Models of olive culture in suitable areas with low environmental impact

INTRODUCTION

From its origins, olive production has played a primary role in the western world. Olives and olive oil in the Mediterranean region hold an important position in the human diet, involving consumers from countries traditionally linked to the use of these products and, more recently, consumers from other countries with no such tradition. Studies on the Mediterranean diet, first conducted in the United States of America (Keys, 1980) and subsequently in Europe, have demonstrated the fundamental role of extra-virgin olive oil in the human diet to prevent diseases such as hypertension, heart disease, arteriosclerosis and diabetes.

The European Union represents the most important area for olive production, representing more than 80 percent of world olive-oil production. Italy, which is the second largest producer of olive oil in the world, accounts for 25 percent of world olive-oil production, and has particular supremacy in the production of virgin oils (Autori Vari 2003).

THE EVOLUTION OF OLIVE GROWING

In the early years, olives were intercropped with other fruit trees. With time, olive-orchard architecture changed dramatically, particularly with the advent of complex drainage systems and olive-tree placements and densities, creating viable growing systems for olives, even in the most inaccessible hills. In these ways, over the centuries, a particular order has been realized, characterizing the agrarian environment of many areas of Italy, with remarkable repercussions on the aesthetics of the landscape.

In the Mediterranean area, it is possible to distinguish two types of olive production (Fontanazza, 1986). The first is where olive production is in "marginal areas", where it is characterized by large expenditure on cultural management and low productivity, with minimal changes over time. None the less, this type of olive production plays a fundamental function in environmental protection (hydrogeological defence, landscape characterization, conservation, biodiversity protection, and minimizing soil erosion). This is especially true where the crop covers large areas. Many examples of such olive production can be found all over Italy, from north to south, but also in other Mediterranean countries such as Greece, Portugal, Morocco and Turkey. The second type of production is where olive production is in "suitable areas", typified by environmental situations where olive species are well matched with topographic and pedoclimatic conditions, facilitating best productivity (high and constant yield), and where mechanization is possible for both harvesting and pruning.

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However, in the main Mediterranean olive-growing countries, there remains a predominance of old olive orchards, even though situated in highly "suitable areas" for olive growing. As a consequence, low yield and high costs characterize such old groves, that additionally require large inputs of labour for harvesting and pruning in order to keep the olive-oil quality high. The persistence of traditional olive production in "suitable areas" appears related to small farm size, and farm and low salary costs, the latter referring to countries characterized by a large availability of labour.

Contrary to the above, in the "suitable areas" for olive-tree cultivation, it is possible to develop profitable olive orchards by following growing techniques that facilitate:

- ➢reducing the unproductive period;
- ➢gaining high and constant yield;
- ➢maintaining high qualitative productive standards;
- ➢achieving a high index of mechanization in order to ensure maximum economic profit.

For these reasons, the need to induce an evolution in olive production, mooted since about the mid-1950s, is being given strong consideration (Fontanazza, 1982).

THE PROPOSED MODELS

Following the idea of complete mechanization of intensive olive groves, from the late 1970s, the Institute of Research on Olive Production of Perugia (IRO–CNR) developed an "intensive olive-orchard model" based on criteria of environmental compatibility and valorization of production both quantitative and qualitative (Fontanazza, 1982).

Medium-density plantation – 1st IRO–CNR model

The 1st IRO–CNR model consists of increasing the number of plants per hectare (350–550), based on rectangular spacing, using the best traditional varieties, and resorting to irrigation where rainfall is not adequate for plant needs.

The model implies a shortened economic cycle of the olive orchard (35–40 years) and considers the monocone (central leader) as the ideal tree-shape for this type of olive production instead of the vase or other globe-like shapes (Fontanazza, 1996). The monocone favours a vertical growth of the plant and implies a coiled insertion of the secondary branches on the main trunk. This allows a reduction in tree spacing, to accelerate growth and fruiting and to facilitate the operation of mechanical harvesting (by shaker) and pruning, starting from the 5th–7th year after planting.

In the IRO–CNR model, it is possible to observe a difference in terms of pruning in the need for labour ranging from about 70–80 h/ha with manual pruning to about 12 h/ha with mechanical pruning. Mechanical pruning is an integrated system based on a three-year cycle (Fontanazza, Camerini and Bartolozzi, 1998) (Plate 1).

Plate 1
Pruning machine operating on a farm in Umbria, Italy.

In terms of harvesting, in this model, the employment of a shaker combined with the use of nets for fruit interception allows a strong reduction in cost compared with manual or aided harvesting, while obtaining tree integrity and high yield quality. Recently, through the use of machines that are a combined trunk-shaker and umbrella to intercept fruit, it has been possible to reduce harvester personnel from 6–7 to 3 units (Plate 2). Both of these situations enable the harvesting of about 200–250 olive plants per day.

Plate 2
Harvesting machine operating on a farm in Umbria, Italy.

The main obstacle to further technological evolution in olive-growing systems is the olive "genetic" situation. Genotype choice plays a fundamental role in the intensive olive-growing model, for controlling constancy, yield levels and oil quality. All traditional cultivars are characterized by medium-high vigour because in the past genetic selection was directed towards genotypes resistant to poor soils, low water availability, disease and towards enhancing rapid growth (Autori Vari, 1996).

The use of high-vigour, traditional varieties tends to lead to negative consequences such as delay in reaching an optimal equilibrium between vegetative growth and fruiting, the need to operate drastic pruning practices, and an inability to reduce tree spacing below certain limits. Moreover, mechanical harvesting remains limited to the trunk shaker, which implies a discontinuous operation. Despite these limitations, the model described remains valid in comparison with traditional systems, because of the mechanization of harvesting and pruning that reduces olive-grove labour requirements to 95–120 h/ha/year.

Taking into account the problems mentioned above and in order to attain further evolution in olive production, the IRO–CNR has (since the mid-1980s) conceived a new model of olive production for high-density systems. Consideration has been given to the development of olive production in flat areas or on moderately sloping hills on a large scale.

High-density plantation – 2nd IRO–CNR model

In order to conceive a new model for high-density olive plantations, it was necessary to investigate, in a different way to that considered in the previous section, some genetic and mechanical olive-grove aspects. The aim was to overcome the problems associated with vigour in traditional varieties through a strong selection of available germplasm and by breeding.

The first selected genotype from the IRO–CNR collection of cultivar varieties was I-77, known for its long-term productivity and low vigour (Fontanazza, 1987). At the same time, the IRO–CNR started a selection of seedling populations arising from a cross-breeding programme established in 1970. Programme selection goals included developing genotypes characterized by high productivity, high quality and resistance to parasites, and to obtain dwarfing rootstocks and new, low-vigour clones. By operating a mass selection within the F1 cv Frantoio population, the activity resulted in a new clonal dwarfing rootstock, the Fs-17. In our experimental fields, this rootstock was capable of reducing vigour in some varieties (Giarraffa, I-77, Bella di Cerignola and, partially, Ascolana Tenera) (Fontanazza, Baldoni and Corona, 1992; Fontanazza *et al.*, 1995).

In addition, during the adult phase, the Fs-17 genotype showed that it had low vigour and was a self-fertile and highly productive cultivar (Fontanazza, Bartolozzi

Plate 3
An example of a high-density plantation.

and Vergari, 1998). With both I-77 and Fs-17, it was possible to establish high-density plantations (about 1 000 plants/ha) (Plate 3). This new model is compatible with mechanical pruning and the use of straddle harvesting machinery that allows a continuous operation.

Initial trials were conducted by the IRO–CNR in the second half of 1980s using straddle harvesting machines developed for grapes and adapted for olive harvesting, operating along rows with olive plants up to 3.5 m high and 1.6 m wide. This straddle machine showed high efficiency as one operator was capable of harvesting 1 ha in about 2 hours, and was capable of working for the whole day. This type of trial continues to give good responses and, today, this system is applicable provided that low-vigour, highly productive and early-fruiting cultivars are used (Plate 4) (Fontanazza and Cappelletti, 1993; Bartolozzi and Fontanazza, 2000; Godini and Bellomo 2002).

Another limitation is represented by farm size, which basically influences the cost and efficiency of such machinery.

The whole productive cycle, using clones such as Fs-17 and I-77, must be reduced to 12–14 years, and, at the end of the cycle, a partial or total renewal of the crown is foreseen.

The number of working hours per hectare required in this model is about 40–50, although this needs to be considered in terms of the high investment for purchasing the harvesting machine.

As well as genetic factors, high-density plantations have some limitations in sloping and hilly country. Straddle harvesting machines can only work appropriately in low slope areas (up to 5 percent). The evolution of this model is dependent on contiguous innovations in processing and production. It is possible that straddle machinery could be improved to achieve greater efficiencies and flexibility, particularly if mechanical pruning and appropriate pest management are conducted during harvest; the latter in order to reduce environment pollution.

Moreover, further research on breeding programmes, conducted by either traditional (breeding and selection) or innovative biotechnological methods (gene transfer and somatic hybridization) could realize medium-vigour plants and low-vigour and dwarf genotypes without the loss of beneficial characteristics such as high productivity, high olive-oil quality, and resistance to parasites. Furthermore, in order to preserve the traditional best varieties, dwarfing-rootstock selection is important (Fontanazza and Cipriani, 2001). This will facilitate the development of intensive olive groves and high-density plantations in "suitable areas" of different countries.

However, the main limiting factor in the development of a high-density plantation model, aside from environment, is the poorness of adapted varieties (low vigour, dwarf clones, dwarfing rootstocks). In fact, we can manage only a few low-vigour traditional cultivars (i.e. I-77 and Arbequina), very few new varieties (Fs-17 Favolosa) and few combinations of appropriate varieties grafted on dwarfing rootstock (Giarraffa/I-77 and Fs-17/I-77). This reduces the olive-orchard productive cycle (12–13 years) because of plant dimensions that must be compatible with straddle harvesters (maximum height = 3 m, maximum width = 1.5 m).

The IRO–CNR is currently engaged in a major breeding programme that is crossing different cultivars in order to achieve this goal (Cipriani *et al.*, 2002).

At the moment, the two intensive olive groves, as developed by the IRO–CNR, are now widespread in several countries, mostly in new plantations in the new olive-growing areas of the southern hemisphere such as Argentina, Australia, Chile, South Africa and, recently, the United States of America.

Plate 4
Straddle machine operating on a 3-year-old high-density plantation of Fs-17.

SOIL AND WATER MANAGEMENT IN THE INTENSIVE IRO–CNR MODELS

Both the models of olive production described above can be managed with low environmental impact. Because of the extended and superficial olive-tree root system, the reduction of space between plants in the intensive cultivation contributes to minimizing the risk of soil erosion. Moreover, this olive-orchard model is characterized by a high leaf area index that reduces raindrop impact and soil exposure to sunlight, thus preventing excessive soil compaction and rapid organic matter decline.

These models of olive production are characterized in terms of management as follows: soil management with natural cover grass periodically mowed and left on top of the soil (aids the prevention of soil erosion especially in hilly areas); returning to the ground the pruned residues that are ground and left on top of the soil; returning to the soil the olive-mill residues that increase soil organic matter content and reduce the need for mineral nutrition, and help increase soil water retention. Complementing these ideas, the olive production section of the ISO–CNR in Perugia has recently indicated a new technology that recycles all types of mill by-products for application to the land. The process occurs at milling level by mixing olive-mill by-products, without stones, with appropriate hygroscopic natural organic material, producing non-percolating and non-bad-smelling olive-mill waste-based substrata (OMWBS), packaged in net sacks, and manageable at district level (Altieri *et al*., 2004).

