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# Ground cover management strategies in an Apulian oil-producing olive grove: agronomic and ecological assessment proposals

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**Abstract: Several studies have pointed out that ground flora in olive groves, such as in any orchard, should ideally combine adequate positive effects on the agro-environment with only marginal negative competitive effects on the olive plants. This paper reports the results of an experiment carried out in an irrigated olive orchard (cv. Leccino), located in the area of Savelletri, Puglia (southern Italy), regarding the effects of ground flora as a consequence of different management techniques. An aggregate index is proposed, able to provide a comprehensive evaluation of flora from both an ecological and agronomic point of view. Four different weed control strategies were compared: A) seeding, every other year, of a cover crop (*Vicia sativa* L.) chopped in springtime; B) weed control using a mixture of a systemic herbicide and a residual herbicide; C) weed control using a systemic herbicide only; D) chopping. The results revealed that the different management practices largely influenced the ground cover values in each study year, but not the yield. Ground cover features, assessed both from an agronomic and ecological point of view varied in particular, as was well reflected by the applied index, which proved to easily and effectively describe the flora features in different plots.**

## 1. Introduction

Although olives are grown in other world regions, such as California, Australia and Argentina, the most important production areas are found in the Mediterranean basin where olive finds its best growing conditions, in particular in Spain, Portugal, Italy, Greece, Albania, North Africa and the Middle East. Olive tree has had traditional importance in the Mediterranean region since ancient times (Loumou and Giourga, 2003) and its cultivation retains importance in this area for its social, environmental and economic value. Currently a large part of the total world olive plantations are found in the Mediterranean basin. The olive tree defines the Mediterranean region within the Holarctic Kingdom (Ubaldi, 2003) and it is considered one of the most typical species of this area, where it represents a very important element in defining the "identity" of the rural landscape.

The ecological function of rural landscapes and the promotion of multifunctional agriculture is an important topic in agricultural and agri-environmental policy within the European Union (Gerowitt *et al.*, 2003). Vegetation related to olive orchards plays an important ecological function that can be efficiently used to improve the multifunctional role of olive growing in the Mediterranean region (Margaris, 1980). For instance, Saavedra (1998) reports over 500 species in the olive area of Córdoba province. In a selection of plantations in western Andalucía, 75 plant species were recorded prior to the spring cultivation (Rodenas *et al.*, 1977). In Greece, traditionally managed olive groves have been identified as important habitats that often support a rich ground flora, which may include species with habitats threatened by land-use changes (Allen *et al.*, 2006).

Surveys in several olive orchards of south-western Albania report more than 80 species belonging to 14 botanical families (Huqi *et al.*, 2009). In Italy, Viggiani (2009) reports more than 50 species as typical of olive groves, most of them having also ethno-botanical importance. The number could be even higher considering the species that can be found along field margins, i.e. roads, stone walls and other traditional human infrastructures typical of olive orchard landscapes.

The presence of a significant number of plant species in olive groves offers favourable conditions for a multitude of animals such as arthropod fauna, reptiles, mammals and birds (Beaufoy, 2000; Loumou and Giourga, 2003). This is due not only to primary production in the food chain, but also to the provision of cover and reproduction sites (Marshall *et al.*, 2003). Potts *et al.* (2006) assessed the biodiversity value of six common habitats on the Greek island of Lesvosmic. They found that man-

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aged olive groves had the highest diversity of bees, comparable with natural habitats such as oak woodlands and pine forests.

Natural flora in olive orchards and the related fauna are also important sources of food for many species of birds, with consequent internationally important effects related to the migration of these animals (Guzman Alvarez, 1999). For example, in southern Italy about 6% of olive groves are included in "*Natura 2000 habitats*" (Birds Directive 92/43/EEC). From an agronomic point of view, natural flora is often able to enhance pest control because it can be an alternative host or direct food source for beneficial organisms (Marshall *et al.*, 2003; Norris, 2005).

In addition, ground cover can positively affect the diversity of soil biota, improving the soil ecosystem function. This effect was shown in a trial conducted in a rain-fed olive orchard, located in south-eastern Spain by Moreno *at al.* (2009) in which covered soils exhibited greater bacterial biomass and diversity, as well as higher microbial functional diversity than non-covered soils.

Conservative flora management can also increase $CO_2$ fixation and enhance the capacity of olive orchards to accumulate significant amounts of biomass and humus (Sofo *et al.*, 2004; Palese *et al.*, 2005).

Vegetation cover also has an important function in significantly reducing soil erosion (Hernandez *et al.*, 2005), one of the most serious and widespread environmental problems in many areas of the Mediterranean region (Pastor Muñoz-Cobo and Castro, 1995) where olive groves are often located in marginal soils and on steep slopes (Gomez *et al.,* 2003; Francia Martínez *et al.*, 2006).

However, olive tree vegetation and yield can be significantly damaged if weed flora is not correctly managed, especially under rain-fed conditions. In addition to competing with olive for water, nutrients and - at early crop stages - even for light, weeds may also hamper olive picking. Moreover, during summer, dead weed residues can catch fire and seriously damage olive plants in cases where the residues are abundant.

Traditional soil management is based on tillage, keeping the soil bare of vegetation all year round. This practice, in addition to undoing the potential benefits of natural flora, is also labour-intensive and expensive, hence it must be considered not sustainable. Several experiments show that it is possible to obtain the same or better productive results by adopting practices, such as chemical weeding or mowing, reducing or eliminating soil tillage and maintaining weed flora density at a level that is not dangerous for olive plants. Some significant results are reported by Huqi *et al.* (2009) in Albania, Montemurro and Mastropirro (1995), Montemurro *et al.* (2002) and Toscano *et al.* (2004) in southern Italy, Hernandez *et al.* (2005) in central Spain, Pastor Muñoz-Cobo (1990; 1991) in Spain, and Kabourakis (1999) in Greece.

These alternative strategies could represent a remarkable sustainable approach for the maintenance of the environment both in intensive systems, mitigating the environmental impact of olive growing, and in low-intensity farming systems located in marginal areas. In these latter areas, reduced tillage could reduce management costs and contribute to preventing abandonment of these groves and preserve natural and cultural resources (Duarte *et al.*, 2008). The effects could be beneficial on a large portion of the European territory; olive groves occupy approximately 5.4 million hectares, or about 4% of the utilisable agricultural area (Source: European Community).

