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COVER CROPPING IN A SLOPING, NON-IRRIGATED VINEYARD: I – EFFECTS ON WEED COMPOSITION AND DYNAMICS

ENRELVAMENTO EM VINHA DE ENCOSTA NÃO REGADA: I – EFEITO NA COMPOSIÇÃO E DINÂMICA DAS INFESTANTES

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SUMMARY

The influence of two sward treatments and soil cultivation on the composition, the structure, and the evolution of the biomass of vineyard weed communities was examined. The 3-year study (2002-2004) was carried out in a sloping, non-irrigated vineyard, cv. 'Cabernet Sauvignon', in the Estremadura winegrowing region of Portugal. The experimental treatments were: soil tillage (control); permanent sown cover crop - *Lolium perenne* 'Nui'*,* *L. multiflorum* 'Bartíssimo'*,* *Festuca ovina* 'Ridu', *F. rubra* ssp. *rubra* 'Echo', *Trifolium incarnatum*. 'Red', *T. repens* 'Huie' and *T. subterraneum* 'Claire'; and permanent resident vegetation. Total weed biomass in the spring did not reveal significant differences between treatments, but varied annually. The management practices – e.g. time and number of soil cultivations and inter-row mowing – were determinant in weed biomass evolution. Canonical correspondence analysis revealed significant treatment effects on community structure. Three years after the experiment was set up, in the soil tillage treatment weed composition was dominated by annual broad-leaved species, namely five *Geraniaceae* species, *Medicago polymorpha* and *Sonchus oleraceus.* The perennial broad-leaved species *Oxalis pes-caprae* was also a dominant species in soil tillage. In both sward treatments there was an increase in the perennial broad-leaved and grass species. Compared to soil tillage, in the resident vegetation treatment there was a significant increase in perennial species, such as *Rumex crispus, Veronica anagallis-aquatica* and *Polypogon monspeliensis*, and in the annuals *Melilotus indica* and *Avena sterilis*. The increase in these perennial species, which are considered to compete with vines, requires more frequent mowing in the summer. In the permanent sown cover crop treatment, *L. perenne* and *T. repens* displayed the ability to re-establish successfully, and their abundance decreased or suppressed most of the annual and perennial weed species.

RESUMO

No presente trabalho é analisado o efeito do enrelvamento, comparativamente à mobilização do solo, na composição, estrutura e dinâmica das infestantes vitícolas. O estudo de três anos (2002-2004) decorreu numa vinha de encosta, não regada, casta 'Cabernet Sauvignon', na região Vitícola da Estremadura, Portugal. Foram comparadas três modalidades: mobilização do solo (testemunha), enrelvamento semeado permanente (*Lolium perenne* 'Nui'*,* *L. multiflorum* 'Bartíssimo'*,* *Festuca ovina* 'Ridu', *F. rubra* ssp. *rubra* 'Echo', *Trifolium incarnatum* 'Red', *T. repens* 'Huie' e *T. subterraneum* 'Claire'), e enrelvamento permanente natural. Não se registaram diferenças significativas na biomassa total da vegetação da entrelinha na primavera entre modalidades mas o valor absoluto variou com o ano. As práticas de gestão aplicadas em cada modalidade, designadamente época e número de mobilizações do solo e corte do enrelvamento foram determinantes na evolução da biomassa. A análise canónica de correspondências revelou efeitos significativos entre modalidades nas espécies inventariadas, com implicações nas comunidades residentes. Três anos após o início do ensaio a composição florística na modalidade mobilizada era dominada por espécies dicotiledóneas anuais, designadamente cinco espécies de *Geraniaceae*, *Medicago polymorpha* e *Sonchus oleraceus.* No enrelvamento natural houve um aumento de espécies perenes como *Rumex crispus Veronica anagallis-aquatica* e *Polypogon monspeliensis* e de algumas anuais tal como *Melilotus indica* e *Avena sterilis*. O aumento daquelas espécies perenes, consideradas como competitivas com a videira implica uma maior frequência dos cortes no verão. No enrelvamento semeado as espécies *L. perenne* e *T. repens* mantiveram a sua capacidade de regeneração e a sua abundância reduziu a dominância ou eliminou a maioria das infestantes anuais e perenes inventariadas no enrelvamento natural.