In terms of water management, if 60–65 percent of the estimated crop evapotranspiration is supplied then this gains the best responses in term of yield, and quantity and quality of oil, even if different genotypes show different responses to dry stress (D'Andria *et al*., 1996; Patumi *et al*., 1996).

Currently, drip irrigation is the most commonly used irrigation system for intensive olive production, using two drippers on the row per plant, each positioned 0.25 m from the trunk. This system has a high water efficiency, particularly where soils are characterized by low water retention, and it also facilitates fertirrigation.

CONCLUSIONS

On the basis of the above considerations, modern olive-cultivation systems combined with innovative olive-oil extraction technology meet a wide range of agronomical and technological principles for both high quantity and quality of oil production. Furthermore, they facilitate the regulation of all agronomic and extractive techniques (Uceda-Ojeda, Hermoso-Fernandez and Gonzales-Delgrado, 1994). Further evolutions in both the agronomic and oil-extraction systems must take into account the fact that extra-virgin olive oil is an absolutely natural product, highly genuine, and with a high biological value. In fact, the profit in olive production is related to a high level of productivity and low cost of management, while maintaining a high quality standard of extra-virgin olive oil. This is the only way to make olive production possible with further technological evolutions, genetic improvement and olive-oil extraction technology.

On other hand, persevering with traditional olive-production systems constitutes a real obstacle to evolution of the productive systems, and at the same time almost guarantees a reduced environmental impact with respect to the proposed intensive olive-growing systems.

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Grass swarding of a non-irrigated hillside vineyard under cv. Sangiovese

INTRODUCTION

Several studies on the use of grass swarding in vineyards have shown both positive and negative effects on vine behaviour (Di Lorenzo *et al*., 1999; Scalabrelli *et al*., 1999; Silvestroni *et al*., 1999). The problems have mainly been linked to the excess vigour of some grass species, which exerted a marked water/nutrient competition with the grapes. More recently, the increased use of grass swards in vineyards has led to a need for a range of sward types characterized by reduced spring–summer growth, limited water/nitrogen use, dense but shallow root systems, and resistance to traffic (Intrieri *et al*., 2002). This paper reports the results of trials that compared the commercial sward mix "Ilmix" (containing 15 percent of vigorous *Festuca arundinacea* "Bartes"), considered as a control, with three weak fescue accessions selected in Hungary which appeared to feature the required qualities, although not yet available in Italy.

MATERIALS AND METHODS

The dwarf Hungarian selections *F. rubra* "Park", *F. ovina* "Favorit" and *F. pseudovina* "Puszta" used in their purity (100 percent), and a commercial mix "Ilmix" were sown in 1991 between rows of a non-irrigated vineyard of cv. Sangiovese in a hillside clay soil. Plastic mulching was used along the rows. The turf composition with respect to the year of sowing and the sward root systems were investigated in 1999. Soil moisture and vine response were recorded over three years (1999–2001).

RESULTS AND DISCUSSION

The analyses of 1999 turf composition showed that the strong *F. arundinacea* of the Ilmix increased its soil covering rate from an initial 15 percent up to 75 percent, while the other species maintained the original coverage rates (80 percent for *F. ovina*, and 90 percent for *F. rubra* and *F. pseudovina*).

The data for sward root length per soil volume at varying depths and row distances showed a very dense root system across the entire width of the interrow at both shallow and deep samplings for *F. arundinacea*. The shallow layers also showed well-developed root systems for the other grasses, whereas their root densities were reduced in the horizons below 30–40 cm (Figure 1). The vine roots were rarely found in the

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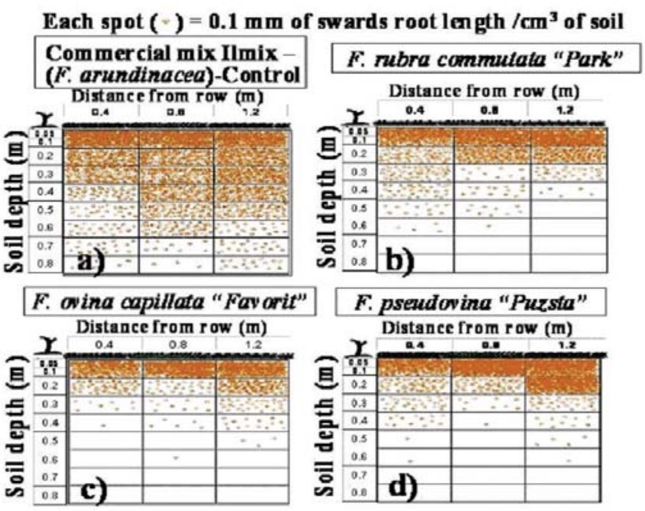
FIGURE 1
Diagram of root density for the tested grasses recorded at different distances from the row and at varying depths, 1999



top layers and were only sporadic in the deepest ones and those farthest from the mulched area.

The soil moisture checked at depths of 15 and 30 cm depths several times throughout the 1999–2001 seasons was lower, as expected, in the topmost horizon (data not shown), but the water available to the plants never dropped below the wilting point, thus indicating scant competition between vines and swards. As a result, no significant differences were recorded among treatments for shoots produced, or their fertility as for cluster number, or for weight and for berry weight (data not shown). Satisfactory yield and quality were achieved, both being uniform in all treatments, and no significant differences were noted on leaf area and pruning-wood weight per metre of cordon (Table 1). The calculated leaf area/yield index showed that all the treated vines maintained a correct balance (Table 1), the values being over the threshold of 1–1.2 needed to ensure adequate berry-sugar accumulation (Kliewer and Weaver, 1971; Iland and Marquis, 1989). All together, these finding showed that the dwarf Hungarian selections and even the Ilmix, marked by the expansive *F. arundinacea* with its dense and deeply growing root system, did not produce adverse effects on vine vigour or on their yield and quality potential. It can be inferred that the plastic intrarow mulching may have contributed to maintaining the distribution of the vine root system along the rows, thus reducing the overall competition with grasses, whose roots were located across the interrow.

CONCLUSIONS

It can be concluded that a cultivation strategy based on interrow swarding combined with inert-matter mulching along the rows can be used even in non-irrigated hillside soils. The advantages of this "integrated" management regime include benefits such as soil conservation, reduced soil compactness, and good vehicle trafficability, as well as, in agronomic terms, achieving excellent grape quality without reduction in crop yield.

TABLE 1
Yield, grape-quality parameters, leaf area, pruned wood weight and leaf area/yield ratio of Sangiovese under different swards, average 1999–2001)

Swards	Yield (kg/m)	°Brix	pH	Titratable acidity (g/litre)	Leaf area (m^2/m)	Pruned wood weight (kg/m)	Leaf area/ yield (m^2/kg)
ILMIX - Control F. arundinacea	5.0	24.0	3.37	9.33	5.07	0.38	1.00
F. rubra "Park"	4.3	23.1	3.32	8.93	5.98	0.42	1.39
F. ovina "Favorit"	5.2	22.7	3.35	9.82	5.41	0.38	1.04
F. pseudovina "Puzsta"	4.1	23.5	3.32	9.23	5.94	0.40	1.44

Note: By columns, no significant differences among treatments were detected.

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Whole-plant gas-exchange measurements in grapevine to estimate water-use efficiency

ABSTRACT

Research was conducted in two different vineyards: one in central Italy (Brunello di Montalcino production area) with upwards vertically trellised vines; and one in southern Italy (table grape) with horizontal trellising (tendone). Four plants were included in a plastic chamber provided with an air circulation system to measure plant-atmosphere gas exchange (CO_2 and water vapour). Additionally, light interception by the canopies was measured.

In the vertical trellising site, grapevine photosynthetic potential was measured using the "tree enclosure" system, demonstrating variability among the sampled plants with the greatest photosynthesis values measured during the mid-morning and, only in the second day, also in the mid-afternoon. These data are correlated to canopy light interception with low values of light. An increase in light interception always led to a higher photosynthesis, while, after a threshold of about 300 $\mu mol/m^2/s$, the increase in light interception was not linked to an increase in photosynthesis. This implies that at this light level there is a saturation point. It must be considered that measures have been obtained in a conditioned environment where a plastic chamber can modify some plant responses – there is an increase in air temperature and humidity as well as in wind turbulence. Measurements show higher transpiration during the period of both highest air temperature and light interception.

In the horizontal trellising site, the different canopy architecture strongly modified the CO_2 assimilation model as different from the vertical trellising system. Photosynthesis and transpiration showed greatest values around midday with some variation among the different chambers. Absolute values were quite high compared with the vertical trellis. It must be considered that in this case the vineyard is irrigated, with high water availability during the measurements. Moreover, the "tendone" training system, with a sparse canopy, causes a high percentage of leaves to be in the full sun with few shaded inside the canopy and, thus, with high efficiency. Light interception is correlated strongly to water-use efficiency (calculated as the ratio of photosynthesis to transpiration). With an increase in light interception, there is a decrease in water-use efficiency.

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INTRODUCTION

The measurement of leaf gas exchange is an important technique used to estimate net photosynthesis. However, individual leaf determinations have limitations when used to estimate whole-plant exchange of carbon dioxide (CO_2). Leaf gas exchange can vary owing to differences in leaf age (Poni, Intrieri and Silvestroni, 1994), chlorophyll content (Candolfi-Vasconcelos and Koblet, 1991; Ferrini, Mattii and Nicese, 1995), angle or incident radiation (Flore and Lakso 1989), respiration of vegetative and reproductive tissues (Corelli-Grappadelli and Magnanini, 1993), or biotic and abiotic stress. Thus, although individual leaf measurements estimate the relative carbon uptake per unit leaf area, it is often difficult to extrapolate to whole-plant assimilation from these values. This is mainly because of the small portion of leaf tissue measured by the instruments, in many cases only a few square centimetres. Consequently, it is obvious that to scale up from a relatively simple system such as a leaf to more complex ones such as a single shoot and, eventually, a whole plant requires an increased number of readings. This goal, still possible for a single shoot, becomes impossible in the case of a whole canopy. The solution leads to a system that, without change, carries over the principle for a single leaf to a whole canopy. This can be very important in order to acquire more in-depth information about canopy water relations and carbon gain, as well as canopy efficiency.

On these bases, this research was performed with the aim of applying the system for canopy measurements in two different vineyards, located in Tuscany (central Italy) and Puglia (southern Italy). Water vapour and CO_2 gas exchange between atmosphere and plant were recorded to evaluate possible differences caused by environmental and cultivation variables.