Each soil management system provides different conditions of the growth for weeds. Tillage destroys the annual flora, but can also create favourable conditions for new germinations and, moreover, it benefits perennial weeds by fragmenting and scattering vegetative reproductive organs such as rhizomes, tubers, bulbs and stolons. Foliar herbicides, such as glyphosate, are able to control both annual and perennial plants, but they could exert a selection pressure on tolerant or resistant species. Residual herbicides, such as oxyfluorfen, keep the soil weed-free for a longer period of time. Generally, chemical weed control can cause a simplification of the flora spectrum with fewer species that are often more problematic to manage. Mowing can encourage those species that are able to re-sprout after cutting. Cover crop (living mulches) may contribute significantly to weed suppression providing early soil coverage and reducing the number of established weed seedlings.

*Research proposal*

Weed flora, also as a consequence of different management practices, can have both positive and negative effects on olive orchards as well as on the agro-ecosystem. Several studies have focused specifically on the ecological importance of natural flora in olive groves; other experiments have been performed in order to suggest the best control practices and to reduce the negative effects of weeds. It is reasonable to suppose that ground flora in olive groves, such as in any orchard, should ideally combine adequate positive effects on the agro-environment with only marginal negative competitive effects on the olive plants.

The objective of the current work is to report data on flora communities established as a consequence of different management techniques and to suggest an aggregate index able to give a comprehensive evaluation of flora, both from the ecological and agronomic point of view. The effects on olive production and oil yield are also considered.

## 2. Materials and Methods

The experimentation was carried out between November 2005 and December 2010 in an irrigated olive orchard located in the area of Savelletri (Puglia -southern Italy) made up of 11-year-old cv. Leccino plants, vase shape trained and spaced 7 x 7 m. The soil that hosted the orchard was loamy-textured (16.9% clay - 35.8%

silt - 47.3% sand), with a moderate presence of shallow pebbles (7.5 to 25 cm in size).

The trial involved the comparison of the following four different weed control strategies: i) Seeding, every other year, of a cover crop (*Vicia sativa* L.) chopped in springtime. The subsequent infestation was controlled by chopping (VE); ii) Weed control using a mixture of a glyphosate-based systemic herbicide and a residual herbicide containing oxyfluorfen, at a rate of 1.08 and 0.12 l $ha^{-1}$ respectively (GLY + OX); iii) Weed control using glyphosate only at a rate of 1.08 l $ha^{-1}$ (GLY); iv) Chopping (TRI).

Herbicides were diluted in a water volume of 400 l $ha^{-1}$ and applied with a hand-pump spray bottle, equipped with flat fan nozzles. Weeds were chopped using a shredder. The vetch was sown broadcast at the rate of 80.0 kg $ha^{-1}$, burying the seed by a shallow harrowing.

The different management strategies of ground flora were applied following the general principle of applications so as to keep the orchard fully free of natural flora in the peak vegetative growth period, i.e. in spring-summer, when the flora reached a mean height of about 10-15 cm. The dates of weeding operations for each treatment are detailed in Table 1.

The other agronomic and plant protection practices were applied using the techniques commonly used in the research area.

The experimental plots, covering an area of 441.00 $m^2$ (21 x 21 m), were arranged in the field following a randomised block design, with four replicates; for flora surveys a central test area of 196.0 $m^2$ was used including the four plants on which vegetation production surveys were conducted.

*Flora surveys and data processing*

Plot flora surveys were run in April and October of each year and in the two peak growth periods of weeds. In these surveys, made prior to the execution of scheduled weed control operations, species were divided into the following two groups: a) species distributed uniformly in the test area; b) species represented either by solitary plants or distributed in restricted patches. Afterwards, for each species of the first group, a percent ground cover value related to the reference test area was estimated. These data have been used to calculate the Specific Contribution (CS), dividing the ground cover of each single species by the total cover (sum of the covers attributed to each single species) and multiplying it by 100. Moreover, the presence of each botanical family was obtained by summing the percent ground covers of each species belonging to it. Nomenclature refers to Pignatti (1982).

To provide an estimate of the ground cover features of each treatment, an index defined as Ground Cover Quality Index (GCQI) was proposed. This index is calculated by the following formula: GCQI = $[\ \Sigma_i(CSi \times V_i)\ ]/6$, where $V_i$ is a total score assigned to each species having a uniform distribution in the test area, calculated by summing the values assigned to the following parameters:

- ability to cover the soil and protect it from erosion processes (0 = negligible; 1 = average; 2 = good);
- general ability to improve/preserve the chemical and physical soil properties through biomass production, nitrogen fixation or development of bunched roots (e.g. grass plants) that increase its porosity (0 = negligible; 1 = good);
- competitive ability against the orchard (0 = very competitive; 1 = normal; 2 = negligible);
- flammability in summer periods (0 = plant that leaves much dry biomass easily flammable; 1 = thin plant that produces little biomass potentially flammable or whose biomass is easily degraded prior to the warm season or that remains green in summer periods).

It follows that the value of $<V_i>$ could range between 0 and 6 and that, by the indicated formula, the Specific Contribution (CS) of each species, based on their morphologic and eco-physiological features, can take a weight varying between 0 and 6 times its value.

The specified parameters are proposed as a general indication, based on the specific needs of the test area. This does not exclude the possibility of using other ones based on other needs related to different conditions (e.g. aesthetic contribution, ability to be intermediate hosts of predators or of hyper pests, etc.).

This work presents only the flora data and the relevant analyses for 2006, 2008 and 2010, i.e. only in the presence of vetch (VE treatment) and in heavy years, considering olive alternate bearing.

*Surveys on olive plants*

For each of the four plants included in the test area, plants were tested for mean shoot growth recorded between April and October of each year, by selecting four shoots per plant arranged along the four cardinal direc-

Table 1 - Calendar of applied practices in different ground cover management strategies

| Strategies | Practices | 2005 | 2006 | | 2007 | | | 2008 | | 2009 | | | 2010 | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Nov | April | Oct | April | July | Oct | April | Oct | April | Oct | Nov | April | Oct |
| 1) VE | Sowing of *Vicia sativa* | x | | | | | x | | | | | x | | |
| | Chopping | | x | x | x | x | | x | | x | | | x | x |
| 2) GLY + OX | Chemical weeding | x | x | x | x | | x | x | x | x | x | | x | |
| 3) GYI | Chemical weeding | x | | x | x | | | x | x | x | x | | x | |
| 4) TRI | Chopping | x | x | x | x | x | x | x | x | x | x | | x | x |

tions. The data concerning each plot was thus obtained as an average of 16 values (four shoots per plant x four plants). At the beginning and end of the trial, the trunk diameter of each plant included in the plot area was also measured, and the mean growth occurred in that period was obtained by difference.

Olive harvesting was carried out in alternate years, i.e. in December 2006, 2008 and 2010. The fruits produced by the four plants of the test area were weighed. The oil yield was measured on a randomly chosen 2 kg sample from all olives harvested in each plot. The applied procedure complied with the guidelines of Annex XV of the EC Reg. No 2568/1991.