Keywords: *Vitis vinifera* L.; grapevine; cover crops; soil tillage; weed community
Palavras chave: *Vitis vinifera* L.; vinha, enrelvamento; mobilização do solo; infestantes

INTRODUCTION

Cover cropping, either by resident or by selected sown species, is an important ecological vineyard management tool. This cropping system is increasingly being used to prevent erosion (Gulick *et al.*, 1994; Shanks *et al.*, 1998), to improve soil structure by limiting soil compaction and improving soil porosity, to manage soil moisture (high porosity makes soil able to absorb water, thereby resulting in low waterlogging or runoff), and to enhance trafficability during wet weather (Folorunso *et al.,* 1992a; Folorunso *et al.,* 1992b; Prichard, 1998). The use of cover crops can also suppress resident vegetation (Elmore *et al.*, 1997) and promote beneficial insects, which can in turn reduce pest densities and interact with soil biota (Costello and Danne, 1998, Campos *et al.*, 2006). Nevertheless, improperly selected or managed cover crops may compete with vines for water (Prichard, 1998, Lopes *et al.*, 2004) and nutrients (Hirschfelt, 1998; Geoffrion, 1999; Chantelot *et al.*, 2001). Water competition can be avoided by limiting the duration of living mulch to between season-long in moist regions and a few months in dry regions (Hartwig and Ammon, 2002).

Weed control is said to be easier with a cover cropping system in a perennial crop, because resident vegetation can be manipulated by using selective herbicides or timely mowing to suppress the seeding of undesirable species. Plant species diversity has been found to be higher, especially in the case of permanent cover (Gut *et al.*, 1997).

Portuguese vineyard practice typically involves integrating soil tillage in the inter row with postemergence and preemergence herbicides in the row (Moreira and Monteiro, 2000, Monteiro and Moreira, 2004), and less emphasis on the incorporation of other weed control practices such as cover cropping, be it sown or natural. This practice partly reflects the paucity of published Portuguese research on weed control in cover cropping vineyards (Frazão and Moreira, 1990; Moreira *et al.*, 1992; Afonso *et al.*, 2003). There is thus a need for research in this field in order to identify effective weed control practices that can be integrated into the cropping system in such a way as not to impact wine grape production while simultaneously producing positive effects on the ecology.

The aim of the present research was therefore to compare the ecological weed control practice of permanent vineyard cover cropping with the conventional practice of soil tillage, in the Estremadura winegrowing region of Portugal. The objectives of this article were to evaluate the efficacy of these practices on weed dynamics during the grapevine growing season, and to characterize the evolution of the weed community. This study is part of a large research project in which water use (Monteiro and Lopes, 2007), vine vegetative growth, yield and wine quality (Lopes *et al.*, 2008), and beneficial arthropods (Campos *et al.*, 2006) have also been monitored.

MATERIAL AND METHODS

Site characteristics and experimental design

The experiment was set up in 2002 at Quinta de Pancas, Alenquer (Estremadura winegrowing region), Central Portugal (lat. 39º 01' N; long. 9° 06'E), in a sloping (7%), non-irrigated vineyard with a sandy clay loam soil with the following average characteristics: clay 23.6%; silt 20.2%; sand 56.2% (USDA classification); organic matter 0.7%; pH 8.4. The weather data, which was recorded by an automatic weather station (Pulsiane, Pulsonic, Orsay, France) located within the experimental vineyard, are shown in Fig. 1. During the experimental period (2002 to 2004), the mean air temperature ranged between 10 ºC (the mean minimum daily temperature in January 2003) and 23.6 ºC (the mean maximum daily temperature in August 2003), while the mean total annual rainfall was 885.3, 941.8 and 564.4 mm, in 2002, 2003 and 2004, respectively. The hot and dry months are usually June, July and August. According to Costa *et al.* (2001), the region's bioclimate is classified as Mediterranean pluviseasonal-oceanic, mesomediterranean, sub-humid.

The trial was carried out in a vineyard growing a commercial 15-year-old 'Cabernet Sauvignon' (*Vitis vinifera* L.) grafted on R110 rootstocks. For a more detailed description of the vineyard training system, see the companion paper (Lopes *et al.*, 2008).

