	7.62	1.39	0.69	81.9	361	147	29.50 ab
Wild turnip	0.85 ab	0.35 a	7.70	1.40	0.68	93.7	424	181	33.80 a
Rye	0.84 ab	0.31 ab	8.03	1.39	0.66	83.8	367	164	30.70 ab
Mowing	0.84 ab	0.29 abc	7.20	1.38	0.70	89.6	510	182	31.70 ab
Weeding	0.84 ab	0.14 c	7.55	1.38	0.75	98.7	471	155	26.50 b
Red clover	0.83 ab	0.32 ab	7.30	1.35	0.74	83.6	661	171	30.50 ab
Black oat	0.79 b	0.32 ab	7.90	1.36	0.65	89.8	607	185	29.50 ab
C.V. (%)	4.32	7.65	3.62	3.12	3.68	12.19	28,25	19,14	8.52

^{ns} – not significant. Means followed by the same leeter in the column do not differ significantly from each other ($p < 0.05$).

CONCLUSIONS

Winter cover crops do not alter the productivity and quality of “Cabernet Sauvignon” grapes.

The rye and ryegrass are effective alternatives for weed control while the white and red clovers presented difficulties in the initial establishment, producing low amounts of biomass and allowing for greater development of the weeds.

Cover plants and cover management, both manual weeding as mechanical mowing, influenced the concentration of N, P and B in the petioles of the leaves of “Cabernet Sauvignon” grapevine.

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