MATERIALS AND METHODS

Research was conducted in 2002 in two experimental vineyards at different locations and utilizing different vine-training systems. In the first case, research was conducted in the “Brunello di Montalcino” wine production area at the “Tenuta Col d’Orcia” winery. Here, the climate is Mediterranean, with dry and hot summers and relatively mild winters, with an average of rainfall of about 500 mm/year, usually during fall and spring. Measurements were made in a Sangiovese/420A upward vertically trained spur pruned (6 “two-bud” spurs/plant) vineyard planted in 1992 with a vine spacing of 3 × 1.2 m with 2 777 plants/ha. Row orientation was NW/SE. In a central area of the vineyard, four homogeneous plants were selected. Each plant was included in a transparent PE “balloon” as described by Poni, Magnanini and Rebucci (1997). In each balloon, air circulation was forced by an electrical fan through a plastic pipe (100 mm in diameter) inserted inside the chamber, while a similar pipe on the upper part provided the air outlet. Carbon-dioxide concentration both in the air inlet and outlet was measured using an infrared gas analyser ADC LCA2 (ADC, Hoddesdon, the United Kingdom), while temperature and humidity were measured with a thermohygrometer. The air-flow rate was maintained as high as possible in order to increase air temperature inside the balloon by no more than 2 °C, to avoid heat stress to the plant. Moreover, in order to calculate net photosynthesis, light intensity was measured using an AccuPAR ceptometer (Decagon, the United States of America). All readings were performed at hourly interval from sunrise to sunset over two consecutive days. At the end of the measuring, the balloons were removed and all the leaves/plant were counted. From a sample of 50 leaves/plant, leaf area was detected using a “laser area meter” (CID Inc., the United States of America). At the same time of the gas-exchange readings, light intercepted by the canopy was measured using the ceptometer described above. The measurement grid was 10 × 1 cm, so each reading can be referred to 10 cm^2 of soil surface.

The second vineyard is located near Taranto (Puglia, southern Italy). The grape cultivar was Regina (table grape) grafted onto 140 Ru planted at a distance of 2 × 2 m. The training system was "tendone" (a horizontal trellis), pruned with both spurs and canes. On the four plants selected to represent the average of the vineyard, the same readings described above for the vertical trellis were taken.

RESULTS

The light-interception percentage in the vertically trained vineyard in Montalcino was less in the middle of the day, around noon (Figure 1). This happened because the row orientation was close to north–south. Figure 2 shows two light interception peaks at 9:00 a.m. and in the afternoon around 3:00 p.m. Actually, the afternoon light intercepted by the canopy was greater compared with the morning light because the row orientation was exactly northwest–southeast. These data were confirmed from absolute values of intercepted light. Morning values were quite low owing to the low intensity of incident light, while the afternoon recorded the highest values because of both the incident light and the good canopy exposure. Lower midday values were caused by the row orientation that did not allow high light interception around solar noon. Plant photosynthesis measured with "tree enclosure" system showed a variability among the four different plants (Figure 2). The highest CO_2–assimilation values were detected in the morning and in the afternoon. These results were affected by plant variability, where probably plants inside balloons 1 and 3 were subjected to a stress situation resulting from ambient conditions inside the balloon. However, in all balloons, it was possible to observe two peaks of CO_2 uptake in the morning and in the afternoon, and a photosynthesis depletion corresponding to solar noon. These data are in accord with light intercepted by the canopy. In

FIGURE 1
Light interception in the vertical trellis

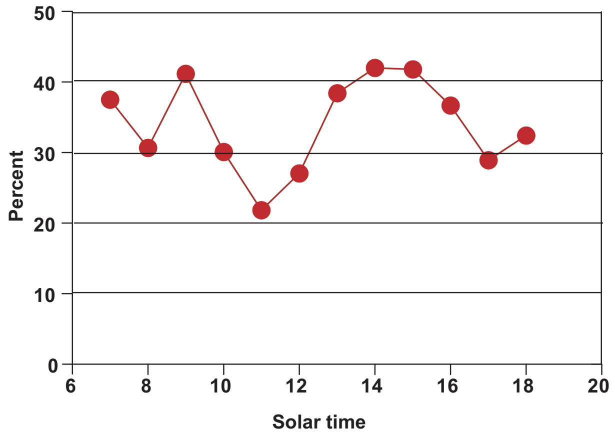


FIGURE 2
Whole-plant photosynthesis in the vertical trellis

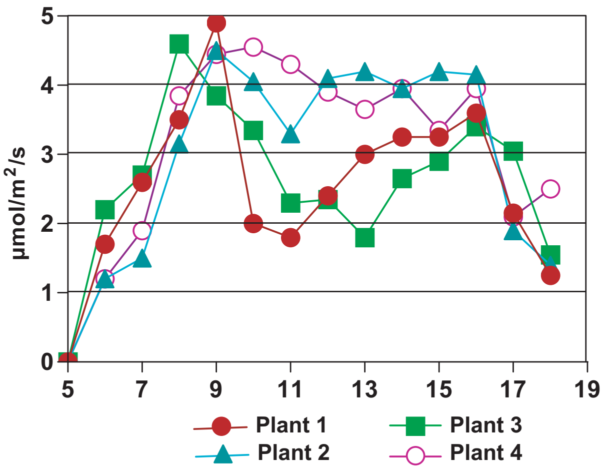


FIGURE 3
Relationship between intercepted light and photosynthesis in the vertical trellis

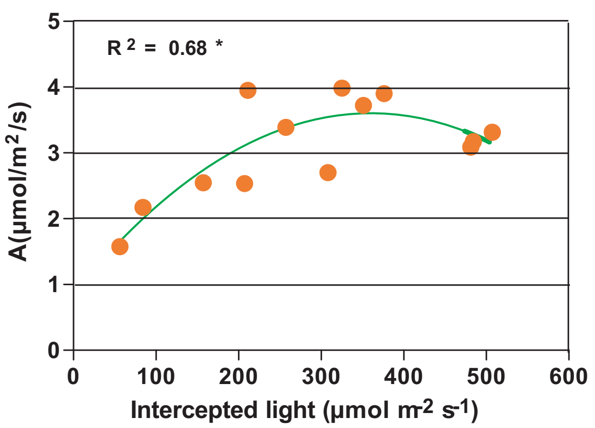


FIGURE 4
Whole-plant transpiration in the vertical trellis

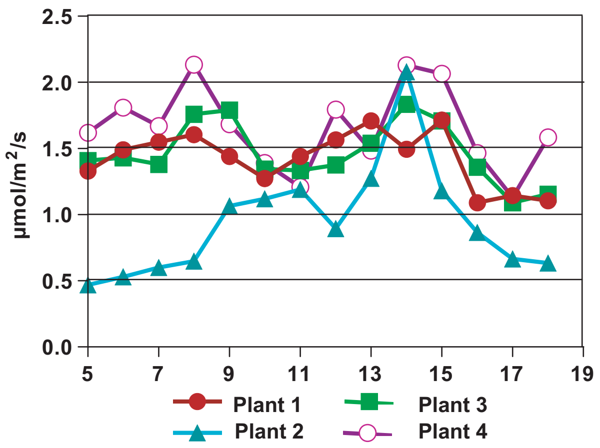


FIGURE 5
Light interception in the horizontal trellis

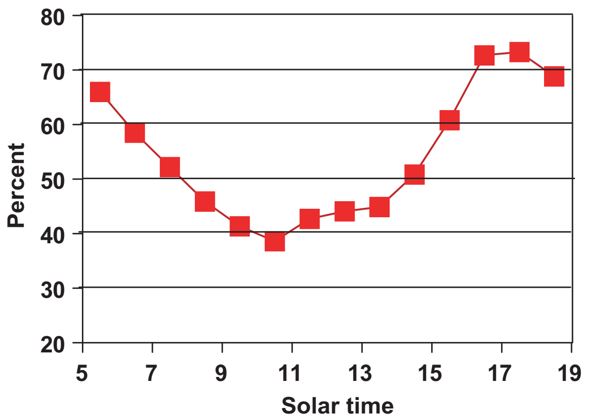
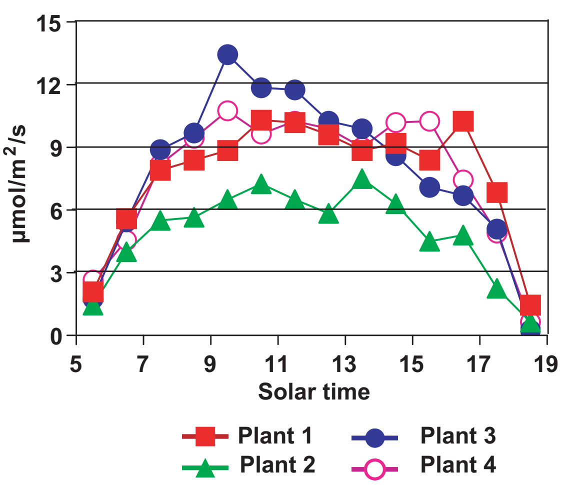


FIGURE 6
Whole-plant photosynthesis in the horizontal trellis



fact, it is possible to detect a relationship between CO_2 assimilation and light interception (Figure 3), where with low values of light intensity, an increase in intercepted light is linked to an increase in CO_2 uptake, while, after the threshold of 300 µmol/m²/s of intercepted light, no increase in CO_2 uptake happened. In other words, at this level of intercepted light, there is a saturation threshold. Like photosynthesis, transpiration also showed variability among the different balloons, with higher values corresponding to the highest level of intercepted light (Figure 4) and also to the highest air temperature.

The second part of the research was carried out in the horizontally trellised vineyard described above. This different canopy structure modified the CO_2–assimilation pattern in a different way to the vertical trellis. First, it has to be noted that canopy development was very low and did not cover the whole soil surface. With an optimal growing "tendone" (horizontal trellis), light interception is quite high, reaching, during the middle part of the day, values close to 70 percent. In our case, the noon measured interception did not reach 50 percent (Figure 5), showing several gaps inside the canopy, so that a considerable part of the soil was in full sun. Although a low percent reading of light interception was measured around solar noon, absolute values of intercepted light were higher in the middle of the day, because of the highest values of incident light at that time. The light-interception pathway is similar to those of photosynthesis and transpiration (Figures 6 and 7), with highest values around solar noon, even if small variations among the different chambers can be observed. Absolute values of both photosynthesis and transpiration were much higher compared with the ones measured for the vertical trellis. It must be considered, first, that in the horizontal trellis, there was an irrigated vineyard, with a good soil-water content at the time of measurements, while in the Montalcino area there was frequent water stress in the vineyards. Moreover, the horizontal system with a quite sparse canopy allowed a high percentage of leaf to be in the full sun, with relatively low shading inside the canopy, so providing good utilization of light energy. In fact, light interception (measured in absolute values) and photosynthesis pathways are quite similar and linked by a good regression (Figure 8).

As observed also in the vertical trellis, there was a saturation level and above that, even if light interception increased, photosynthesis remained stable. Transpiration had a similar pathway to photosynthesis with a peak around solar noon. From the photosynthesis and transpiration pathways of both training systems, it is possible to calculate the values for dry matter produced and water transpired in one day by simply integrating the curves and multiplying by the leaf area of the different plants after making some simple unit conversions. The values of dry matter produced in one day vary from an average of 65 g/day in the horizontal trellis to about 14 g/day in the vertical one (Figure 9). More interesting seems to be the value of daily water consumption within the day, which was about 12.5 litres/day in the horizontal trellis and 4 litres/day in the vertical canopy (Figure 10).

