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Sustainable management of an intercropped Mediterranean vineyard

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ABSTRACT

In the Mediterranean area, the use of cover crops in vineyards is still debated and the results of the few scientific experiments considering the influence of cover crop on grapevine are often conflicting. This work aims at providing useful indications on sustainable management for irrigated vineyards growing in a hot and dry region. A five year study was carried out in NW Sardinia, Italy, in a 8 year old vineyard cv. Carignano. To evaluate interactions between grapevine and cover crop as well as the economic impact of intercropping, soil tillage (T1) was compared with 4 inter-row treatments: natural covering (T2), complex commercial grass–legume mixture (T3), simple experimental grass–legume mixture (T4) and perennial grass *Dactilys glomerata* cv Currie (T5).

During the five years of the experiment, the mixtures have ensured a higher level of soil covering compared to the other treatments. Moreover, the covering and the contribution to the dry matter yield for every component of the mixtures changed drastically with an increased presence of *D. glomerata*. Compared to the soil tillage, the cover crops reduce the vigor but does not affect yield. Regarding fruit quality, only the perennial grass influenced positively the amount of total anthocyanins. The cost analysis has not evidenced strong differences among treatments or limiting factors for growers related to the use of cover crop in vineyards.

1. Introduction

The increasing environmental awareness widespread among global consumers and wine producing companies, has recently been transposed, in several national agriculture regulations and laws. In Italy and other EU countries, a new integrated cultivation set of rules will be mandatory from 2014; according to this new obligation the use of numerous current herbicides and pesticides will be forbidden. The promotion of the environmental sustainability in viticulture requires increasing knowledge in all the issues related to vineyard ecosystems; as well as the need to reconsider management techniques for plants and their hosts, for soil and topsoil, paying an increasing attention to actions aiming at safeguarding the structure and fertility of the cultivation sites.

The management techniques of the field influence also the chemical and physical characteristics of the soil, other than water dynamics and nutrition cycle, determining an important effect on the output, both from the qualitative and the quantitative point of view. Among different soil management techniques with a low environmental impact, an important role is given to cover crops, not only for production purposes but also to ensure year-after-year fertility, including the physical, chemical and microbiological aspects (Nieddu et al., 2000; Castro et al., 2008).

The cover cropping experiments have been proposed in Europe to tackle soil erosion due to surface runoff; in fact numerous studies were carried out in the past twenty years on the beneficial effects (Guerra and Steenwerth, 2012). Several goals may be reached through cover cropping. First of all, the nutrition cycle, as well as the soil structure and the microbiological soil characteristics are positively influenced by cover cropping while the continuous tilling, especially in hot environments, promote an exaggerated mineralization of the organic substances in the soil (Morlat and Jacquet, 2003; King and Berry, 2005).

Mediterranean viticulture is strongly affected by rainfall seasonality that puts the grapevine under a significant hydrological stress, especially during the critical phase of the ripening process (Celette et al., 2005; Koundouras et al., 1999; Mancosu, 2013). Despite cover cropping reduces weed development (Porqueddu et al., 2000), the hydrological competition between herbaceous plants and vine has

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always been the cause for reducing the adoption of cover cropping practice in Mediterranean regions, especially when irrigation was not widely used.

Celette et al. (2005) found that grape vine predawn leaf water potential and stomatal conductance did not differ significantly in vines where weeds were controlled in each inter-row by applying glyphosate during the growth period or sown with tall fescue (*Lolium arundinaceum* Schreb/Darbysh.). Despite this, the authors have highlighted, in the plants managed by covering a lower length of the canes and a lower number of leaves, suggesting that vine and tall fescue were competing for nutritional resources.

Similar conclusions have been drawn by Monteiro and Lopes (2007) that in a three years intercrops experiment, comparing soil tillage, permanent resident vegetation and permanent sown cover crop, showed that it may be possible to use permanent living mulches for soil with adequate water availability in the Extremadura wine region in Portugal, where the average annuals rainfall is about 700 mm. Despite these differences in vine water status did not affect yield or berry sugar accumulation however, in the third season after experimental setup, the mild water stress caused by the permanent presence of living mulch induced a significant reduction in vegetative growth in sward treatments, compared to soil tillage (Lopes et al., 2008).

Literature indicates that cultivation practices can significantly influence vineyard qualitative and quantitative performance (Jackson and Lombard, 1993).

Ingels et al. (2005) underlined that with an adequate distance between the row and the cover crop, the short time effects of grass cover on the vineyard performance are negligible. Tesic et al. (2007) working in two sites different for climatic conditions, shows that intercrops altered canopy architecture and reduced vine vigor and yield but only after treatments had been imposed for two or three years. however the extent of this effect was site-dependent, whereby sward-vine competition for water was more severe in the dry-hot climate compared to the milder climate.

Gontier et al. (2011), in an experiment carried out in three field cases, comparing chemical weeding with natural grass and sown grass, observed reduction of vigor and yield, fall in nitrogen content of the must and increase in sugar and polyphenolic content using cover crops. However, those effects were not the same on all the experimental fields (water reserve of the soil, variety) and on all the studied treatments (species sown).