The experimental design was a randomized comple-

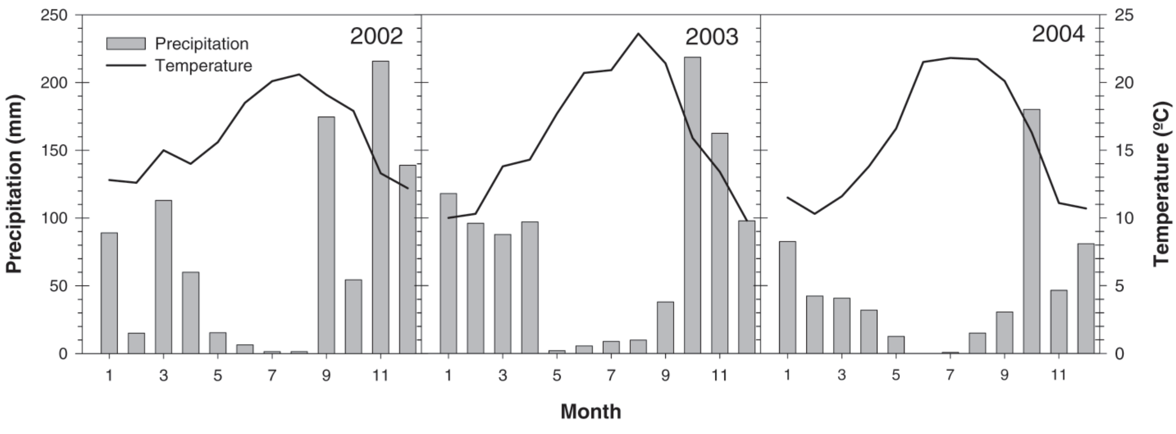

Fig. 1 - Mean daily temperature (lines) and total monthly precipitation (bars) from 2002 to 2004 at Quinta de Pancas, Alenquer, Portugal.
Temperatura diária média (linhas) e precipitação mensal de 2002 a 2004, Quinta de Pancas, Alenquer, Portugal.

te block with three treatments and four replications per treatment. The three treatments were: (1) soil tillage over the between rows (ST); (2) permanent resident vegetation cover between rows (RV); (3) permanent sown cover crop between rows – 50 kg/ha, with a mixture of 60% grasses (*Lolium perenne* L. 'Nui', *L. multiflorum* Lam. 'Bartíssimo', *Festuca ovina* L. 'Ridu', *F. rubra* L. ssp. *rubra* 'Echo') and 40% legumes (*Trifolium incarnatum* L. 'Red', *T. repens* L. 'Huie' and *T. subterraneum* L. 'Claire') (SCC), which were sown in March 2002. Each replicate (plot) had four rows with 100 vines each, and all the measurements were made in the central space between the 2 innermost rows.

In all the treatments, a 0.8 m-wide herbicide strip was achieved along the row under the vines by a single application of the foliage herbicide 1,800 g a.i. ha^{-1} glyphosate (ROUNDUP 360®, Monsanto) just before bud burst. The herbicide was sprayed with a motorized knapsack, with one APG 110V Albuz® flat-fan nozzle delivering 500 L ha^{-1} at 200 kPa. The fertilization, vine-pest and disease control and other cultivation practices, including grapevine canopy management, were similar in all the treatments, with soil management practice the sole exception. For fertilization, 39 kg ha^{-1} of N and P and 63 kg ha^{-1} of K were supplied evenly over the surface of the soil every two years, at the beginning of March.

Conventional soil tillage treatment included vegetation mowing in the first week of February – a common operation that aims to shred vine prunings – and a soil cultivation with a spading machine in spring (bud burst) and a rotary tiller in summer (end June), to incorporate weeds into the soil.

In the two cover cropping treatments the sown and resident vegetation was mowed by a flail mower twice a year, namely before vine bud burst (first week of February) and at vine flowering (end of May or first week of June), always at a height of 10-15 cm.

Weed assessment and data analysis

Shoots from each plant species were harvested by cutting plants at soil surface level inside four 0.5 m^2 areas per plot (16 samples per treatment). Dry matter per species was recorded. Plant species were grouped according to annual grass species, annual broad-leaved species, perennial grass species, and perennial broad-leaved species. Species biomass values were complemented by a relative biomass value for each species. This characterized the importance of single species, given that possible non-homogeneous plant population distributions within the plots were equalized. The values were calculated using the method described by Derksen *et al.* (1993) and Streit *et al.* (2003), but applied to species biomass instead of species density.

Vegetation composition at each treatment was analysed using a canonical discriminant analysis (CDA). The relative biomass from the April 2004 survey was used as the weed species descriptor in the multivariate analysis. This option was based on the results from the surveys carried out during 2002 and 2003. Vegetation richness attained the highest values at that time of year. Individual plot scores were plotted on a scattergram in which the axes represent the first two canonical variables. The type and degree of association between species and treatments were evaluated in an ordination biplot created by superimposing a vector diagram on the scattergram, with vectors representing weed species (Bàrberi and Lo Cascio, 2001). The statistical significance of the factors was evaluated by permutation tests that took the experimental design into account.