CONCLUSIONS

The data collected in the current experiment appear most important in terms of vineyard management. First, the experimental operating system is less complicated than it appears. The system may take a long time to establish, but once the system is working, it is very easy to collect data and to manage all the chambers. In the current experiment, data collection was made by hand. However, it is possible to set up an automatic data logger, so the system can work alone for several days or weeks without injury to the plants. The type of data collected here can give a broad

FIGURE 7

Whole-plant transpiration in the horizontal trellis

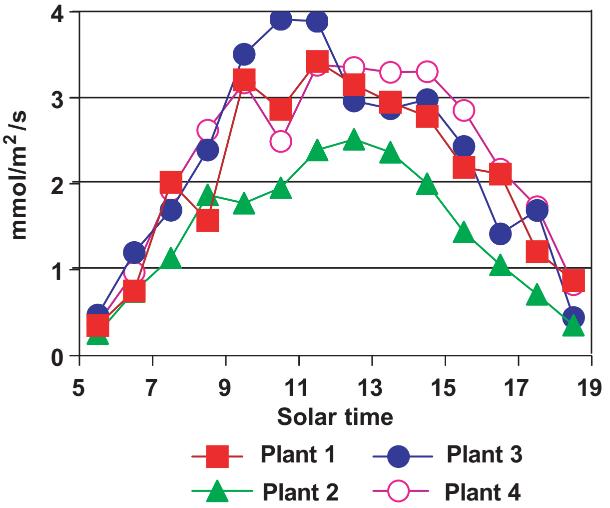


FIGURE 8

Relationship between intercepted and photosynthesis in the horizontal trellis

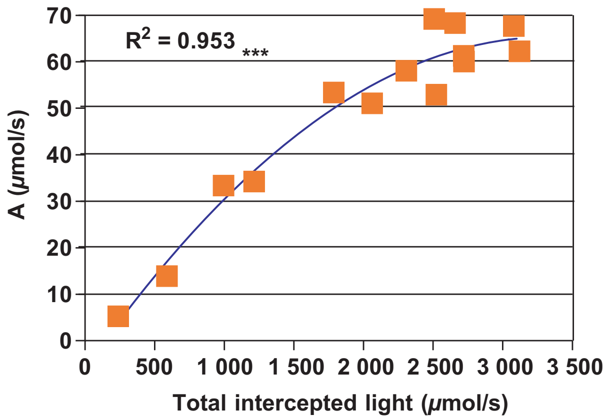


FIGURE 9

Daily dry-matter production per plant

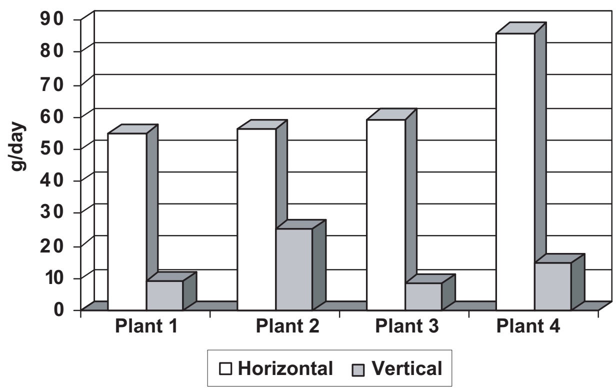
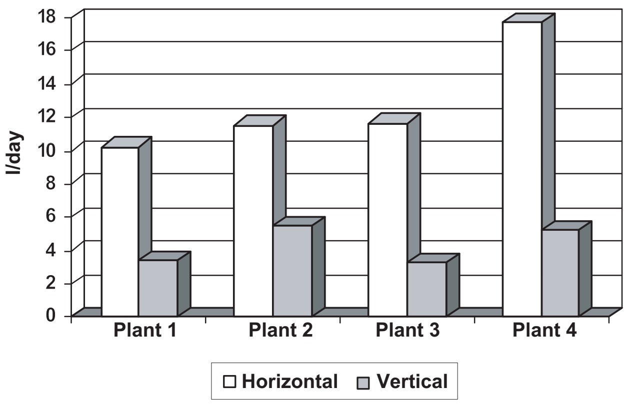


FIGURE 10
Daily water consumption per plant



range of information about grapevine behaviour from a physiological point of view, and can help growers to understand what makes a better canopy structure, particularly to have the highest light interception. In fact, in the current experiment, the light intercepted by the canopy was strongly correlated to both whole-plant photosynthesis and transpiration. Moreover, current results emphasize the need for knowledge on water consumption; data that are particularly useful for managing grapevine irrigation.

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Relationship between water availability and viticultural performance of Sangiovese, Montepulciano, and Trebbiano Toscano

ABSTRACT

The script reports a long-term research project, located in the Ascoli Piceno area, that investigated the characterization of climatic parameters, physical and chemical properties of the soils and viticultural performance of three vine varieties (Montepulciano, Sangiovese, and Trebbiano) over three consecutive years (1999–2000–2001). The varieties were selected as having different capacities of adaptation to the environment and distinct seasonal courses. All three varieties, but particularly the Montepulciano and Sangiovese, are affected by "through the season" effects and subsequently alter the length of the phenological intervals, budding-flowering and flowering-veraison. Annual rainfall is decisive, in particular for Montepulciano, as it limits the dry matter accumulation. The climate in June, July, and August, expressed as the Selyaninov Aridity Index (AI), affected acidity in all the varieties as well as the must, in Sangiovese the sugar content, and in Montepulciano the amount of polyphenols in the wine.

INTRODUCTION

The formulation of a variety range as a mean of improving wines' quality requires careful control of the vine varieties' adaptability to the environment so as to obtain commercial enological production. To date, international varieties have been preferred because of the wines' qualification trend. However, to face the global market, every viticultural – enological situation has reverted to improving the traditional varieties to get originality and value added. Each one of these situations includes a wide range of varieties, but according to production specifications of a determined area it is necessary to assess potentiality of the permitted varieties. As far as the Ascoli Piceno area and its VQPRD wines' production, several vine varieties have been identified among which Montepulciano, Sangiovese and Trebbiano Toscano are most common. These varieties have been surveyed during several years both in open fields and in cellar tests. This effort has facilitated the identification of four viticultural-enological realities (Moretti *et al.,* 2002). According to these results and considering that rainfall, after 15 August

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facilitates the completion of grape ripening with the essential requirements for a VQPRD production, an assessment of the effects of the dry period in the pre-ripening phase has been conducted. Particular consideration has been given to investigating phenological trend with related intervals, as well as to the addition to vegetative-productive capabilities and to related must components.

MATERIALS AND METHODS

From the study of a long term series of agro-meteorological, vegetative, and productive parameters on different varieties (as prescribed in "Falerio dei colli ascolani" and "Rosso Piceno" VQPRD production disciplinary, including the sub-denomination "Superiore", and "Offida"), three successive vintages have been considered in the current study: 1999, 2000 and 2001. This choice was due to the peculiarity of the seasonal trend and to the absence of extraordinary events. Three different vine varieties have also been chosen because of their successful adaptation to the environment. Site selection was restricted to the most representative vineyards of the four main areas in the Ascoli district (Moretti et al l.c.), an appraisal of the meteorological data (rainfalls and temperatures), phenological stages expressed in Julian calendar (gg) together with vegetative-productive (bud's fertility, grapes and wood production) and qualitative features of must and wines. The Selyaninov index (AI; Costantinidis 1970) was calculated as it considers water supply and its combined effect with temperature. A forty year historical average was reported to indicate that rainfall data can be considered representative of an average year (Table 1).

To evaluate soil moisture content, samples were taken at two depths (30 and 60 cm). The two vineyards sampled were the same age. On each farm, in ten contiguous vine blocks (replicates), the number of buds per vine was made uniform leaving two fruit-bearing branches and two spurs with two buds on each vine. Cultivation was used between and on the vine rows. The soil in each vineyard can be considered uniform (ASSAM and Regione Marche, 2002) since they originated from minimally evolved soils, so can be termed a "regosol" (Calandra 1978). They are characterized by a medium texture with a tendency to be slimy and clayey. The deep substrates in each vineyard were clay with alkaline reaction, lacking in organic matter, rich in total carbonate and with a medium-high cation exchange capacity. Relationships between AI value and viticultural parameters, obtained by considering moisture content in the soils, were calculated to indicate the grapevine response to the annual climatic variability. Correlation coefficients (r) and relative significance P=0.05 (*) were considered as a reliable evaluation for the individual environments.

RESULTS AND DISCUSSION

The Sangiovese early response to rises in temperature is confirmed by the phenological data as different from the Montepulciano and Trebbiano varieties, which because

TABLE 1
Rainfalls, mean temperature and accumulated degree-days (DD) during 1999–2001 years and historical average (1950 – 1989)

	Rainfall (mm)				Mean temperature (°C)				Accumulated DD		
Year	1999	2000	2001	avg	1999	2000	2001	avg	1999	2000	2001
Autumn	343	374	145	240	9.52	10.05	11.4	10.20	572	534	437
Winter	116	108	135	210	6.77	6.86	9.15	6.50	132	190	342
Spring	238	102	139	170	17.59	18.49	17.13	16.80	1680	1714	1236
Summer	308	167	105	150	22.24	22.10	22.19	21.50	1915	1850	2037
Oct.-sep.	1005	751	524	770	14.03	14.37	14.96	13.75	4299	4288	4052

TABLE 2
Phenological stages: Montepulciano, Sangiovese and Trebbiano in 1999–2001 years with their intervals

	Year	Budburst		Bloom		Véraison		Budburst-bloom		Bloom-véraison	
Montepulciano	1999	97	ns	153	a	220	a	56	a	67	a
	2000	104		147	b	204	b	44	b	57	b
	2001	94		151	a	208	b	57	a	56	b
Sangiovese	1999	88	b	150	a	215	a	62	a	65	a
	2000	96	a	141	b	201	b	45	b	60	b
	2001	83	b	150	a	204	b	67	a	54	b
Trebbiano	1999	97	ns	153	a	223	a	57	b	70	a
	2000	103		147	b	204	b	44	c	57	b
	2001	85		153	a	214	b	67	a	61	b

Mean separation in a column by DMRT at 5% level.

they are usually later, take advantage of rises in temperature starting from flowering. This is confirmed by the high correlation (r^2=0.544) between springtime temperatures and length of budding-flowering period, from similar observations in another experiment (Calò et al 1992). In terms of the Sangiovese variety, with accumulated DD of 1714 (as in 2000, Table 1) there is a tendency to have a short phenological interval but, if in the same period rainfalls take place, it gets close to Trebbiano. In the same way, with a warm seasonal trend (as in 2001; Table 1) if temperatures remain high from flowering, a reduction of flowering-veraison interval (Table 2) is determined.

Relative length is strictly correlated to the average temperature and to the June–August rainfalls (r^2=0.541) (the same for Montepulciano and Sangiovese with the average AI for the same months) but if values of this index remain below a value of 1, they tend to anticipate the veraison (Figure 1). It is known that during this period bud differentiation occurs for the following production, as confirmed by the May–August average of AI (Figure 2). In this regard, it has been noticed that the number of inflorescence per shoot rises in Montepulciano and Trebbiano, as the AI values increase until it reaches the optimum with a value of approximately 1.2 (Figure 2).