Ingels et al. (2005) argued that the use of sown cover crops results in higher grower expense for seeds, planting and additional cultural practices. This extra expense may be justified if one or more benefits of equal or greater value are obtained, such as improved wine composition, optimized soil moisture content, increased water penetration, addition of nitrogen, and/or enhanced pest management.

Soil management, being part of the vineyard cultivation practice, should give a contribution to reach specific goals, including by all means reducing production costs. It is very important, to determine the impact of implementing a practice on production costs, the resulting weed dynamic and its effect on crop yield and quality (Tourte et al., 2008). These evaluation process has to consider environmental issues and the corporate image, which may justify the revision of traditional cultivation techniques. More in detail, the economic convenience of intercrop is determined on the basis of private rather than public criteria of judgment: in this way it is possible to evaluate the sustainability of the investment for farmers and indicate eventual needs of support by financial resources from government. In other words, the focus of the analysis is the farmer's point of view: this is consistent with a correct conception of multifunctional agriculture, where external economies – i.e. the 'non-commodity outputs' – are joint products from commodity outputs, which are the 'core business' of farms (OECD, 2001).

This paper is intended to provide useful indications on sustainable management for irrigated vineyards growing in Mediterranean regions. Our objectives were (i) to analyze the effects of grass intercrops on grapevines and (ii) to evaluate the economic impact following the establishment of intercropping.

2. Materials and methods

2.1. Study area and plant materials

The experiment was carried out during five growing seasons, between 2006 and 2010, in a private vineyard of variety Carignano, planted in 1998 and located in the Nurra Valley, Alghero, NW Sardinia, Italy (40°33′28″44 N; 08°19′19″56 E).

Carignano is a traditional red Sardinian variety, genetically similar to the Spanish grape varieties Cariñena and Mazuela (Nieddu et al., 2006). The variety is spread in South-Western Sardinia, areas characterized by sandy soil and without irrigation. These limiting pedo-climatic conditions reduce the high vine vigor of the variety and still allow a cultivation without rootstock in this area. Conversely, when introduced in more fertile areas, such as the one selected for the trial, vine vigor increases and its control is necessary.

The vines were grafted onto 779 P rootstock, spaced 2.7 m × 1.0 m and trained by a cordon spur pruned. The soil is calcareous alluvial, with an average depth of 60–70 cm, and the following physical characteristics: sand 51.0%; clay 24.9% and silt 24.1%; the pH is 7.44 while the content of organic matter is 16 g/kg.

The hydrological constants, obtained by Richards equation, are 42.0 for field capacity and 20.0 for the wilting point, both expressed as % of volume. The experimental field is 40 m.a.s.l., under a typical central Mediterranean climate with mild winter, most rains occurring between October and May.

Before sowing, a shallow soil preparation (1st passage 25 cm and 2nd passage 15 cm depth) followed by fertilization with 40 P kg ha^{-1}, 100 K ha^{-1}, 80 CaO kg ha^{-1} and 8 MgO kg ha^{-1} were done. The trial was conducted in a randomized complete block design with four replications. Each experimental plot consisted in three adjacent rows. Measurements were taken only in the central row, along 20 vines. The following five inter-row treatments were compared (T1) soil tillage, representing typical management, consisted of two or three passes (0.15 m deep) with a disk harrow and cultivator twice or three times a year to control weeds when their soil covering reached 20%; (T2) natural covering; (T3) cover crop of a complex commercial grass–legume mixture: *Trifolium subterraneum* L. cv Nungarin (24%), *Trifolium yanninicum* Katzn. and Morley cv Trikkala (16%), *Ornithopus compressus* L. cvs Charano and Santorini (16%), *Medicago polymorpha* L. cv Santiago (16%), *Biserrula pelecinus* L. cv Casbah (8%), *Lolium perenne* L. cv Victoria (12%), *Dactylis glomerata* L. cv Currie (8%); (T4) cover crop of a simple experimental grass–legume mixture: *M. polymorpha* cv Anglona (42%), *Trifolium yanninicum* cv Trikkala (30%), *L.* Katzn. and Morley *Loliumrigidum* cv Nurra (12%), *D. glomerata* cv Currie (9%) and *Trifolium brachycalycinum* cv Funtana Bona (7%); (T5) cover crop by a summer semi-dormant perennial grass (*D. glomerata* cv Currie).

Sowing was done on October 28, 2005 by hand, using a seeding rate of 30 kg ha^{-1} in the inter-row (2.00 m) for T3, T4 and T5. Rolling was done immediately after sowing. Weeds along the row were controlled by herbicide application for all treatments during the five experimental seasons. Spring fertilization was done with 15 N kg ha^{-1}, 30 P kg ha^{-1} and 60 K kg ha^{-1}. A total of 9 N kg ha^{-1} and 20 K kg ha^{-1} were provided by ferti-irrigation at veraison and two weeks before harvesting only in the first year. Ferti-irrigation on the rows with 9 N kg ha^{-1} and 20 K kg ha^{-1}was also applied as usual. Generally, from late June to mid August a total of 4–5