All data were submitted to variance analysis and the means were compared using Duncan's test.

*Climate pattern*

Figures 1 and 2 show the climate pattern observed during the experiment. Each year, in accordance with the climate pattern of the test area, the hottest months were June, July and August, whereas the coldest ones were December, January and February. The highest positive deviations (from +2.0 to +3.6°C) were recorded for the mean temperatures of January, June, July and August of 2007, January 2008 and November 2010; the highest negative difference was observed in February 2009 (-2.0°C compared to the plurennial mean). As to rainfall, the rainiest years were 2009 and 2010 with values exceeding the plurennial mean of the area (577.2 mm) by 243.5 mm and 162.1 mm, respectively. In those years, the months that deviated most from the average were January (+110.7 mm), March (+57.5 mm) and October (+64.6 mm) in 2009, and May (+72.9 mm) and October (+147.3 mm) in 2010.

## 3. Results

Table 2 lists the species found during the experiment. A total of 60 were identified; only 34 had a uniform distribution in the plots. The results obtained with regard to the uniformly distributed species are addressed in this section.

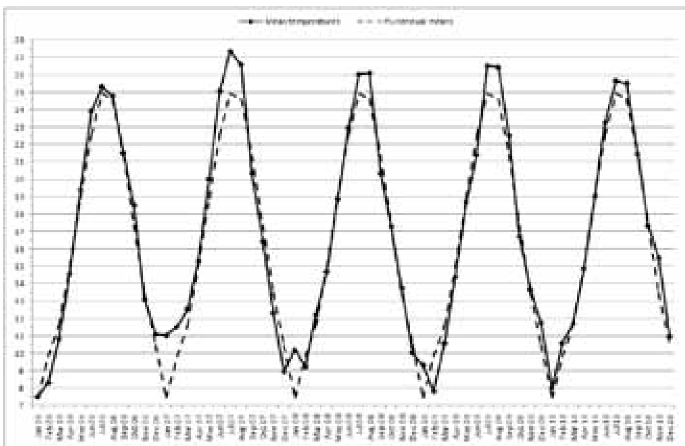

Fig. 1 - Mean monthly temperatures recorded during the trial and pluriannual means (1951-2001).

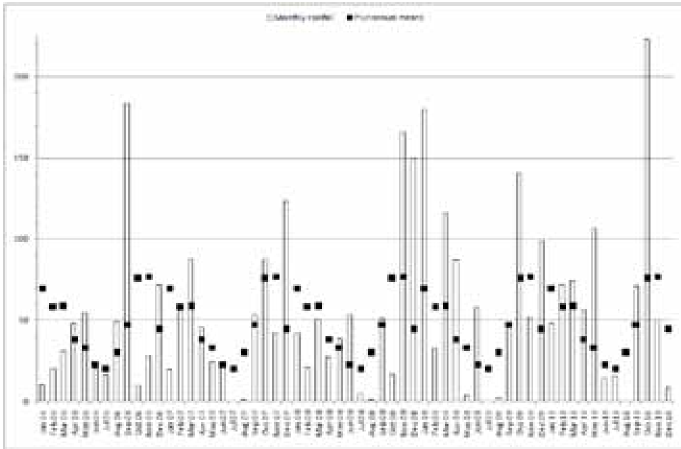

Fig. 2 - Monthly rainfall recorded during the trial and pluriannual means (1951-2001).

*Spring flora surveys*

In 2006 (Table 3), the statistically lowest total ground cover values were observed in treatments GLY and GLY+OX with 35.6 and 33.9%, respectively, followed by vetch-sown plots with 91.5%. The highest mean number of species, equal to 23.0, was recorded in vetch-sown areas, whereas the highest number of families (10.0) was observed in the plots subjected to chopping. Table 4 reveals that in the TRI treatment the statistically highest mean ground cover values were found for *Gramineae*, *Compositae and Leguminsae,* equal to 113.9-12.8 and 12.5% respectively, whereas the lowest values were recorded in treatment GLY (10.2% *Graminae* and 0.4% *Leguminosae*), GLY+OX (13.3% *Graminae*, 5.7% *Compositae* and 0.1% *Leguminosae*) and VE (6.1% *Compositae*). As to single species (Table 5), the highest specific contributions were calculated in chemically weeded plots for *Malva sylvestris* L. with 16.7% in treatment GLY+OX and 12.8% in GLY; these values were significantly higher than those observed in the plots of treatments VE and TRI. For *Avena sterilis* L.*, Bromus sterilis* L. and *Lolium rigidum* Gaudin, in chopped or vetch-sown plots higher specific contributions were observed than in chemically weeded plots. On the contrary, the specific contribution of *Hordeum murinum* L. and *Setaria verticillata* (L.) Beauv. was significantly higher in the GLY+OX treatment. With regard to the Ground Cover Quality Index in treatments TRI and VE, the observed values (52.4 and 55.1 respectively) were shown to be statistically higher than those calculated for chemically weeded treatments (Table 3).

In 2008*,* the highest values of total infestation and mean number of species (Table 3) were found in chopped (83.7% - 18.0) and vetch-sown plots (85.3% - 18.0), whereas the number of families was lower in treatment VE. The family *Gramineae* had a ground cover equal to 63.8% in treatment TRI, which is statistically higher than

Table 2 - Species found in experimental plots [z]