CDA and ANOVA were respectively carried out in accordance with the CANDISC and GLM procedures from the SAS® program package (SAS Institute, Cary, NC, USA).

RESULTS AND DISCUSSION

Weed communities

The total amount of above-ground weed biomass changed annually, due mainly to the occurrence and amount of precipitation in March and April (174.8 and 72.8 mm in 2003 and 2004, respectively) and to increases in mean daily temperature (Fig. 1). The total vegetation biomass consequently changed from year to year (Fig. 2). However, each year saw an increment in total vegetation biomass between March and May, with a subsequent decrease until harvest (Fig. 4).

In the first two years of the experiment, SCC presented the significantly lowest total spring above-ground biomass. In 2002, the differences can be explained by the short period of time between the sowing of the cover crop and its biomass harvest. In 2003, the frost in February that caused the disappearance of *O. pes-caprae*, and the rainfall during March, both induced the dominance of the annual broad-leaved species in ST and RV treatments. The highest total biomass presented by the swards in 2004 can be explained by cover crop species and perennial species attributes, such as early vegetative regrowth and establishment (Olmstead *et al.*, 2001; Fourie, 2005).

In 2002, a total of 29 species were surveyed before soil cultivation and vegetation mowing in ST and RV. Three families were dominant: *Oxalidaceae* (52% of the total biomass), with a single species *Oxalis pes-caprae*; *Geraniaceae* (36% of the total biomass), with 5 species (*Erodium malacoides, E. moschatum.*, *Geranium dissectum*, *G. molle* and *G. rotundifolium*); and Asteraceae (8% of the total biomass), with 6 species (*Leontodum taraxacoides* ssp. *taraxacoides*, *Picris echioides*, *Sonchus asper* ssp. *glauscescens*, *S. oleraceus*, *S. tenerrimus*), amongst which *Calendula arvensis* had the highest biomass. *Fabaceae* presented 2% of the total biomass, and

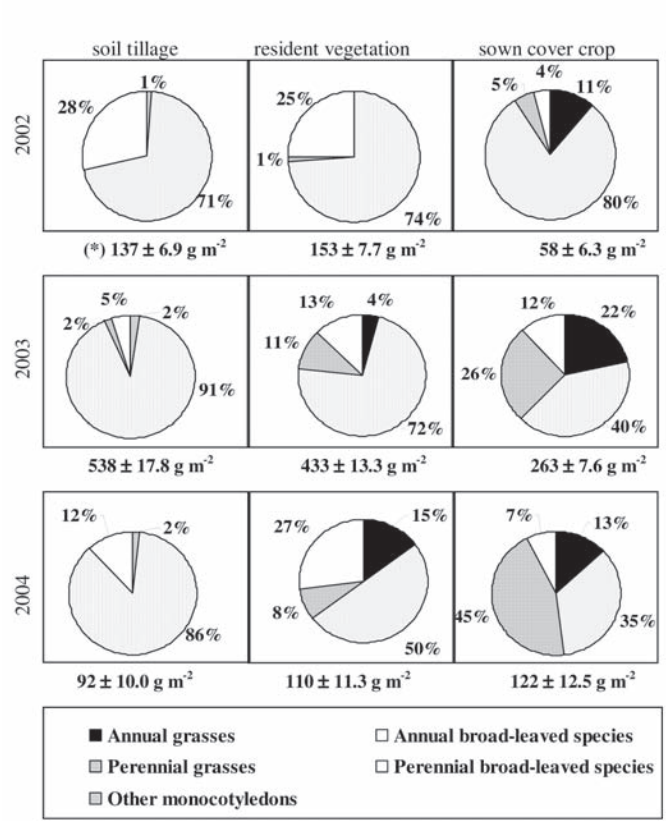

Fig. 2 - Main weed species groups (percentage of the total above-ground dry-matter) at the end of April from 2002 to 2004, at Quinta de Pancas, Alenquer. (*)Above-ground dry biomass; average of 16 surveys per treatment ± SE.
Principais tipos biológicos (percentagem da biomassa total seca) no final de Abril de 2002 a 2004, Quinta de Pancas, Alenquer, Portugal. (*)Biomassa seca; média de 16 levantamentos por modalidade ± SE.

