



**INTERNATIONAL
SYMPOSIUM
ON**

**THE OLIVE TREE
AND THE
ENVIRONMENT**



PROCEEDINGS

Editor: E. Stefanoudaki

CHANIA

OCTOBER 1-3 2003

Proceedings of the
International Symposium on
"The Olive Tree and the Environment"

October 1 - 3, 2003
MAICH – Chania, Crete, Greece

Editor
Evangelia Stefanoudaki

Organized by:
National Agricultural Research Foundation
Institute of Olive Tree and Subtropical Plants of Chania
Cretan Centre of Oil Promotion

Co-organized by:
International Olive Oil Council
FEMO
FAO
European Union
CIHEAM - MAICH

Under the auspices of the Minister of Agriculture

CAN OLIVE GROWING MITIGATE THE GREENHOUSE EFFECT? A STUDY OF CARBON CYCLE FROM ATMOSPHERE TO OLIVE TREE PRODUCTS

A. Sofo, A.M. Palese, C. Xiloyannis

Università degli Studi della Basilicata – Dipartimento di Scienze dei Sistemi Culturali, Forestali e
dell'Ambiente - 85100, Potenza, Italy

email: sofo@unibas.it - phone: +39- (0)971-205269

Abstract

Olive tree is one of the most typical and economically important species belonging to the Mediterranean area but the role of olive orchards and the involvement of different cultivation techniques on atmospheric CO₂ fixation is still not completely known.

Values of fixed atmospheric CO₂ and CO₂ accumulation rates were calculated by the increments of dry matter measured at the end of vegetative season in a young olive orchard during a period of seven years from the planting.

Fixed CO₂ has been allotted mainly in the permanent structures. Movements of fixed carbon in pruning material and senescent leaves, and their contribution in soil organic carbon increase and in humus production were studied. The number of plants per hectare and the use of appropriate agricultural practices (pruning, green manure, cover crops, irrigation), as well as local pedoclimatic characteristics, had a fundamental importance in transforming a significant part of CO₂ in biomass and humus.

The results obtained underline the important role of olive orchards in mitigating the damage caused by greenhouse effect and highlight the positive role of olive growing in the fixation of atmospheric CO₂.

Introduction

The greenhouse effect can be defined as a phenomenon created by the earth's atmosphere in trapping heat from the sun (McGraw-Hill, 1994). This effect is caused by the presence in atmosphere of 'greenhouse gases', such as carbon dioxide (CO₂), water vapour (H₂O_{vap}), methane (CH₄), nitrogen oxides (N₂O and NO_x), ozone (O₃) chlorofluorocarbon compounds (CFC) and other volatile compounds (Vitousek, 1994).

The concentration of CO₂ increased during the last century, reaching the value of 370-mmol mol⁻¹ in 2000 (Keeling and Whorf, 2000). It was estimated that if some actions will not be taken against this increase, a doubling of current concentrations is anticipated before the end of the 21st century. In fact, about 3.2 Gt CO₂ year⁻¹ are released in the atmosphere (Lal, 1997) and this amount derives mainly from the combustion of fossil fuels and forests, deforestation, desertification, urbanisation and modern agricultural practices (Schlesinger, 2001). At this rate, an increase of temperature of 2 °C to 8 °C due to greenhouse effect will occur within this century (Strong, 1989) and this increment will determine secondary negative effects on the ecosystems (Vitousek, 1994).

Agriculture plays a key role in CO₂ emission and fixation. Agricultural practices account for one-fifth of the annual increase in anthropogenic greenhouse warming, most of which is due to CO₂, CH₄ and N₂O emissions. Moreover, deforestation for new cultivable lands, inappropriate management practices, and simplification of agroecosystems, intensive agriculture, soil erosion and combustion of fossil fuels contribute to the increase of atmospheric CO₂. An amount of about 1.5 to 3.0 X 10³ Mt year⁻¹ CO₂, equivalent to 47% to 94% of the amount yearly released in atmosphere, could be immobilised worldwide in agricultural soils by implementation of appropriate management practises to increase productivity (Lal, 1997). A correct utilisation of agricultural techniques (i. e. fertilisation, irrigation, reduced tillage, green manure, cover crops, restoration of wasteland soils), biofuel production from energy crops and wastes, improved cultivars and promotion of agricultural research could contribute to mitigate CO₂ emission.

Pedospheric, atmospheric and biotic carbon pool contain 1550 Gt, 750 Gt and 550 Gt of carbon, respectively (Lal, 1997). In particular, about 80% of the biospheric pool of carbon is fixed in plants and fungi (Kimmins, 1997). Unfortunately, modern agricultural practices converted the pedosphere, which is normally a carbon sink, in a conspicuous carbon source, with heavy repercussions on the amount of atmospheric CO₂.

Olive tree (*Olea europaea* L.) is a sclerophyllous species of the Mediterranean basin with a high degree of drought tolerance (Lo Gullo and Salleo, 1988), a parsimonious consumption of soil water (Moreno et al., 1996) and a higher specific transpiration in comparison with other fruit tree species (Xiloyannis et al., 1988; Angelopoulos et al., 1996; Fernández et al., 1997; Nogués and Baker, 2000; Moriana et al., 2002; Dichio et al., 2002)

A complete understanding of the agricultural options for reducing the amount of anthropogenic CO₂ emission is a very actual problem but is, at present, lacking. Moreover, the role of olive orchards and the involvement of the different cultivation techniques on atmospheric CO₂ fixation is still not completely known. In the present investigation, we show some results of a study on the carbon fluxes in a young experimental olive orchard over seven years after planting. We hypothesise that a correct utilisation of agricultural techniques and soil management in olive growing could minimise the release of CO₂ in the atmosphere, thereby contributing to mitigate the environmental damages caused by greenhouse effect.