| Treatments | VE | | | GLY+OX | | | GLY | | | TRI | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | 2006 | 2008 | 2010 | 2006 | 2008 | 2010 | 2006 | 2008 | 2010 | 2006 | 2008 | 2010 |
| *Adonis aestivalis* L. | | | | | | | | | + | | | |
| *Anagallis arvensis* L. | | | X | | | X | X | | X | X | | X |
| *Anthemis arvensis* L. | | | X | | | X | | | X | X | | X |
| *Arum italicum* Miller. | + | | | | | | + | | | + | | |
| *Asparagus acutifolius* L. | + | + | + | + | + | + | + | + | + | + | + | + |
| *Asphodelus fistulosus* L. | | | | | | + | | | | | | |
| *Aster squamatum* (Sprengel) Hieron. | + | | + | + | + | + | + | + | + | + | + | |
| *Avena sterilis* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Bellardia trixago* (L.) Ali. | X | | X | X | | X | | | X | X | X | X |
| *Briza maxima* L. | | | | | | | | | | | | + |
| *Bromus sterilis* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Calendula arvensis* L. | | X | X | | X | X | | X | X | | X | X |
| *Capsella bursa-pastoris* (L.) Medicus | X | X | | | X | | | X | | | X | |
| *Catapodium rigidum* (L.) Hubbard | | | + | | | + | | | + | | | + |
| *Cerinthe major* L. | | + | | | | | | | | | | |
| *Chrysanthemum segetum* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Convolvulus arvensis* L. | X | | | X | X | | X | X | | X | | |
| *Conyza canadensis* (L.) Cronq. | X | | X | X | X | X | X | X | X | X | X | X |
| *Cynodon dactylon* (L.) Pers. | X | X | | X | X | | X | X | X | X | X | X |
| *Digitaria sanguinalis* (L.) Scop. | + | | | + | | | + | | | + | | |
| *Diplotaxis erucoides* (L.) DC. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Diplotaxis muralis* (L.) DC. | | X | | | | | | X | | | X | |
| *Dittrichia viscosa* Greuter. | | | | | | | | + | + | | | |
| *Erodium malacoides* (L.) L'Hér. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Euphorbia chamaesyce* L. | + | | + | + | | + | + | | | + | | + |
| *Galactites tomentosa* Moench. | | + | + | | | | | | | | + | + |
| *Geranium molle* L. | | | + | | | | | + | | + | + | + |
| *Heliotropium erupaeum* L. | X | X | | X | X | | X | X | | X | X | |
| *Hippocrepis unisiliquosa* L. | | | | | | | | | | | | + |
| *Hordeum murinum* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Lactuca serriola* L. | | | + | | | | | | | | | |
| *Lamium purpureum* L. | | | | X | | | | | | | | |
| *Lolium rigidum* Gaudin | X | X | X | X | X | X | X | X | X | X | X | X |
| *Lotus ornithopodioides* L. | | | | | | | | | + | | | + |
| *Malva sylvestris* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Medicago hispida* Gaertner | X | X | X | X | X | X | X | X | X | X | X | X |
| *Melilotus indica* (L.) All. | | | | | | + | | | | | | |
| *Mercurialis annua* L. | | | | | | | | + | | | | + |
| *Muscari neglectum* Guss. | | | | | + | | + | + | | + | | |
| *Ononis natrix* L. | | | + | | | + | | | + | | | + |
| *Oxalis pes-caprae* L. | X | X | X | X | X | X | X | X | X | | X | X |
| *Papaver rhoeas* L. | X | X | | X | | X | X | X | X | X | X | X |
| *Phalaris paradoxa* L. | X | X | X | | | X | | X | X | | X | X |
| *Portulaca oleracea* L. | X | | | X | | | X | | | X | | |
| *Raphanus raphanistrum* Strobl. | | + | + | | + | | | + | | | + | |
| *Scorpiurus muricatus* L. | X | | | | | | | | X | X | | X |
| *Serapias* sp. | | | | | | | | | + | | | + |
| *Setaria verticillata* (L.) Beauv. | X | X | | X | | | X | | | X | X | |
| *Sherardia arvensis* L. | | | + | | | + | | | + | | | |
| *Solanum nigrum* L. | X | | | X | | | X | | | X | | |
| *Sonchus oleraceus* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Sonchus tenerrimus* L. | | | X | | | X | | | X | | | X |
| *Tetragonolopus purpureum* Moench. | | | | | | | | | | | + | + |
| *Trifolium campestre* Shreber | X | | X | X | | | X | | X | X | | X |
| *Trifolium fragiferum* L. | | + | + | | | + | | | + | | + | + |
| *Trifolium repens* L. | X | X | X | X | X | X | X | X | X | X | X | X |
| *Trifolium scabrum* L. | X | X | X | X | | X | X | | X | X | X | X |
| *Trifolium tomentosum* L. | X | X | X | X | | X | X | | X | X | X | X |
| *Valerianella eriocarpa* Desv. | | + | + | + | + | + | | + | + | + | + | + |
| *Verbascum sinuatum* L. | + | | | | | | + | | | + | + | + |
| Total species with uniform distribution (n.) | 27 | 22 | 22 | 25 | 18 | 22 | 24 | 21 | 25 | 26 | 24 | 25 |
| Total others (n.) | 6 | 6 | 12 | 5 | 5 | 10 | 7 | 8 | 11 | 9 | 9 | 15 |

[z] X = Uniformly distributed species; + = Others: solitary plants or restricted to patchy areas.

the values recorded for the other strategies under consideration (Table 4). The *Leguminosae*, instead, showed the highest cover value (16.2%) in chopped plots. The data presented in Table 5 point out that the statistically highest CS value of *A. sterilis* was found in vetch plots VE (18.1%), whereas that of *B. sterilis* was higher with only chopping, where the lowest specific contribution of *L. rigidum* was also calculated. Within *Leguminosae*, the most represented species were *Medicago hispida* Gaertner, *Trifolium repens* L. and *Trifolium tomentosum* L., whose specific contributions were higher in chopped plots. *Conyza canadensis* (L.) Cronq. and *M. sylvestris*, instead, showed the significantly highest CS in the experimental plots weeded only by Glyphosate. As for the Ground Cover Quality Index (Table 3), the highest statistical value was calculated in chopped plots (61.0), followed by treatment VE (54.6).

In 2010, the statistically highest total cover percentage (Table 3) was observed in the chopped plot (107.5%), followed by vetch plots (74.5%). The lowest mean number of families and species (4.5 and 12.5, respectively) was recorded in OX treatment. The data included in Table 4 point out that the most significant cover value of *Graminae* and *Leguminosae* was found, respectively, in the plots with vetch (51.9%) and in TRI treatment (63.5%). As for single species (Table 5), *A. sterilis* and *B. sterilis* showed the statistically highest mean values of CS in the VE treatment (21.3 and 22.0% respectively); the CS of *L. rigidum* and *Trifolium campestre* Shreber were found to be, instead, the lowest in statistical terms in treatments TRI (4.2%) and GLY+OX (0.0%). With regard to the GCQI (Table 3), the statistically highest mean value (80.9) was observed in chopped plots among all compared treatments.