Poaceae and a group of other families recorded a biomass of less than 1%. In April 2002, annual broad-leaved species were dominant in the three treatments (Fig. 2).

In April 2003, in the soil tillage treatments the vegetation richness did not change, but the biomass returned the highest values for any of the three years (Fig. 2). The total biomass was distributed among 28 species, 93% of which were annuals. *M. polymorpha* was the species with the highest biomass (408 g m^{-2}), followed by the *Geraniaceae* species (87 g m^{-2}). These values can be attributed to a reduction in inter-species competition due to the disappearance of *O. pes-caprae* and the decrease of *C. arvensis,* which were caused by the frost in February. The species *C. arvensis*, *Juncus bufonius*, *Mentha longifolia* and *Sherardia arvensis* only occurred in cases of soil tillage treatment. Where the permanent resident vegetation (RV) was concerned, the number of species surveyed was 29, and the ratio of annuals to perennials was 76:24 (Fig. 2). The total vegetation biomass was also dominated by *M. polymorpha* (179 g m^{-2}), *Ranunculus muricatus*, (44 g m^{-2}), *Veronica anagalis-aquatica* (35 g m^{-2}), and *Lolium multiflorum* (28 g m^{-2}). The species *Avena sterilis*, *Linum usitatissimum*, *Muscari comosum*, *Poa annua*, *R. muricatus*, and *Trifolium arvense* were only recorded in RV. In the permanent sown cover (SCC), a total of 24 species were surveyed. Sown *Poaceae* and *Fabaceae* dominated, with 6 species from each family. The shoot biomass was 130 g m^{-2} for *Lolium* spp., 10 g m^{-2} for *Festuca* spp., and 20 g m^{-2} for *Trifolium* spp., while the resident species *M. polymorpha* was also present (38 g m^{-2}).

In 2004, flora composition remained almost the same in the soil tillage treatment, despite the decrease in the number of species (20). There were significant changes in species biomass in ST, RV and SCC (Table I). In the recorded *taxa* in the three treatments, the species with high biomass were *M. polymorpha*, *Trifolium* spp., *Lolium perenne*, *L. multiflorum*, *Erodium* spp., *Geranium* spp., *A. sterilis*, *Sonchus oleraceus*, *O. pes-caprae*, *V. anagallis-arvensis*, and *Rumex crispus* (Table I). Significant differences between treatments were also observed in the vegetation groups. In the soil tillage system the vegetation community composition was still dominated by annual broad-leaved species, which represented 86% of the total biomass, while in the swards this figure was 50% and 35% in RV and SCC, respectively (Fig. 2). The perennial species increased their presence and dominance in RV, where the perennial broad-leaved species recorded a relative biomass of 27% and the perennial grass species 8%. In the permanent sown cover crop the perennial grass species displayed a significantly higher relative biomass than in ST and RV, and the dominant species was *L. perenne*. In the sward treatments there was also a significant increase in annual grass species (Fig. 2). The increase in this vegetation group in RV was due to the presence of *A. sterilis* (from the vineyard seed bank), and in SCC to the sown species *L. multiflorum*.

Canonical correspondence analysis (CCA) revealed significant community differences among treatments (Fig. 3). Although all the species recorded in April 2004 were included in the multivariate analysis, only those with the greatest ability to explain differences between treatments are shown in Fig. 3. The first canonical axis in the biplot of flora species explained 65% of the variance between treatments, while the second axis explained 27%. Based on the ordination diagram, *Lolium* spp., *Trifolium* spp., and *Festuca* spp. were well related with the permanent sown cover crop, *C. arvensis*, *Melilotus indica* and *A. sterilis* for the permanent resident vegetation, and *S. oleraceus*, *Euphorbia helioscopia* and *Geranium* spp. for the soil tillage system. Most of the annual and perennial broad-leaved species surveyed in the ST treatment did not appear in the SCC one. This suggests that the sown species could compete with any potential weed and were quite adaptable to the local environmental conditions.