From these data, it appears that rainfall plays a more decisive role

FIGURE 1
Length (in days) of the flowering-veraison interval in relation with June–August average aridity index (AI)

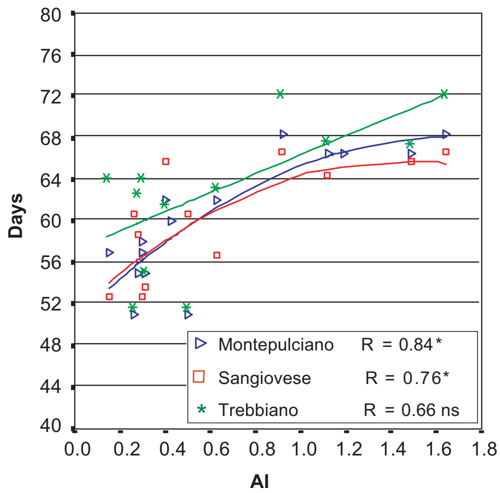


FIGURE 2
Correlation between May–August average aridity index (AI) and real buds' fertility

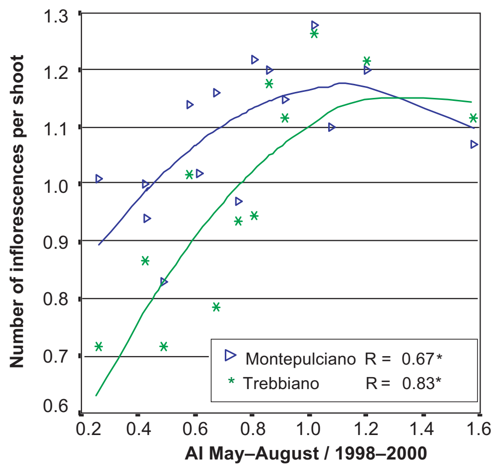


TABLE 3
Rainfall (mm) and average soil water content (swc) (% w/w) at two depths (30 and 60 cm) over time

		date								
Year		**28/5**	**11/6**	**25/6**	**8/7**	**20/7**	**4/8**	**18/8**	**3/9**	**22/9**
1999	Rainfall (mm)	14.7	17.0	75.1	62.1	36.4	2.8	9.0	99.4	49.0
	swc 30 cm %	15.9	15.3	18.2	15.9	15.7	14.4	13.7	14.8	15.5
	swc 60 cm %	16.2	15.7	18.6	17.6	16.7	15.9	14.4	15.5	16.2
2000	Rainfall (mm)	8.1	1.3	19.1	35.7	0.5	11.8	8.5	60.6	39.7
	swc 30 cm %	12.9	12.8	13.1	13.5	12.8	13.0	12.9	14.0	13.5
	swc 60 cm %	14.8	14.7	14.9	15.2	14.6	14.8	14.8	15.6	15.3
2001	Rainfall (mm)	15.3	19.0	0.6	0.6	19.6	1.2	2.1	39.3	10.4
	swc 30 cm %	13.1	13.1	12.8	12.8	13.1	12.8	12.8	13.5	13.0
	swc 60 cm %	14.9	14.9	14.6	14.6	15.0	14.7	14.7	15.3	14.8

FIGURE 3
Correlation between annual rainfall (mm) and dry matter production (kg/vine)

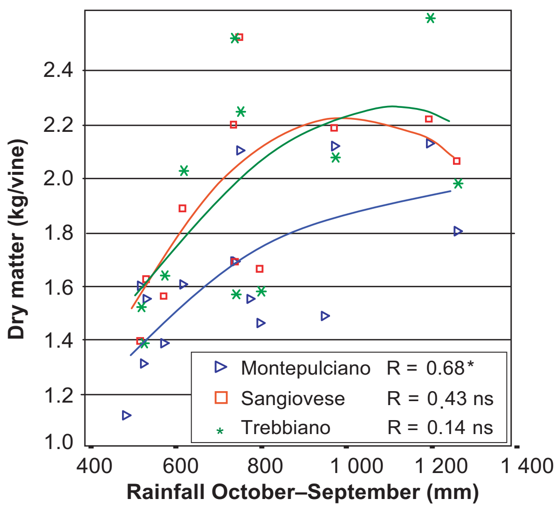


TABLE 4
Average productive capability for "Montepulciano" in 1999–2001

	year					
	1999		**2000**		**2001**	
Rainfall Oct.- Sep (mm)	1 005		751		524	
Yield (kg/vine)	7.30	a	6.35	ab	5.64	b
Pruning weight (kg/vine)	1.42	a	1.29	a	1.35	a
Dry matter weight (kg/vine)	2.10	a	1.85	ab	1.74	b

Mean separation in a line by DMRT at 5% level.

than temperature. The soils at the experimental sites, because of their medium-texture, have a potential to retain approximately 32 % moisture. However, moisture content tended to be uniform especially at 60 cm despite small amounts of rainfall as happened in 2001 between June the 25th and July the 8th or between August the 4th and August the 18th (Table 3). These amounts of moisture relate well to the annual rainfall of 500 mm per year and for Montepulciano, Sangiovese and Trebbiano they are just enough to produce 1.9, 2.45 and 2.6 kg of dry matter per vine (Figure 3).

These values reported above are similar to those established by Sotez Ruiz (2001) and though related to different vine varieties, they have been recorded in areas which have similar rainfall amounts. This relationship has been confirmed only for the Montepulciano variety because it positively responds by producing more grapes (expressed as dry matter) (Table 4) when it can take advantage of greater water availability (Figure 3).

This trend was evident in 1999 under xeric circumstances when, similar to 2001, there was a significant productivity decrease, also in 2000 when rainfall approximately equated the annual average. With constant moisture content as those recorded between May and September at a depth of 60 cm (Table 3), the Sangiovese and Trebbiano production levels do not show the effects of the annual rainfall (Figure 3) while acidity contents for all three vines' musts are strongly connected with the climatic trend in the months from June to August (Figure 4). Even with above average rainfall it is usual to have musts with greater acidity. In these circumstances the

Sangiovese proves able to accumulate sugar during seasons with cooler trends, which are quantifiable around 1.6 AI values (Figure 5). As different to this, the relationship between polyphenol content and the Temperature Variability Index (TVI) (Gladstones 1992) cannot be confirmed in spite of thermal decreases which usually take place after the middle of August with the onset of rainfall (Table 3). Causes of this lack of correlation can be found in productive capability, quantified as approximately 2.45 kg per vine of dry matter, and in vintage time, as it is usually widely anticipated. The Montepulciano, which is tardier and less productive (kg 1.9 per vine of dry matter) has the possibility to accumulate more polyphenols (Figure 6) because it takes advantage of TVI in September (F = 4.46*).

FIGURE 4
Correlation between total acidity content (g/l) and aridity index (AI)

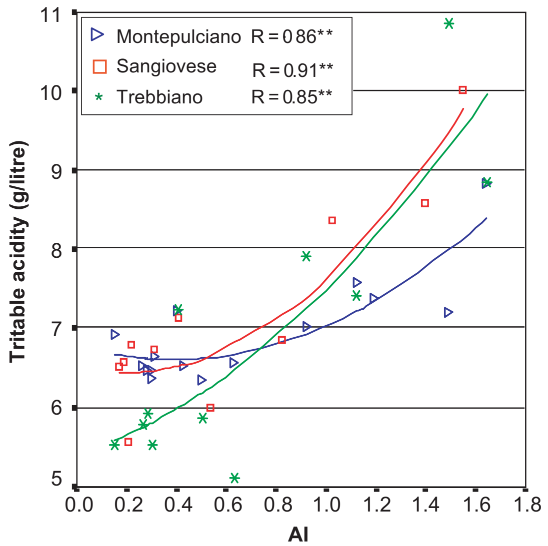
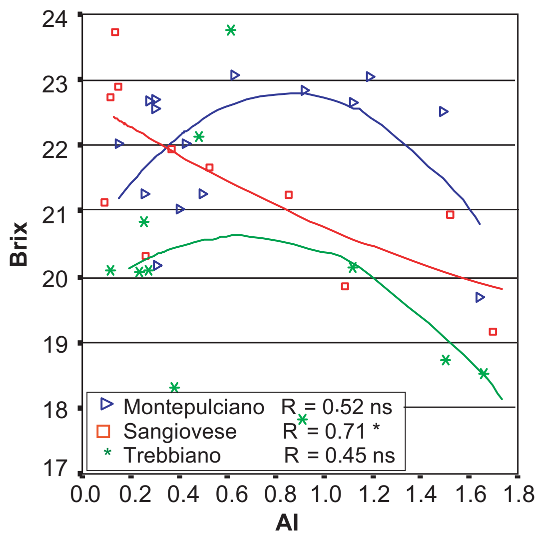


FIGURE 5
Correlation between sugar content (°Brix) and aridity index (AI)

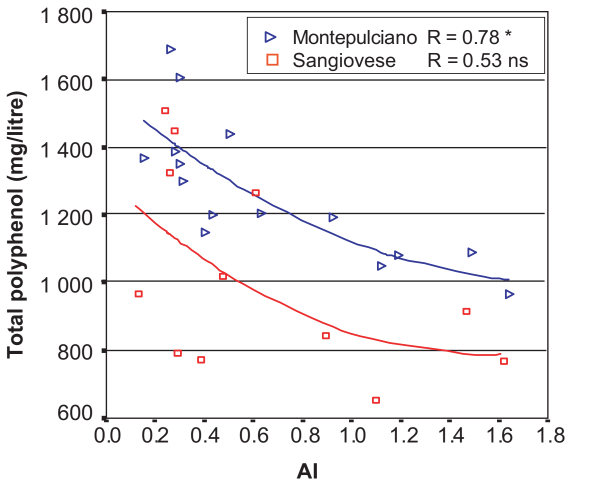


CONCLUSIONS

Peculiar climatic trends verified over a three year period, indicated that the three vine varieties investigated had different reactions to the environment. The current research confirmed that the Sangiovese suffers more than Montepulciano and Trebbiano from climatic variations. This situation also occurs at the production level, though this has only been proven for Montepulciano. These results confirm that in terms of production Sangiovese and Trebbiano are not influenced by cultural environment, as proven in other tests (Egger et al 1993; Orlandini et al 2000) Both these grape varieties are also advantaged by transversal tillage (cross-cultivation) as asserted by Givone (1988). The resultant improved water percolation improves moisture storage in the deeper soil layers that the vines can reach. These water stores are useful during summertime particularly in dry ones as occurred in 2001, on condition that rainfalls keep near or above average. In the current research, water proved to be the most important element compared to temperature as rainy springs increase the bud's productive potentiality in the Trebbiano and Montepulciano vines. This was particularly true when the rainfall was in May and August.

Rainy summers (for example 1999) justify the production of musts with higher acidity but in any case the Sangiovese also guarantees good levels of sugar due to its ability to anticipate the flowering-veraison interval and for its best leaf system

FIGURE 6
Correlation between total polyphenol content (mg/l) and aridity index (AI)



efficiency (De Palma et al 2000). This peculiarity enables Sangiovese to adjust more quickly to the environment and for this reason it is well-known as a very adaptable and productive grape type. In less rainy years it is able to anticipate the veraison and this enables the berry to remain unreactive in times of drought (Rebucci 1994). This corroborates the theory that temporary deficits have more influence on vegetative development than on accumulation capability, therefore renewal of rainfalls, which usually happen from the middle of August, is enough for vines to become ripe. Montepulciano is the quickest to take advantage of water availability providing increased quantity of grape without stimulating the vegetation. With good reason it is classified among the more tolerant varieties as regards drought, and this feature is expressed in its capability to store polyphenols even if their relative quantities decrease starting from AI values greater than one.