*Autumn flora surveys*

In 2006, the statistically highest infestation value (Table 6) was observed in chopped plots (34.6%). The statistically lowest mean number of species and families, 13.0 and 9.0 respectively, was recorded in the TRI treatment. In TRI and VE treatments the mean cover values of *Gramineae* species were 22.4 and 21.5% respectively, statistically higher values compared to treatments GLY and GLY+OX (Table 7). As to specific contributions, Table 8 shows that *L. rigidum* is the species with the highest mean data of all the monitored species; more specifically, it accounted for 63.5% of cover in the VE treatment and 61.1% in TRI, both values being significantly higher than those observed in chemically weeded plots. The highest GCQI (Table 6),

Table 3 - Total ground cover, number of families and species, agro-ecological indices in spring surveys

| Ground cover management strategies (2) | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLY | GLY+OX | TRI | VE | GLY | GLY+OX | TRI | VE | GLY | GLIY+OX | TRI | VE |
| Total ground cover (%) | 35.6 c | 33.9 c | 155.7 a | 91.5 b | 45.3 c | 61.5 b | 83.7 a | 85.3 a | 74.2 b | 58.2 c | 107.5 a | 74.5 b |
| Botanical families (n.) | 8.5 b | 8.0 b | 10.0 a | 7.7 b | 9.0 a | 9.0 a | 9.0 a | 8.0 b | 7.0 a | 4.5 c | 5.5 b | 6.0 b |
| Species | 16.0 c | 15.5 c | 20.7 b | 23.0 a | 17.0 b | 17.0 b | 18.0 a | 18.0 a | 16.2 a | 12.5 b | 15.7 a | 15.7 a |
| GCQI | 53.2 B | 49.6 C | 52.4 A | 55.1 A | 53.1 C | 53.9 C | 61.0 A | 54.6 B | 57.5 B | 58.4 B | 80.9 A | 57.3 B |

(z) Values that do not have a letter in common are significantly different at 0.01 P (capital letter) or at 0.05 P (small letter) (Duncan's test).

Table 4 - Ground cover (%) of the botanical families found in spring surveys

| Weeds | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLI | GL+OX | TRI | VE | GLY | GLIY+OX | TRI | VE | GLY | GLY+OX | TRI | VE |
| *Gramineae* | 10.2 c | 13.3 c | 113.9 a | 68.5 b | 22.7 d | 40.0 c | 52.4 b | 63.8 a | 23.2 b | 22.4 b | 30.0 b | 51.9 a |
| *Compositae* | 9.1 b | 5.7 c | 12.8 a | 6.1 c | 8.2 a | 7.4 a | 7.3 a | 5.9 b | 21.5 a | 20.0 a | 6.7 b | 6.6 b |
| *Leguminosae* | 0.4 c | 0.1 c | 12.5 a | 7.3 b | 1.4 d | 2.9 c | 16.2 a | 6.7 b | 12.0 b | 11.1 b | 63.5 a | 10.5 b |
| *Cruciferae* | 1.6 a | 1.6 a | 1.0 b | 0.6 b | 1.6 b | 1.7 ab | 0.5 c | 1.9 a | -- | -- | -- | -- |
| *Primulaceae* | 2.6 a | 0.0 c | 1.9 b | 0.0 c | -- | -- | -- | -- | 4.5 b | 0.0 d | 5.7 a | 1.9 c |
| *Scrofuliaraceae* | 0.0 b | 0.0 b | 2.0 a | 0.1 b | 0.0 | 0.1 | 0.6 a | 0.0 | 1.9 a | 0.5 b | 0.5 b | 0.5 b |
| *Convolvulaceae* | 5.1 | 4.9 | 4.9 | 4.7 | 2.3 a | 2.2 a | 0.0 b | 0.0 b | -- | -- | -- | -- |
| *Geraniaceae* | -- | -- | -- | -- | 2.0 b | 1.9 b | 2.9 a | 2.6 ab | -- | -- | -- | -- |
| *Boraginaceae* | -- | -- | -- | -- | 0.9 b | 1.7 a | 2.4 a | 1.9 a | -- | -- | -- | -- |
| *Labiatae* | 0.0 | 0.5 | 0.0 | 0.0 | -- | -- | -- | -- | -- | -- | -- | -- |
| *Malvaceae* | 4.5 b | 5.6 a | 3.2 c | 0.0 d | 5.7 a | 2.6 b | 1.0 c | 0.6 c | 7.0 a | 3.6 b | 0.5 c | 2.5 b |
| *Papaveraceae* | 0.1 c | 0.3 c | 1.3 b | 3.0 a | 0.4 b | 0.0 b | 0.4 b | 2.0 a | 4.0 a | 0.5 b | 0.5 b | 0.0 b |
| *Portulacaceae* | 1.9 | 1.8 | 2.0 | 1.5 | -- | -- | -- | -- | -- | -- | -- | -- |

(z) Values that do not have a letter in common are significantly different at 0.05 P (Duncan's test).

equal to 54.9, was calculated in the plot submitted to chopping; this data is statistically different from that observed in the other treatments.

In 2008, the statistically highest values of total cover percentage and number of species (Table 6) were observed in chopped plots (49.6% and 13.7%, respectively). For the number of families (Table 6), which varied between 6.0 and 6.5, no sharp differences were found. The statistically highest mean cover values of *Gramineae* (21.8%), *Leguminosae* (5.0%) and *Compositae* (14.5%) were recorded in the TRI treatment (Table 7). The data shown in Table 8 point out that the highest specific contributions were found for: a) *A. sterilis* in the treatment weeded by the mixture of Glyphosate and Oxyfluorfen (22.9%); b) *B. sterilis* (12.6%) and *Oxalis. pes-caprae* L. (14.6%) in VE; c) *C. canadensis* (47.0%) in the plots weeded by Glyphosate only; d) *Heliotropium erupaeum* L. in both chemically weeded plots; and e) *M. hispida* in the plots submitted to chopping

Table 5 - Specific contributions (%) calculated for the species found in spring surveys