The data revealed that the soil management system had a clear effect on plant species biomass and weed communities. This is in accord with studies conducted in various other countries (Derksen *et al.,* 1993; Bàrberi and Lo Cascio, 2001; Shrestha *et al*., 2002; Felix and Owen, 2004), as well as in Portugal (Frazão and Moreira, 1990; Moreira *et al.*, 1992; Afonso *et al.,* 2003). Results of this three-year study indicated that annual broad-leaved species spread and persist under a tillage system. Permanent resident vegetation induced the spread of some perennial broad-leaved species, such as *V. anagallis-arvensis, R. cripus, Lavatera* spp., and *P. echioides* (Table I), because they were able to re-grow after vegetation mowing – a trait that can be considered negative, as some of these weeds can compete with vines for water and disrupt management practices (Lopes *et al*., 2004). To reduce or even avoid a negative impact on the part of those weeds, cultivation every four or five years would be recommended. In the case of a sown cover crop it is often necessary to replant the selected species – sometimes as often as every 3 to 5 years – in order to disrupt the growth of problematic perennial weeds. Having said this, the RV treatment had a positive effect on vegetation diversity, in that it induced the presence of some annual species, such as: *M. indica* – a species which is important to the soil nitrogen balance; *A. sterilis* – an annual grass species with a short life cycle, which is important in this ecosystem; and the perennial grass species *Polypogon monspeliensis* (Table I). The increase in the perennial grasses in the two swards provides excellent trafficable surfaces that permit vehicular access for critical fungicide applications or mechanical harvesting during wet periods.

The effect of sward treatments on annual species can be either positive or negative, because it is related with the species flowering stage time and with the number of times and moments at which vegetation is

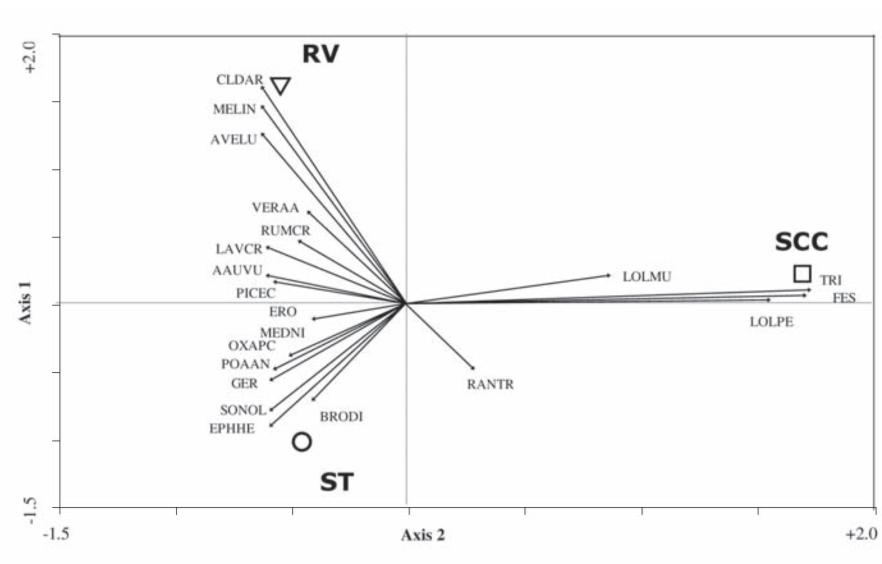

Fig. 3 – Species-treatment biplot from canonical discriminant analysis of vineyard weed communities in the three treatments, recorded 3 years after the beginning of the study. The circle, triangle and square represent soil tillage (ST), permanent resident vegetation (RV) and permanent sown cover crop (SCC), respectively. Only the species with the best fit to treatments are displayed. Bayer codes for full species names are given in Table I.

Ordenação gráfica das infestantes vitícolas nas três modalidades, inventariadas 3 anos após o início do estudo. O circulo, triângulo e quadrado representam a mobilização do solo (ST); o enrelvamento natural permanente (RV) e o enrelvamento permanente semeado (SCC), respectivamente. Só se referem as espécies com o melhor ajustamento aos tratamentos. O Quadro I apresenta a correspondência entre o Código Bayer e o nome científico da espécie.

TABLE I

Effect of vineyard soil management on weed species above-ground biomass in the third year of the experiment (April 2004).
Efeito do sistema de gestão do solo da vinha na biomassa seca das infestantes no terceiro ano do ensaio (Abril 2004).