Results here confirm the adaptability of the three vine varieties from the Ascoli Piceno area. From this point of view it is better to assign the Montepulciano to areas usually subject to drought, the Sangiovese to cool areas, while the Trebbiano is found to be the most adaptable variety. These considerations are true when a defined bud-load is assigned (in our case 16 per vine) because with different conditions lower yield and quality have been recorded. On the other hand the use of irrigation is considered beneficial, especially if vineyards are planted in soils with predominantly sandy texture, as in some locations near the city of Fermo (Moretti et al 2002).

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Foliar fertilization on olive-growing – first results of a specific foliar-fertilizer application on some cultivars in different environments of southern Italy

ABSTRACT

In 2003, a nutritional investigation was conducted to evaluate the effects of a specific foliar fertilizer "Nutrivants" on different cultivars of olive trees as well as in different environmental locations.

Soil fertilizer was applied once, at budbreak in spring, and foliar treatments were applied in two sessions, one before flowering (Prebloom Olive Nutrivant) and the other at pit hardening (Summer Olive Nutrivant).

Trees were monitored for vegetative and productive parameters such as growth rate, percent of fruit set and, at harvest, percent of fruit drop and yield.

On samples of drupes at harvest, the average weight and the pulp-to-pit ratio were calculated. The results after the first year generally showed an improvement in the vegetative parameters and yield of the foliar-fertilized trees. The foliar application of macroelements, with the built-in Fertivant penetration adjuvant facilitating absorption, increased tree productivity both when used as an addition to soil fertilization and also when used as an alternative to it.

INTRODUCTION

The olive tree is still often considered as a rustic plant having few nutritional requirements and quite capable of surviving in rough environments with minimal care and management. Nevertheless, these factors have a negative effect on its productivity, also enhancing the potential for alternate fruit bearing.

The determination of the most suitable plan for olive-tree fertilization, in order to ensure the best nutritional levels, depends on the local environmental and climate factors as well as on the effectiveness of the composition of the fertilizers and their method of application.

Foliar fertilization has been considered a valid support to soil fertilization. It contributes to increased levels of nutrients and the yield of plants while reducing the competition among metabolic sinks (shoots, inflorescences and fruits) (Cimato *et al.*, 1991; Borrelli, 1992). The foliar application of macroelements (especially nitrogen) has a positive influence on growth and yield because of its quick assimilation and translocation, and in increasing nutrient absorption through the roots (Cimato, Marranci and Tattini, 1990; Fiume, Lombardo and Settineri, 1975; Pugliano, 1983). However, other results demonstrate that foliar fertilization cannot entirely replace

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nutrition through the roots, even though it leads to less need for soil-applied fertilizers (Castorina, 1955; Fontanazza, 1988; Toscano, Briccoli-Bati and Sirianni, 2000).

Several authors have presented different reports on the nourishment requirements of olive trees. Variables considered have been tree age, vegetative state, production, etc. These studies have indicated that, for these reasons, the planning of fertilizer application cannot be approached as a standard procedure (Mazzali, 1992; Natali, 1993; Petruccioli and Parlati, 1983). Most often, olive-tree fertilizer programmes follow empirical solutions.

The current research was conducted to investigate the effects of foliar fertilization and the nutritional efficiency of specific types of foliar fertilizers on selected Calabrian olive cultivars in a range of environments in southern Italy.

MATERIALS AND METHODS

In 2003, tests were conducted in three different, young olive orchards, 6 × 4 scaled, reared in dry conditions. Soil fertilizer was applied once in spring, using about 1 kg/tree of an NPK (20:10:10) commercial fertilizer. For foliar fertilization, two specific products were used, provided by Agrovant Ltd. of Beer Sheva (Israel): Prebloom Olive Nutrivant (PON: 10:33:21+1.8B+FV) applied before flowering; and Summer Olive Nutrivant (SON: 8:16:40+FV) at pit hardening, using 2–3 litre/tree solution 3-percent concentrated, in line with the recommendations of the supplier.

Growth rate (new nodes), percent of fruit set and fruit drop, and yield at harvest were monitored in all trees and fields under observation. On samples of drupes, at harvest, the average weight, the pulp-to-pit ratio and the percent of oil contents, were calculated. All data were statistically analysed using analysis of variance (ANOVA) and specifically the Tukey test.

In the first of the three fields, located in a hilly environment, three comparative tests, each one involving eight plants, were conducted on 15-year-old Carolea cultivar trees (Table 1):

- A: soil fertilization with NPK;
- B: foliar spraying with Nutrivant (NV) (PON and SON) + NPK on soil;
- C: foliar spraying with NV (PON and SON).

In the second field, located in a littoral environment, a trial run on 8-year-old trees of Carolea and Rossanese cultivars was conducted in two tests, each one involving 30 trees of each cultivar (Table 2):

- NV: foliar spraying with NV (PON and SON);
- CTR: control not fertilized.

In the third field, also on a hilly soil, three tests were conducted on 6-year-old trees of Nocellara del Belice cultivar (Table 3). The tests, each one involving 20 trees, were run as follows:

- A: foliar spraying with NV (PON and SON) + NPK on soil;
- B: foliar spraying with NV (PON and SON);
- C: control not fertilized.

RESULTS

In the first field, with plants in the “off” year (Table 1), the foliar-fertilized trees (B, C) showed a better growth and fruit set, and a significantly lower fruit drop than the soil-only fertilized test (A).

Test B (fully fertilized) showed a significantly higher yield, but a lower pulp-to-pit ratio, while similar production and pulp-to-pit ratio was obtained in tests A and C. The applied NV products also showed a positive effect on inolition processes, seen in the significantly higher oil percentages in drupes, relative to test A.

TABLE 1
Vegetative and productive results on Carolea (field 1)

	Growth		Fruit set		Fruit drop		Yield		Av. drupe weight		Pulp-to-pit ratio		Fat in drupe	
	(new nodes)				(%)		(kg/plant)						(%)	
A (NPK)	8.4	ns	1.50	ns	18.98	a	2.29	B	3.48	B	8.05	A	16.59	B
B (NPK+NV)	10.2		2.01		10.70	b	5.74	A	3.63	B	7.56	B	18.16	A
C (NV)	9.6		2.04		11.26	b	2.54	B	4.00	A	7.93	A	18.44	A

Note: Means, followed by different letters, are significantly different at $p < 0.01$ (uppercase) or $p < 0.05$ (lowercase) level.

TABLE 2
Vegetative and productive plants parameters (field 2)

	Growth		Fruit set		Fruit drop		Yield		Av. drupe weight		Pulp-to-pit ratio		Fat in drupe	
	(new nodes)		(%)				(kg/tree)						(%)	
Carolea														
NV	10.16	a	2.67	ns	25.81	a	12.87	ns	6.16	ns	9.0	ns	16.29	ns
CTR	9.04	b	2.55		21.76	b	11.22		6.32		9.2		16.63	
Rossanese														
NV	14.54	a	3.20	ns	25.48	B	9.91	A	2.34	ns	5.0	A	15.43	ns
CTR	12.96	b	3.40		34.30	A	7.29	B	2.41		4.7	B	15.36	

Note: Means, followed by different letters, are significantly different at $p < 0.01$ (uppercase) or $p < 0.05$ (lowercase) level.

TABLE 3
Vegetative and productive plants parameters (field 3)

Test	Growth		Fruit set		Fruit drop		Yield		Av. drupe weight		Pulp-to-pit ratio		Fat in drupe	
	(new nodes)				(%)		(kg/tree)						(%)	
A (NPK+NV)	20.29	AB	1.61	A	32.98	B	3.34	ns	4.54	B	6.39	C	21.48	ns
B (NV)	18.78	B	1.30	A	32.53	B	3.98		4.94	AB	7.22	B	20.15	
D (Control)	23.47	A	0.88	B	43.73	A	2.33		5.01	A	8.46	A	23.09	

Note: Means, followed by different letters, are significantly different at $p < 0.01$.

In the second field, with plants in the "on" year (Table 2), both NV-treated cultivars showed better results than their unfertilized tests (CTR) in terms of growth and yield.

The NV products used in the current work also gave significant benefits in the Rossanese cv. fruit drop, as different to the response from the Carolea, which even showed a slight reduction in pulp to pit and dupe-oil content, whereas Rossanese cv. gave a significant increase in pulp to pit compared with the control test.

In the third field (Table 3), with plants in the "off" year stage, the use of foliar spraying (A, B) significantly enhanced the fruit set and the fruit drop, relative to the control tests (C), with higher yield, but lower drupe weight, pulp-to-pit ratios and percentage of drupe-oil contents. In this field, unlike the results from the first field, the soil-fertilized test, in addition to the NV foliar spraying (A), did not provide a significant difference compared with the trial with only NV foliar spraying (B), except for a small increase in the fruit-set value.

CONCLUSIONS

In the "off-year" fields, the trees treated with foliar sprays generally showed an increase in vegetative parameters and yield, relative to the control tests.

The provision of NV fertilizers, additional to the soil fertilizers, showed better results on the Carolea cultivar in the first trial field, than the similar test on the Nocellara cultivar in the third field.

Furthermore, in the "on-year" field, the NV test had good results on both observed cultivars, demonstrating an improved productivity in comparison with their respective controls. Therefore, it is confirmed that the foliar application of NV products enhanced tree responses significantly both when used in addition to soil fertilizer and as an alternative to it.

Although the effectiveness of foliar treatments is conditioned by the metabolic activity of the plants, the results of this first trial year seem to confirm that this technique can be a valid option where no soil fertilizer is added. It will be necessary to continue these tests in the years ahead, with new products and dosage optimization, in order to establish the most valid methods and techniques of application, keeping in mind the long-term health and behaviour of olive trees. The current recommendation of Agrovant Ltd is to spray the PON at 20-percent bloom.

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Soil-erosion assessment in vineyards

ABSTRACT

Vineyards are one type of land use that incurs large amounts of soil loss in the Mediterranean environment. The objective of the current paper is to investigate the suitability of one agronomic practice for the conservation of soil and the minimization of soil erosion within Italian viticulture. The work was performed in cooperation with the European Commission project "Pan-European Soil Erosion Risk Assessment". The research site was situated in a hilly area of the Abruzzo region (central Italy) at 170 m above sea level on a clay-loam soil with an average slope of 20 percent. Two soil-management methods were compared: soil conservation management and conventional tillage. Runoff and soil losses caused by erosion were measured with a suitable trapping system installed at the end of four vine rows during the winter of 2002. Subsamples of the collected eroded soil were analysed to evaluate the total sediment loss, size and distribution of eroded particles, organic matter and nutrient content. During extreme runoff events, both the runoff and the sediment load from the conservation-management treatment was less than that from the conventional treatment. Specific parts of the conventional plots had more severe losses. Under light rainfall, no differences between treatments were found. These preliminary results demonstrate that with conservative land management there is considerable potential to lower rates of soil erosion and, consequently, to increase the potential for soil-water infiltration. Furthermore, the exclusion of tillage practice gave beneficial effects not only in terms of farm economics and personnel-time management as a whole but also in term of improved soil chemical and physical characteristics.

INTRODUCTION

"Sustainable agriculture" has become an important part of conceptual thinking in modern environmental science. Part of this area of scientific discussion surrounds the minimization of topsoil loss from agricultural land. Ochse *et al*. (1961) wrote "the most important phase in soil management and probably the outstanding problem in general is the control of erosion."