| Weeds | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE |
| *Anagallis arvensis* L. | 7.3 a [z] | 0.0 c | 1.2 b | 0.0 c | -- | -- | -- | -- | 6.1 a | 0.0 c | 5.3 ab | 2.6 b |
| *Anthemis arvensis* L. | 0.0 b | 0.0 b | 1.2 a | 0.0 b | -- | -- | -- | -- | 4.8 a | 0.9 b | 0.4 b | 3.3 a |
| *Avena sterilis* L. | 3.3 c | 3.9 c | 20.2 a | 17.1 b | 0.5 c | 2.1 c | 13.0 b | 18.1 a | 0.6 c | 5.1 b | 3.8 b | 21.3 a |
| *Bellardia trixago* (L.) Ali. | 0.0 c | 0.0 c | 1.3 a | 0.1 b | 0.0 c | 0.2 b | 0.7 a | 0.0 c | 2.7 | 0.9 | 0.5 | 0.7 |
| *Bromus sterilis* L. | 3.0 c | 3.9 c | 19.9 a | 16.5 b | 23.5 c | 25.6 b | 29.2 a | 17.9 d | 9.4 c | 12.7 b | 14.3 b | 22.0 a |
| *alendula arvensis* L. | -- | -- | -- | -- | 0.3 b | 0.2 b | 0.2 b | 1.1 a | -- | -- | -- | -- |
| *Capsella bursa-pastoris* (L.) Medicus | 0.0 b | 0.0 b | 0.0 b | 0.2 a | 0.2 | 0.2 | 0.1 | 0.2 | -- | -- | -- | -- |
| *Chrysanthemum segetum* L. | 3.2 b | 4.8 a | 1.3 c | 1.0 c | 5.9 a | 4.4 b | 3.2 c | 3.2 c | 6.2 a | 8.5 a | 1.1 b | 4.0 a |
| *Conyza canadensis* (L.) Cronq. | 9.8 a | 11.0 a | 2.9 b | 0.5 c | 3.2 a | 0.4 b | 0.0 b | 0.0 b | 12.7 b | 16.2 a | 0.9 c | 0.9 c |
| *Convolvulus arvensis* L. | 14.3 a | 14.7 a | 3.2 b | 5.1 b | 5.1 a | 3.7 b | 0.0 c | 0.0 c | -- | -- | -- | -- |
| *Cynodon dactylon* (L.) Pers. | 14.8 a | 14.4 a | 3.1 b | 0.2 c | 3.2 a | 2.5 b | 0.4 d | 2.1 c | -- | -- | -- | -- |
| *Diplotaxis erucoides* (L.) DC. | 4.4 a | 4.8 a | 0.6 b | 0.5 b | 4.4 a | 3.1 b | 3.5 b | 3.0 b | -- | -- | -- | -- |
| *Hordeum murinum* L. | 0.3 d | 6.3 a | 2.1 c | 3.5 b | 2.1 | 2.8 | 2.8 | 2.2 | 2.6 bc | 0.8 c | 4.6 b | 5.4 a |
| *Lamium purpureum* L. | 0.0 b | 1.3 a | 0.0 b | 0.0 b | 1.3 c | 14.0 a | 13.6 ab | 12.9 b | -- | -- | -- | -- |
| *Lolium rigidum* Gaudin | 5.6 c | 6.4 c | 27.1 b | 34.7 a | 24.9 a | 24.8 a | 6.9 b | 25.8 a | 16.7 a | 17.8 a | 4.2 b | 20.0 a |
| *Malva sylvestris* L. | 12.8 b | 16.7 a | 2.1 c | 0.0 c | 12.7 a | 4.3 b | 1.2 c | 0.7 c | 9.5 a | 6.3 a | 0.5 b | 3.4 a |
| *Medicago hispida* Gaertner | 0.7 b | 0.1 b | 1.9 a | 0.0 b | 1.9 d | 3.9 b | 6.6 a | 2.9 c | 4.1 | 7.9 | 5.2 | 2.0 |
| *Papaver rhoeas* L. | 0.3 b | 0.9 b | 0.8 b | 3.3 a | 1.0 b | 0.0 c | 0.5 bc | 2.3 a | 5.5 a | 0.8 b | 0.4 b | 0.0 b |
| *Phalaris paradoxa* L. | 0.0 b | 0.0 b | 0.0 b | 0.1 a | 0.0 b | 0.0 b | 0.0 b | 0.1 a | 1.6 a | 1.7 a | 0.9 b | 1.6 a |
| *Portulaca oleracea* L. | 5.5 a | 5.3 a | 1.3 b | 1.7 b | -- | -- | -- | -- | -- | -- | -- | -- |
| *Setaria verticillata* (L.) Beauv. | 1.7 b | 4.3 a | 0.7 b | 2.4 b | -- | -- | -- | -- | -- | -- | -- | -- |
| *Scorpiurus muricatus* L. | 0.0 c | 0.0 c | 0.2 b | 1.1 a | -- | -- | -- | -- | 0.7 | 0.0 | 0.4 | 0.0 |
| *Sonchus oleraceus* L. | 12.5 a | 1.1 d | 2.9 c | 5.1 b | 8.8 a | 6.9 b | 5.4 c | 2.5 d | 5.5 b | 8.5 a | 3.8 b | 1.0 c |
| *Trifolium campestre* Shreber | 0.3 b | 0.1 b | 1.5 a | 1.8 a | -- | -- | -- | -- | 3.4 a | 0.0 b | 5.2 a | 3.4 a |
| *Trifolium repens* L. | 0.1 b | 0.1 b | 1.3 a | 1.4 a | 1.1 c | 0.8 c | 5.2 a | 1.8 b | 0.6 c | 1.2 c | 11.8 a | 3.4 b |
| *Trifolium scabrum* L. | 0.1 b | 0.1 b | 1.6 a | 1.9 a | 0.0 c | 0.0 c | 1.4 a | 0.9 b | 1.9 b | 2.7 b | 21.9 a | 2.0 b |
| *Trifolium tomentosum* L. | 0.1 b | 0.1 b | 1.5 a | 1.8 a | 0.0 c | 0.0 c | 6.3 a | 2.2 b | 5.5 b | 7.8 b | 14.9 a | 3.4 b |

[z] Values that do not have a letter in common are significantly different at 0.05 P (Duncan's test).

Table 6 - Total ground cover, number of families, number of species and agro-ecological indices in autumn surveys

| | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE |
| Total ground cover | 23.4 c [z] | 23.6 c | 34.6 a | 31.9 b | 19.1 c | 20.7 c | 49.6 a | 39.8 b | 8.2 b | 9.1 b | 24.0 a | 22.0 a |
| N° of families | 10.0 a | 10.0 a | 9.0 b | 9.7 a | 6.5 | 6.5 | 6.0 | 6.2 | 6.7 ab | 5.7 bc | 5.5 c | 7.5 a |
| N° of species | 14.0 a | 14.0 a | 13.0 b | 13.7 a | 8.7 c | 11.5 b | 13.7 a | 11.7 b | 9.7 | 7.7 | 8.2 | 10.7 |
| GCQI | 53.3 b | 52.7 b | 54.9 a | 53.6 b | 42.2 c | 55.7 a | 54.2 a | 52.6 b | 58.8 | 62.0 | 58.4 | 56.8 |

[z] Values that do not have a letter in common are significantly different at 0.05 P (Duncan's test).

(10.1%). The GCQI with the lowest statistical value was in the treatment weeded by Glyphosate only (42.0), whereas the values calculated in the other treatments were not statistically different from each other (Table 6).