Bayer Code / Scientific name		Species Biomass (g m^{-2} dry-matter)				
		ST	RV	SCC	*F*-test	SED
Annual grass species		**3.4**	**18.9**	**16.0**	*	**10.52**
AVEBA	*Avena barbata* Link	0.0	0.1	0.0	NS	
AVELU	*Avena sterilis* L.	0.0	15.4	0.0	*	
BRODI	*Bromus diandrus* Roth	2.0	0.0	0.0	NS	
LOLMU	*Lolium multiflorum* Lam.	1.4	3.3	16.0	*	
POAAN	*Poa annua* L.	0.0	0.1	0.0	NS	
Annual broad-leaved species		**77.8**	**64.6**	**49.5**	*	**10.58**
ANAAR	*Anagallis arvensis* L.	0.8	3.9	0.5	NS	
CLDAR	*Calendula arvensis* L.	0.0	0.3	0.0	NS	
CERGL	*Cerastium glomeratum* Thuill.	0.1	0.0	0.0	NS	
CHYMY	*Coleostephus myconis* (L.) Rchb. f.	0.0	0.1	0.0	NS	
ERIFL	*Conyza albida* Spreng.	0.0	0.1	0.0	NS	
EROMC	*Erodium malacoides* (L.) L'Her	5.4	6.7	1.3	NS	
EROMO	*Erodium moschatum* (L.) L'Her	14.3	12.6	4.2	*	
EPHHE	*Euphorbia helioscopia* L.	0.1	0.0	0.0	NS	
GERDI	*Geranium dissectum* L.	3.5	3.0	0.7	NS	
GERMO	*Geranium molle L.*	10.0	4.0	2.2	*	
GERRO	*Geranium purpureum* Vill.	3.9	1.2	0.0	NS	
MEDNI	*Medicago polymorpha* L.	31.6	19.4	12.0	*	
MEDIN	*Melilotus indica* (L.) Allioni	0.0	10.0	0.0	*	
RANTR	*Ranunculus trilobus* Desf.	0.9	0.1	1.8	NS	
RAPRA	*Raphanus raphanistrum* L.	0.0	1.8	0.0	NS	
SENVU	*Senecio vulgaris* L.	0.3	0.0	3.6	NS	
SILFU	*Silene fuscata* Brot.	0.0	0.5	0.0	NS	
SONOL	*Sonchus oleraceus* L.	6.2	0.4	0.0	*	
TRIIN	*Trifolium incarnatum* L. 'Red'	0.0	0.0	8.0	*	
TRIRS	*Trifolium resupinatum* L.	0.0	0.0	14.6	*	
TRFSU	*Trifolium subterraneum* L. 'Clare'	0.0	0.0	0.4	*	
VICSA	*Vicia sativa* L.	0.7	0.5	0.2	NS	
Perennial grass species		**0.0**	**10.5**	**63.1**	*	**12.03**
FESOV	*Festuca ovina* L. 'Durius Spartan'	0.0	0.0	0.9	*	
FESRU	*Festuca rubra* L. ssp. *rubra* 'Echo'	0.0	0.0	4.2	*	
LOLPE	*Lolium perenne* L. 'Nui'	0.0	1.0	58.0	*	
POHMO	*Polypogon monspeliensis* (L.) Desf.	0.0	9.5	0.0	*	
Perennial broad-leaved species		**11.0**	**38.8**	**10.5**	**NS**	**11.92**
CICIN	*Cichorium intybus* L.	0.0	0.2	0.0	*	
CHOJU	*Chondrila juncea* L.	0.0	0.8	0.0	*	
CIRAR	*Cirsium arvense* (L.) Scop.	0.0	0.3	0.0	*	
DAUCM	*Daucus carota* L. ssp. *maximus* (Desf.) Ball	0.0	0.1	0.0	*	
LAVCR	*Lavatera cretica* L.	0.1	0.6	0.0	NS	
OXAPC	*Oxalis pes-caprae* L.	7.0	3.9	1.0	*	
PICEC	*Picris echioides* L.	0.0	2.4	0.0	*	
RUMCR	*Rumex crispus* L.	0.9	8.6	1.1	*	
TRIRE	*Trifolium repens* L. 'Huia'	0.0	0.0	6.8	*	
VERAA	*Veronica anagallis-aquatica* L.	3.1	21.9	1.6	*	
Other monocotyledons		**0.1**	**0.1**	**0.0**	**NS**	**0.40**
AAUVU	*Arisarum vulgare* O. Targ. Tozz	0.1	0.1	0.0		

* = significant at $P < 0.05$. NS = not significant. ST – soil tillage over the between row; RV – permanent resident vegetation between row; SCC – permanent sown cover crop between row.

mown. The permanent sown cover crop system was dominated by the perennial grass species – particularly *L. perenne*. The two species of *Festuca* germinated well, but their growth was weak. *T. repens, T. incarnatum* and *T. subterraneum* increased their biomass annually. As with the other annual species, the survival of *T. incarnatum* depends on mowing timing and frequency, as it flowers during March, which implies a mowing at the end of May.