In comparison with other crops grown in the Mediterranean region, land under vines suffers the greatest soil losses. Previous studies in the European Mediterranean region have recorded significantly increased runoff and soil losses for specific sites: 47–70 Mg/ha/year in northwest Italy (Tropeano, 1983), 35 Mg/ha/year in the Mid-Aisne region of France (Wicherek, 1991), and 22 Mg/ha/year in the Pendes-Anoia region of northeast Spain (Usón, 1998). The rationalization of these results is based on the following interrelations:

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- the climate, characterized by a complex pattern of spatial and seasonal variability, with wide and unpredictable rainfall fluctuations and frequent extreme events of high rainfall intensity (Llsat and Puigcerver, 1992, 1994; López-Bermùdez and Romero-Dìaz, 1993; Ramos and Porta, 1994);
- an abundance of unconsolidated parent materials such as limestones (Poesen and Hooke, 1997; Martinez-Casasnovas, 1998);
- clay soils, which have a slow water infiltration rate and tend to form a crust on top, which lowers infiltration capacity even further;
- orographic factors such as steep slopes.

In addition, external factors such as the elimination of soil conservation measures (Cerdà, 1994; Chisci, 1994; Porta, López-Acevedo and Rodrìguez, 1994; Pastor and Castro, 1995; Usón 1998) and tillage have also played a part in increasing both the potential for and actual soil degradation.

In vineyards, which is a type of dryland cropping, soil management should enable maximum use of rainfall by increasing water infiltration and reducing evaporation losses. Moreover, it should preserve microfauna, microflora and earthworm populations, and allow vine roots to explore freely both the uppermost and deep soil layers.

One of the most effective methods for controlling soil erosion, which combines all the above-mentioned positive effects, is to grow a live, or retain an inert (stubble), plant cover on the soil (Moreira, 1990).

The aim of the current study is to evaluate the soil losses from two different soil-management systems: traditional tillage with 4–5 tillage passes each year, and conservative management. The field research is designed to demonstrate that the timely and judicious use of herbicides has a role to play in soil conservation, especially compared with intensive soil cultivation.

MATERIALS AND METHODS

The trial is being conducted in the vineyards at the experimental site, close to the University of Teramo located in the municipality of Mosciano S. Angelo in the Province of Teramo, Italy. The site is located at 45° 45' N, 13° 54' E, 170 m above sea level on a typical slope of a hilly Adriatic belt with an average slope of 20 percent. It has a Mediterranean climate, with an annual rainfall of 760 mm, with the rainfall concentrated mainly in two periods: September–November and March–April. Soil depth ranges from 50 to 100 cm. The chemical-physical characteristics of the soil are given in Table 1.

The vineyard consists of trained vines, with a 1.5 × 3.1 pattern with the vine rows parallel to the maximum slope gradient. The vineyard has been cultivated regularly within the interrow spaces for a number of years. Each row, owing to previous soil

TABLE 1
Soil chemical-physical characteristics of the field trial site

Horizon	Depth (cm)		Sand (%)	Silt (%)	Clay (%)	$CaCO_3$ (%)	C org. (%)	pH H_2O
A_p	0	25	16	49	35	16.3	0.96	8
B_w	25	60	14	47	39	12.4	0.17	8.3
BC_k	60	130	15	48	37	31.7	0.12	8.3

Horizon	Depth		Exchange complex						TSB	ESP	N tot	P	K	Bulk den.	Cond.
			Ca	Mg	Ca + Mg	Na	K	CSC							
	(cm)				(meq/100g %)				(%)	(%)	(g/kg)	(ppm)	(ppm)		(mS/cm)
A_p	0	25	18.7	2.2	21.0	0.43	0.81	22.2	100	1.9	0.95	19	317	1.2	0.22
B_w	25	60	21.7	2.6	24.3	0.43	0.59	25.3	100	1.7	0.27	5	231	1.4	0.13
BC_k	60	130	17.5	2.8	20.3	0.48	0.47	21.2	100	2.3	0.18	5	184	1.6	0.13

TABLE 2
Rainfall, runoff and sediment recorded at each event in each of the conventional and conservative treatments

Event	Rainfall	Conservative		Conventional	
		Runoff	Sediment	Runoff	Sediment
(time)		(mm)			
1–10/09/2002	177.0	10.2	0.3	3.8	1.2
11–14/09/2002	19.0	0.5	0.3	1.7	0.5
15–27/10/2002	62.6	0.1	0.0	1.6	0.0
1–10/12/2002	18.6	0.4	0.0	0.5	0.0
11/12/2002–12/01/2003	64.4	1.4	0.2	1.3	0.3
21–27/04/2003	31.8	0.5	0.0	0.5	0.0

losses, forms the equivalent of a bound plot. This will negate the necessity to bund any plots for subsequent erosion assessment.

The vineyard plots that are the object of the present study have an area of 155 m^2 (dimensions of the plots: 50 m long by 3.1 m wide).

During the winter of 2002–03, a suitable trapping system was installed at the end of four vine rows in order to trap runoff losses. Two rows have been maintained using current cultivation practices and the other two follow soil conservation principles (herbicide application with no tillage). After each rainfall event, the water quantity and soil sediment were measured in each of the trapping systems. Subsamples of the sediment were collected and characterized to evaluate the following properties: total sediment loss; size and distribution of eroded particles; organic matter content; and nutrient content. Soil samples were also collected from within each of the plots at specified times to measure any changes in soil status within the plots.

RESULTS AND DISCUSSION

Because of the limited period of observations, only preliminary results are reported in Table 2. They show the rainfall intensity and the related runoff and sediment on the conventional and conservative treatments.

The greatest total rainfall occurred in the period 1–10 September (177 mm), and it occurred in a short period of time, conferring it an extraordinary character (but not unheard of in this region). In that event, the runoff from the conservative treatment was greater than the conventional treatment (Table 2). The reason for this was quite obvious at the time (Plate 1) as the large sediment load washed off the conventional treatment totally blocked the grating in the trapping system. In all other events, the water flow registered from the conventional treatment, except for that recorded on January 2004, was always greater than that from the conservative treatment.

In terms of soil-sediment loss, for the rainfall events of September 2003 and January 2004, losses were always greater from the conventional treatments than those from the conservative ones. The majority of those sediments were produced by concentrated surface runoff. As visible in Plate 2, soil losses were large in some points of the plot of the conventional treatment, particularly along the flow concentration lines. In those zones, up to 0.2 m of the topsoil was removed producing rills and gully erosion.

Plate 1
Soil particles obstructing the grating of the trapping system in the conventional treatment.

Plate 2
Severe erosion in the conventional plots caused by extreme rainfall events.

The other rainfall events, recorded during the period of observations, produced very small soil losses, and no differences between treatments were evident.

In the conservative system, there is considerable potential to lower rates of soil erosion and to increase the potential for soil-water infiltration. Moreover, with the exclusion of any tillage practice, organic matter content, root development and earthworm populations are well preserved (Lee, 1985; Paoletti *et al*., 1998; Werner and Dindal, 1989; Edwards and Bohlen, 1996).

It is clear that the cultivation of vines in many areas of the southern Mediterranean is not sustainable without some form of soil protection. Farmers are an integral part of the process to develop locally appropriate conservation systems. However, they require help in understanding the benefits of adopting erosion-control practices if their farms are to continue to produce grapes in environmentally sound ways.

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The role of vegetative bands in sloping olive orchards – erosion rates and runoff (preliminary results)

INTRODUCTION

Andalusian olive orchards have traditionally been planted in marginal lands. For example, 70 percent of the plantations have slopes of more than 6 percent. This fact, together with the rapid development of suitable herbicides and the increasing number of politicians and farmers with concerns about soil loss, has resulted in some changes in the "traditional" soil-management strategy, i.e. conventional tillage.

One of the first alternatives that appeared was no-tillage with chemical control of weeds. However, this technique has yielded contradictory results with respect to soil losses (Gómez *et al.*, 2003). On the other hand, the use of no-tillage with full vegetation cover or with some vegetative bands (for improved water economy) appears to be a more promising way of reducing erosion rates.

Therefore, the aim of the current work was to study this type of soil management and to indicate its benefits and any shortcomings. To achieve this, an experiment was designed to assess erosion rates, runoff and herbicides losses from: (i) no-tillage combined with herbicide use; and (ii) no-tillage with vegetative bands.

MATERIALS AND METHODS

The experiment was conducted at the Alameda del Obispo Experimental Station near Cordoba, in southern Spain. Three plots of 6 × 14 m were delimited by a metal frame over a typical Xerofluvent (montmorillonitic rich) soil with a uniform slope of 15 percent.

Two of these plots were established with two 4-m wide vegetative bands of natural vegetation (mainly grass) each being 3 m apart. The remaining plot was an absolutely bare-soil plot so that a comparison between management strategies was possible. In order to keep the bare-soil areas clear of weeds, Terbuthylazine and Diuron were applied according to the new Andalusian legislation on herbicide use: a maximum of 1 kg of active matter per hectare per year, applied between 2 and 4 atmospheres of pressure. A runoff collector consisting of a tipping bucket similar to the one described by Barfield and Hirschi (1986) was installed in the field together with a rainfall simulator of six sectorial sprinkles per plot, developed ad hoc for this experiment. The tipping bucket was calibrated for varying flow rates, obtaining the so-called calibration equation for

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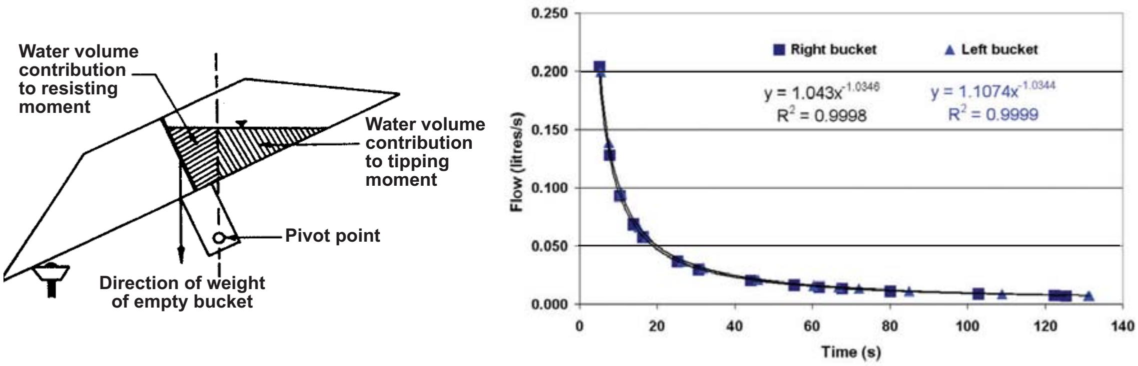
FIGURE 1
Runoff collector and calibration curves per bucket



each bucket which relates flow (Q) to the tipping rate (T) and which can be written as: $Q = aT^b$ where a and b are the calibration constants. Subsequently, the rainfall uniformity was measured by a network of 38 rain gauges sited at regular intervals over the experimental plots (Christiansen coefficient). Drop size was also checked in order to avoid including values outside the natural rain range.