In 2010, the highest total cover values were observed in TRI and VE treatments, with 24.0 and 22.0%, respectively (Table 6). The highest mean number of families (7.5) was recorded for treatment VE. As to the number of species, statistical analysis did not point out any reliable difference between the values of different strategies that ranged between 7.7 for treatment GLY+OX and 10.7 for VE. The data in Table 7 show that *Graminae* and *Compositae* had a statistically higher mean cover value in TRI and VE plots, whereas the cover values of *Leguminosae* species did not show any remarkable difference between each other. As to single species (Table 8), the highest CS values in statisti-

Table 7 - Ground cover (%) of the botanical families found in autumn surveys

| Weeds | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE |
| *Graminaceae* | 11.1 b (z) | 11.6 b | 22.4 a | 21.5 a | 1.1 d | 6.3 c | 21.8 a | 9.3 b | 1.3 b | 1.7 b | 4.3 a | 5.9 a |
| *Compositae* | 2.5 a | 2.7 a | 2.9 a | 1.5 b | 10.8 b | 6.1 c | 14.5 a | 11.5 b | 2.2 b | 3.5 b | 6.6 a | 6.6 a |
| *Leguminosae* | 1.2 c | 1.1 c | 3.3 a | 1.7 b | 0.1 c | 0.3 bc | 5.0 a | 0.6 b | 0.9 | 1.0 | 1.5 | 1.2 |
| *Cruciferae* | 2.1 a | 2.2 a | 1.3 c | 1.9 b | 0.3 b | 0.5 b | 0.2 b | 6.0 a | 0.1 | 0.1 | 0.2 | 0.7 |
| *Convolvulaceae* | 2.6 | 2.4 | 2.4 | 2.3 | -- | -- | -- | -- | -- | -- | -- | -- |
| *Geraniaceae* | 0.5 b | 0.5 b | 0.5 b | 1.0 a | 0.0 | 0.0 | 0.0 | 0.1 | 1.0 | 0.2 | 0.4 | 1.0 |
| *Boraginaceae* | 0.6 | 0.6 | 0.8 | 1.0 | 5.2 b | 5.1 b | 5.1 b | 6.5 a | -- | -- | -- | -- |
| *Malvaceae* | 1.3 a | 1.0 ab | 0.9 b | 0.7 b | 0.1 | 0.1 | 0.0 | 0.0 | 1.6 a | 0.4 b | 0.2 b | 0.7 b |
| *Oxalidacee* | 1.0 a | 1.0 a | 0.1 b | 0.0 b | 1.5 d | 2.2 c | 2.9 b | 5.8 a | 0.6 d | 2.1 c | 10.2 a | 5.5 b |
| *Primulaceae* | -- | -- | -- | -- | -- | -- | -- | -- | 0.3 | 0.3 | 0.5 | 0.4 |
| *Solanacee* | 0.4 a | 0.5 a | 0.2 b | 0.2 b | -- | -- | -- | -- | -- | -- | -- | -- |

(z) Values that do not have a letter in common are significantly different at 0.05 P (Duncan's test).

Table 8 - Specific contributions (%) calculated for the species found in autumn surveys

| Weeds | Crop year 2006 | | | | Crop year 2008 | | | | Crop year 2010 | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE | GLI | GLI+OX | TRI | VE |
| *Anagallis arvensis* L. | -- | -- | -- | -- | -- | -- | -- | -- | 4.1 | 0.5 | 1.9 | 2.0 |
| *Avena sterilis* L. | -- | -- | -- | -- | 0.0 c (z) | 22.9 a | 5.0 b | 3.7 b | -- | -- | -- | -- |
| *Bromus sterilis* L. | -- | -- | -- | -- | 0.0 c | 1.3 b | 11.6 a | 12.6 a | 2.4 c | 1.5 c | 13.3 b | 25.0 a |
| *Calendula arvensis* L. | -- | -- | -- | -- | 8.9 b | 1.7 c | 10.6 b | 16.3 a | 4.3 b | 1.1 b | 20.1 a | 16.0 a |
| *Chrysanthemum segetum* | -- | -- | -- | -- | -- | -- | -- | -- | 3.8 | 0.0 | 0.9 | 2.5 |
| *Conyza canadensis* (L.) Cronq. | 6.5 b | 7.6 a | 4.4 c | 1.4 d | 47.0 a | 3.6 c | 8.6 b | 0.0 c | 11.0 a | 12.9 a | 0.1 b | 1.6 b |
| *Convolvulus arvensis* L. | 10.9 a | 10.3 a | 6.9 b | 7.2 b | -- | -- | -- | -- | -- | -- | -- | -- |
| *Cynodon dactylon* (L.) Pers. | 5.4 a | 5.3 a | 3.6 b | 3.9 b | 5.9 a | 5.3 a | 2.2 b | 0.4 c | 3.5 | 0.0 | 1.1 | 0.0 |
| *Diplotaxis erucoides* (L.) DC. | 4.9 a | 5.0 a | 3.3 b | 5.5 a | 1.4 | 2.4 | 0.3 | 13.8 | 1.5 | 1.2 | 0.9 | 3.2 |
| *Diplotaxis muralis* (L.) DC. | 4.2 a | 4.1 a | 0.4 b | 0.5 b | 0.1 bc | 0.0 c | 0.2 b | 1.3 a | -- | -- | -- | -- |
| *Erodium malacoides* (L.) L'Hér. | 2.1 b | 2.0 b | 1.4 c | 3.1 a | 0.1 | 0.0 | 0.0 | 0.1 | 12.4 a | 2.5 b | 1.7 b | 4.6 b |
| *Heliotropium europaeum* L. | 2.7 | 2.7 | 2.4 | 3.1 | 27.5 a | 24.5 a | 10.3 c | 16.4 b | -- | -- | -- | -- |
| *Hordeum murinum* L. | -- | -- | -- | -- | 0.0 b | 0.7 b | 10.1 a | 0.1 b | -- | -- | -- | -- |
| *Lolium rigidum* Gaudin | 42.3 b | 43.9 b | 61.1 a | 63.5 a | 0.0 b | 0.2 b | 9.6 a | 0.2 b | 10.0 ab | 16.5 a | 3.7 bc | 1.6 c |
| *Malva sylvestris* L. | 5.4 a | 4.1 b | 2.5 c | 2.4 c | 0.5 | 0.7 | 0.0 | 0.0 | 19.9 a | 4.1 b | 1.1 b | 3.2 b |
| *Medicago hispida* Gaertner | 0.9 c | 0.9 c | 7.0 a | 2.0 b | 0.3 c | 1.4 b | 10.1 a | 1.6 b | 12.2 | 12.0 | 6.1 | 4.2 |
| *Oxalis pes caprae* L. | 4.3 a | 4.1 a | 0.0 b | 0.3 b | 7.7 c | 10.9 b | 5.9 c | 14.6 a | 8.5 c | 25.0 b | 42.6 a | 25.8 b |
| *Setaria verticillata* (L.) Beauv. | -- | -- | -- | -- | 0.0 b | 0.0 b | 5.6 a | 6.3 a | -- | -- | -- | -- |
| *Sonchus oleraceus* L. | -- | -- | -- | -- | 0.5 d | 24.2 a | 10.1 c | 12.6 b | 2.9 | 5.4 | 0.9 | 4.0 |
| *Sonchus tenerrimus* L. | 4.2 | 4.1 | 3.8 | 3.1 | -- | -- | -- | -- | 3.3 b | 16.9 a | 5.2 b | 5.2 b |
| *Solanum nigrum* L. | 1.9 a | 2.2 a | 0.6 b | 0.4 b | -- | -- | -- | -- | -- | -- | -- | -- |
| *Trifolium campestre* Shreber | 4.3 | 3.7 | 2.5 | 3.5 | -- | -- | -- | -- | -- | -- | -- | -- |