Management implications

The evolution of the above-ground dry matter during 2004 is presented in Fig. 4. The above-ground biomass (data not shown) increased after the first mowing in February in all treatments, but in ST after the first cultivation at bud burst, the soil was kept almost bare until harvest. This first mowing also

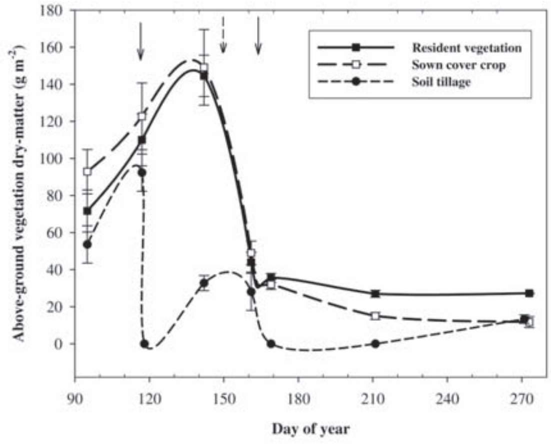

Fig. 4 - Evolution of dry-matter in weed above-ground biomass (g m^{-2}) during 2004 in soil tillage (ST), resident vegetation (RV) and sown cover crop (SCC). Arrows indicates soil cultivation (solid) and vegetation mowing (dash)
Evolução da biomassa seca total (g m^{-2}) durante 2004 nas modalidades mobilizada (ST), enrelvamento natural (RV) e semeado (SCC). As setas indicam mobilização do solo (sólida) e corte do relvado (tracejado)

improved and enhanced sward establishment and performance, inasmuch as it removed taller species that shaded grasses and legumes. In the sward treatments the amount of above-ground biomass increased until the mowing at vine flowering (end of May); the sown and most of the resident species then stopped growing until harvest, thus creating dead mulch. The vegetation growth limitation can be attributed to the low level of topsoil water that was available after mowing (Monteiro and Lopes, 2007). This indicates that the second mowing should be adjusted to the amount of spring precipitation, which is directly related to vegetation growth and vine water use. Water competition can be avoided by limiting the duration of living mulch to a few months (Hartwig and Ammon, 2002; Monteiro and Lopes, 2007). Species composition evolution – namely as regards some perennial species that are considered competitive with vines and were observed in RV – also requires an increase in mowing frequency during summer.

When it comes to weed community composition, the differential species responses to the treatments are consistent with the findings of past research in annual and perennial cropping systems, which show that frequency, timing and tolerance to cultivation or mowing interact, with multiple and varied effects on weed species (Hartwig and Ammon, 2002, Shrestha *et al*., 2002; Baumgartner *et al*., 2007).

Sward impacts on water use, vine yield, and wine quality were discussed by Monteiro and Lopes (2007) and (Lopes *et al.*, 2008). The lack of treatment effects on yield and the improvement in wine quality suggest that changes in species biomass along the vine growth cycle or in species composition did not have a negative impact on production. As such, it seems that the sward treatments are unlikely to harm grapevines, at least under ecological conditions similar to those of our study site.

CONCLUSIONS

Three years after the experiment was set up, weed composition in the soil tillage treatment was dominated by annual broad-leaved species. In the two sward treatments there was an increase in the perennial broad-leaved and grass species. In the permanent sown cover crop *L. perenne* and *T. repens* established well, and their abundance decreased annual species and suppressed resident perennial species that can be considered competitive with vines. The resident vegetation treatment had a positive effect, not only on the perennial broad-leaved competitive species, but also on weed plant species that are considered to enhance trafficability. The programmed number and time of the mowings was appropriate, but both the number and the time should be adjusted to vegetation growth and species composition every year.

The present study indicates that it may be possible to use permanent living mulches for soils with adequate water availability in the Estremadura Wine Region, where there is about 700 mm of precipitation annually. However, detailed knowledge of when the most problematic vineyard weeds become established and senesce in the swards – information that is not currently available – is crucial to expanding the cover cropping system in other Portuguese winegrowing regions. In addition, it would be useful to conduct studies throughout the country to select the cover crop species that are best adapted to the “terroir”.

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