Two types of rainfall simulations were chosen in order to study the runoff and soil and herbicide losses: (i) an "intense" rain event of 35 mm/h lasting for 1 h and having a return frequency of 5 years according to the intensity-duration-frequency curves of the study area (García Marín, 2000); and (ii) a moderate-to-low-intensity rain event of 15 mm/h, also for a duration of 1 h. Runoff water and sediments were sampled for every rainfall event. The instant unit hydrograph technique was used to perform a "deconvolution" of the obtained hydrographs and pollutographs to simulate shorter rainfall events.

PRELIMINARY AND EXPECTED RESULTS

Although the study is still underway, some preliminary results have already been obtained. For example, the calibration of the runoff collector and of the sprinklers has been done. The former yielded the relationships to be used to transform each tip into flow (Figure 1).

Expected results include the comparison of erosion rates between bare soil and the use of vegetative bands for the two types of rainfalls to be simulated. Additional results will consist of the adjustment of the so-called BKG model to predict herbicide movement in the soil and, finally, the determination of the runoff water quality in terms of herbicide contamination.

CONCLUSIONS

Previous studies have demonstrated the feasibility of measuring runoff and erosion using an experimental design similar to the one used in the current work. Therefore, we hope that the current study will shed some light onto the complex dynamic of herbicides and soil movement in olive orchards with different soil-management strategies.

The instant unit hydrograph technique seems promising in terms of differentiating different rainfall events from a unique event. The idea is to apply the same deconvolution also to the pollutograph so that herbicide losses can be predicted. The use of herbicide-movement models, such as GLEAMS could be of great help in validating this technique.

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Annexes

Annex 1
Summary of the discussions of the four working groups of the concluding "round table"

Fifty delegates participated in the concluding "round-table" discussion; structured to cover the four major discussion topics of the earlier sessions:

1. the role and importance of cover crops;
2. machinery use;
3. soil and water measurement/monitoring;
4. types and role of simulation models.

Each of four working groups deliberated the theme: "moving towards future initiatives in research, teaching, technology and development" in the light of:

- background;
- perceived "gaps";
- required research and education.

The groups then reconvened for a plenary discussion on "putting it all together – the development of linkages between land, water, crop quality, institution building, marketing, policies and modelling".

WORKING GROUP 1. THE ROLE AND IMPORTANCE OF COVER CROPS

Background

The use of cover crops in vineyards and olive groves is necessitated by the strong potential for erosion. This stems from the nature of the lands principally used for vine and olive production – sloping lands with low-quality soils. However, a balance is required as there is strong potential to cause compaction damage where cover crops are cut (or sprayed-out) under wet soil conditions.

Gaps

More information is required on varieties, types and required growing regimes of cover crops that can be incorporated into vine and olive production. This should be conducted in line with studies investigating the nature and degree of competition between cover crops and olives/vines for available soil water. The question of competition was one of the major discussion points of the group. However, it was agreed that the data available were minimal and that studies are urgently needed. Cover crops should also be available to cover a range of farmer, agronomic and environmental needs, e.g. balancing short-term cover/erosion aspects with longer-term carbon-dioxide emission mitigation and carbon sequestration issues. Again, studies were deemed lacking. The potential to increase and supplement nitrogen status with leguminous cover crops was also cited as an area lacking information.

Research and education

The group felt strongly that there was an urgent need for farmer education in the specifics and wider role/use of cover crops with vines and olives. This requires research inputs in order to ensure correctness and full testing of the information being provided to the farmer. The suggestion was that the researchers should provide and identify the options and then let farmers make the choice that is best for them.

A final topic discussed by the group was the requirement to promote the social benefits of soil improvements with cover crops and improved farmer practices. The group felt that this was a strong method for ensuring wider adoption of good agricultural practices.

WORKING GROUP 2. MACHINERY USE

Background

The group agreed that the vine and olive industries will never stop using machinery at all levels of field enterprise, and that the use of machinery (and most probably the size thereof) will most probably increase. With this background, the group emphasized that a most important issue was the continuing recognition of the need for education of farmers in the sustainable use of machinery in vineyards and olive groves. The outcomes of this conference were seen as an excellent way to commence this.

Gaps

Following from the above, the gap considered most important and current was the lack of one-on-one education of farmers in the "correct" and sustainable use of machinery. Additional to this, the group stressed that they saw little need for further inventions of "more and more" new machinery. Sophistication was deemed far less important than good practice with existing equipment.

Research and education

The group considered the most important theme was to "develop real-life, practical examples of good machine use in the field". Theory and laboratory studies are important, but demonstrating real-life examples on individuals and groups farms is essential. The group also saw a need for education of urbanites, particularly in order to counter the general belief that "agricultural practices are bad and ruining the environment for others". Positive, environmentally aware examples from the olive and vine industries should be collected and relayed to urbanites.

In terms of future actions, the group believed firmly that there should be more of this type of workshop – in other areas and in other countries. Farmers must be invited and involved in future workshops, to create a mutual learning environment. Important, too, was the realization that there is no one prescriptive answer to good land management for olives and vines. Rather, the group wanted to see the forming of a real and conceptual "toolbox" of good agricultural practices, with efforts to educate farmers to use these on-farm.

WORKING GROUP 3. SOIL AND WATER MEASUREMENT/MONITORING

Background

The fact that most olive and vine production is situated on relatively poor, sloping lands in semi-arid and arid zones places great emphasis on achieving optimal conditions of both soil condition and water dynamics.

Gaps

A theme of Group 1 was further emphasized by this group – that the relative roles of cover crops and vine/olive plants in terms of soil-water use is poorly understood. As this group said: "in light of this non-information there is no way forward, either in cover crop use or in rationalizing and improving soil water dynamics beneath olives and vines". In terms of irrigated olive and vine production, the group felt strongly that the emphasis should be on learning to use the irrigation water to maximize the quality of the product. This will require a definition of vine and olive "quality", particularly one that matches well with descriptors and measures of soil quality and health. The group also identified a major gap between the researcher and the farmer, in particular, the delay between gaining research findings and their practical implementation on the farm.

Research and education

The group considered that policy-makers are most important and that it is vital to involve them in the researcher/farmer discussions. This was seen as a three-way process with each group learning from the other towards a common good. The group considered the farmer/farm–industry link to be far closer than links between farmers and either researchers or policy-makers. This needs resolving. Furthermore, the group emphasized the need to "empower" young people through research and teaching institutes, and to ensure their education and research is problem-oriented, and that they have strong technology-based solutions. A final point from this group was the need to consider water quality, and the group suggested this as the basis of a future workshop.

WORKING GROUP 4. TYPES AND ROLE OF SIMULATION MODELS

Background

The role of models in the olive- and vine-production industry is vital. One important role is the "filling of gaps" in knowledge, both in terms of content as well as spatially. Simulating potential best practice scenarios, say with limited water supply or after rejuvenating compacted root systems, was an important role for modellers – to assist in directing research initiatives and focus.

Gaps

The group agreed that current models tend to focus too much on individual trees ("one-tree studies") or on one orchard in one condition (e.g. with bare soil). More realistic scenarios need to be investigated, challenging and difficult as this is. For example, there is a need for more studies on radiation intercept with different canopy covers, cover crops, and tree densities. There are also problems concerning knowledge about and definitions of the root systems of olive trees and vines. There are many unknowns in areas such as whether olives and vines have deep or shallow root systems, and whether the root system acts differently in different parts of the year (as temperatures and rain/soil water fluctuate) and under cover crops. There is a need to study all three important aspects – canopies, bare soil/cover crops, and root systems – and to model the variations, interdependencies and sensitivities of all three, concurrently.

Research and education

The group stated clearly that they did not like the concept of using "crop coefficients" as generalisms of tree/crop types in their modelling work. They are too broad and vague. It was felt that better information could be gained using remote sensing and measures such as leaf-area index. The group recognized the difficulties of achieving a good/reliable/meaningful simulation of water dynamics under olives and vines, to perhaps complement the measures of Group 3. Problems with knowledge gaps about the nature and dynamics of root systems were seen as the major shortfall, requiring much more work. Problems with scale are also unresolved. There is a need to quantify a whole cropping system – a very complex but important task. The growing demand is to link such work with precision agriculture, particularly as private (commercial) companies have a great interest in this. However, they require a very soft (user friendly) "front-end" to such simulation models – a very demanding task. There is scope to research the combined approach of: simulation models with geographical information systems and digital terrain (elevation) models, and remote sensing. The plan is to combine these in order to gain a closer approximation of reality.

THE CLOSING STATEMENT

The closing statement emphasized the need to use the outputs of the two days to "go forward" and face the continuing challenge of achieving practical, sustainable use of land in vineyards and olive groves, worldwide. There is a need for simple approaches, firmly based on good science, to reach farmers in order to achieve widespread adoption of good and improved agricultural practices.

Annex 2
Seminar programme

Sunday 9 May	
08:30–09:30	Registration of participants
09:30–13:00	Field trip to the experimental field of the Food Sciences Department – Crop and Soil Sciences Division Unit – to include: • On-site demonstrations in soil pits of Soil Visual Assessment for soil compaction recognition and improved soil health with Conservation Agriculture practices • Soil moisture monitoring apparatus (capacitance measurement for soil moisture and crop management).
13:00	Lunch buffet A full tutored wine tasting will be arranged in the farm wine cellar *(Mr. Camillo Montori, Controguerra)*
Monday 10 May	
09:00–09:20	Welcome address Prof. Luciano Russi, Chancellor Università degli Studi di Teramo Prof. Dino Mastrocola, Dean Facoltà di Agraria *Università degli Studi di Teramo.*
09:20–09:30	Introduction and programme briefing *Michele Pisante, Dipartimento di Scienze degli Alimenti, Università degli Studi di Teramo*
09:30–10:00	Emerging issues in soil and water management for vineyard and olive tree orchards *Luca Montanarella, EC Joint Research Centre, Italy*
10:00–10:40	Overview presentations Importance of olive oil production in Italy *Giuseppe Fontanazza, CNR-ISAFOM, Perugia* The role and importance of integrated soil and water management for Vineyards and olive orchards. *José Benites, FAO, Michele Pisante and Fabio Stagnari, Dipartimento di Scienze degli Alimenti, Università degli Studi di Teramo*
10:40–11:00	Coffee break

11:00–11:45	Overview presentations
	Comparative assessment of practices and their effects using a Soil Visual Assessment (SVA)
	Des McGarry, Natural Resource Sciences, Queensland Government, Australia
	Soil and water management for olive orchards in Portugal
	Anacleto Cipriano Pinheiro, University of Èvora, Portugal
	Management of vineyards for high quality wine and cava production in two contrasting regions of Catalunya
	Idelfonso Pla Sentis, University of Lleida, Spain
11:45–13:25	Invited presentations
	Australia (*Peter Buss, Sentek Pty Ltd, Stepney*)
	Chile (*Samuel Ortega-Farias, University of Talca*)
	Spain (*José Gomez, CSIC, Cordoba*)
	United States of America (*Joe T. Ritchie, University of Florida, Gainesville)*
	Syrian Arab Republic (*Masri Zuhair, ICARDA, Aleppo*)
13:20–15:00	Lunch
15:00–16:00	Poster session
16:00–16:30	Coffee Break – Round table participants registration
16:30–19:00	Round Table
	Research, teaching, technology and development: "The role and importance of integrated soil and water management for vineyards and olive orchards"

Annex 3
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