(z) Values that do not have a letter in common are significantly different at 0.05 P (Duncan's test).

cal terms were observed: a) for *B. sterilis* (25.0%) in the plots of treatment VE; b) for *Calendula arvensis* L. both in VE (16.0%) and TRI (20.1%); c) for *C. canadensis* in both chemically weeded plots; and d) for *O. pes-caprae* in the chopped treatment (42.6%).The GCQI (Table 6) ranged between 62.0 in treatments GLY+OX and 56.8 in treatment VE and did not show any significant differences between the values of the strategies being compared. Finally, Table 2 lists the other species found during the experiment, with low cover percent values and a non-uniform distribution. The occurrence of these 26 species increased during the years for all treatments, although none of them attained a uniform distribution over time.

*Vegetation surveys*

Shoot growth and trunk diameter did not show any significant differences between the mean values measured for the compared treatments (Table 9) during the study three years.

*Olive production and oil yield*

As shown by the data in Table 10, no statistical differences were observed between the mean recorded values during the study period for the different strategies being compared with regard to olive production and oil yield per plant.

## 4. Discussion and Conclusions

In this work diachronic analysis was not carried out given the limited number of years under study, however synchronic comparisons have supplied data that can lead to some interesting conclusions.

The different management practices employed in the study largely influenced the ground cover values in the various years, both quantitatively and qualitatively, but not the yield. In all surveys, the most represented families, both in terms of ground cover and number of species, were *Graminae*, *Leguminosae* and *Compositae*.

With regard to single species, significant specific contributions were recorded for *A. sterilis*, *B. sterilis*, *C. canadensis*, *L. rigidum*, *M. sylvestris*, *O. pes-caprae* and *Trifolium* spp. The largest differences, in terms of total ground cover, were observed between the chemically weeded plots and plots submitted to chopping only or sown with vetch. Moreover, at the time of surveys, no important differences were found between the treatment with the systemic herbicide only and the plot supplied also with the residual herbicide; this is presumably due to the low application rate of oxyfluorfen. In particular, in spring and autumn surveys, the highest total infestation was found in chopped and vetch-sown plots. The latter, although covering the whole plot area at spring surveys, has only partially limited the growth of weeds, especially grasses (*Graminae*).

The number of species having a uniform distribution in springtime in the plots controlled by chopping or through the sowing of the cover crop rarely exceeded the value observed under different management practices. The number calculated in autumn, instead, was virtually equal for all strategies.

The species that showed the highest specific contributions in chemically weeded plots include *C. canadensis* and *M. sylvestris*, which might be related to the fact that those species are tolerant to the applied rates of herbicides or maybe, for *C. canadensis*, resistant to Glyphosate (Montemurro, 2008; Herbicide Resistance Action Committee, 2012). In the two other conditions, in general, no single species was found to be markedly present.

The most influenced families in spring surveys were *Leguminosae* and *Graminae*; in particular, the latter seemed to be facilitated by vetch sowing, whereas the former was aided by chopping, conditions that were more evident in spring than in autumn surveys when all differences in general seemed to be less marked.

Table 9 - Shoot and trunk growth measured during the trial

| Treatments | Shoots (cm) | | | Trunk diameter (cm) |
|---|---|---|---|---|
| | April-October 2006 | April-October 2008 | April-October 2010 | April 2006-October 2010 |
| VE | 15.9 | 14.2 | 15.0 | 3.0 |
| GLI + OX | 13.5 | 16.6 | 14.0 | 3.5 |
| GLI | 16.4 | 17.3 | 13.4 | 3.9 |
| TRI | 13.1 | 16.6 | 14.8 | 3.1 |

Table 10 - Olive production per plant and oil yield

| | Production per plant (Kg) | | | Oil yield (% ) | | |
|---|---|---|---|---|---|---|
| | 2006 | 2008 | 2010 | 2006 | 2008 | 2010 |
| GLI | 13.6 | 11.7 | 14.8 | 18.0 | 19.1 | 21.6 |
| GLI+OX | 13.9 | 10.8 | 15.0 | 19.0 | 20.0 | 21.7 |
| TRI | 15.8 | 11.1 | 15.6 | 19.0 | 19.0 | 22.3 |
| VE | 12.8 | 10.9 | 15.1 | 17.9 | 20.1 | 20.9 |

The Ground Cover Quality Index calculated in spring 2006 and 2008 was on average higher in the chopped or vetch-sown plots. In 2010 the value calculated in chopped plots was markedly higher than in the other treatments, which, instead, did not show any differences for this parameter. This would suggest a shifting, over time, of vegetation towards a higher quality composition which was more accentuated in the case of the strategy involving chopping only. These effects are well summarized by the applied index, which indicates that for the same weed species assortment influenced the ground cover quality.

Differences in the flora composition, both quantitatively and qualitatively, did not affect olive yield or vegetation, since weeds were however controlled during the plants' critical periods. What varied was above all the ground cover features, assessed both from an agronomic and ecological point of view. From our perspective, this feature is well reflected by the applied index, which easily and effectively described the flora features in different plots. In this regard it should be said that this index is obviously influenced by the value attributed to each species that may vary in relation to the objectives of weed management, as previously mentioned. In our case emphasis was placed on competition, protection from erosion and on the capacity to preserve or even increase fertility: these features coincide with the objectives that olive growers normally try to achieve, especially in our areas. In other situations different parameters could be applied, namely by varying the index numerically while still keeping its functional meaning. Moreover, in the case under study, the GCQI value was largely influenced by the total ground cover because none of the weeds found in the trial was assigned a zero score ($V_i$). In the event that undesired species were found in among the cover composition, the index would certainly have been less dependent on total ground cover.

Finally, since different cover crop and ground flora management practices seemed to give results, in terms of yield, that were not different from each other, a long-term approach could be applied for their selection. Currently it seems possible to prefer a ground cover management strategy that enables a sustainable use of olive agro-ecosystems and emphasizes the different roles of wild flora, including landscaping. This keeps in mind the fact that in 2006 the Puglia Regional Government enacted a law regarding the protection and enhancement of monumental olive trees and of the olive agro-ecosystems of its region (L.R. N. 39 del 03/10/2006) and that the location where the trial was conducted falls within the areas of highest density of ancient and traditional olive tree landscapes. The value of this area was also further declared by its inclusion among the "High Nature Value Farmland" areas (European Environment Agency, 2004).

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