Materials and methods

Trials were conducted on own-rooted *Olea europaea* L. plants, cv. 'Coratina', planted in 1992 at distances of 6 x 3 meters (555 plants ha⁻¹). The study site was located at Lavello (Southern Italy - Basilicata Region - N 41° 03', E 15° 42'). The irrigation was carried out by microjets discharging 80 L h⁻¹ over a 1-meter radius. Soil was of medium texture and had enough amounts of potassium, calcium and magnesium, and very small quantity of organic matter, total nitrogen and available phosphorus. A fertilisation with 248 units of phosphorus in the form of triple perphosphate was carried out before planting. The doses of nitrogen were applied annually on March, at

the beginning of the annual vegetative cycle, and on May, at flowering time, in the soil volume explored by roots. Slight pruning was carried out every year.

At the end of each vegetative season the following determinations were carried out: dry matter of the whole plant and partitioning among the plant organs, pruning material, yield, amount of senescent leaves. The values of dry matter were calculated as annual increments. The values of fixed carbon were determined using the following equation:

$$1 \text{ g of dry matter} = 0.5 \text{ g carbon} = 1.83 \text{ g CO}_2$$

Results and Discussion

During the first years after planting fixed CO₂ was located mainly in the epigeal part of the plant (Figure 1). Fixed CO₂ was immobilised in the permanent structures of the young olive tree such as trunk, stump and main roots. These organs represent important pools of fixed CO₂ subtracted to the carbon cycle for a period equivalent to the tree life. On the contrary, fruits and leaves can be considered short-life organs and the C immobilised in them (Figures 2 and 3) has a different fate: in the first case it is definitively lost from the orchard system because of the yield harvest; in the other case, it is converted soil organic carbon (SOC) when the leaves, after about 18 months (their mean life), fall on the ground. In the 5th year the olive trees lost 1.55 t ha⁻¹ of CO₂ fixed in senescent leaves (Figure 3), with a production of 0.17 t ha⁻¹ of humus deriving from their decomposition in the litter (Table 1). Humus is a long-term C reserve and improves physical and chemical soil characteristics.

Pruning material could represent another C loss from the orchard system unless it is cut and left on the ground of the grove. In our experimental orchard, the value of fixed CO₂ in pruning material ranged from 0.11 t ha⁻¹ in the 2th year after planting to 3.62 t ha⁻¹ in the 5th year (Figure 4). Carbon contained in pruning material is converted in SOC with a turnover time of 20-50 years (and sometimes more) causing the immobilisation of CO₂ in humus for a long period (Table 1). Furthermore, winter and summer pruning, carried out in order to improve the vegetative-productive balance of plants, allow the tree a further CO₂ fixation due to wood renewal.

It is very difficult to estimate in the orchard system the C loss depending on the natural drop of flowers and fruits, the root decomposition, the release of liquid assimilates by roots and mycorrhizas.

A conservative soil management (green manure, cover crops) can increase CO₂ fixation of the olive orchard system. The adoption of species with a high biomass production is recommended. A *Vicia faba/Avena sativa* mixture (dry matter = 7,5 t ha⁻¹) (Celano et al., 1997) can produce every year 1,13 t ha⁻¹ of humus (Table 1). In semi-arid regions, in rainfed condition, it is recommended to plant cover crops in autumn and mow them just before spring (when the ratio biomass/lignification is optimal) in order to avoid water and nutrients competition (Celano et al., 2002). The residues obtained could be used for green manure, thus improving soil characteristics and increasing the availability of mineral elements for plants. Otherwise, the residues kept on soil surface (mulching) could maintain soil moisture, reduce erosion and delay the respiratory processes, which contribute to CO₂ production.

Conclusions

The results highlight the important role of the orchard in fixing atmospheric CO₂, in particular during the formation of the permanent structures of the plant. Fruit production and soil preservation are not the only functions of olive orchards, which can also give a contribute in mitigating the increase of atmospheric CO₂, therefore having a positive impact on the environment. The number of plants per hectare and the use of appropriate agricultural practices have a fundamental importance in transforming a significant part of CO₂ in biomass and humus, thus enhancing carbon fluxes from atmosphere to pedosphere and biosphere.

References

- Angelopoulos K, Dichio B, Xiloyannis C (1996) Inhibition of photosynthesis in olive trees (*Olea europaea* L.) during water stress and rewatering. *J Exp Bot* 47 (301): 1093-1100
- Celano G, Dumontet S, Xiloyannis C, Nuzzo V, Dichio B (1997) Responses of peach-orchard system to green manuring and mineral fertilisation. *Acta Horticulturae* 448: 289-296.
- Celano G, Palese AM, Xiloyannis C (2002) La gestione sostenibile del suolo nell'albicoccheto. *Frutticoltura* 3: 37-39
- Dichio B, Romano M, Nuzzo V, Xiloyannis C (2002) Soil water availability and relationship between canopy and roots in young olive trees (cv Coratina). *Acta Horticulturae* 586: 255-258
- Fernández JE, Moreno F, Girón IF, Blázquez OM (1997) Stomatal control of water use in olive tree leaves. *Plant Soil* 190: 179-192
- Keeling CD, Whorf TP (2000) Atmospheric CO₂ concentrations – Mauna Loa observatory, Hawaii, 1958-2000.
- Kimmins JP (1997) *Forest Ecology*. Prentice Hall Inc., New Jersey: pp 596-597
- Lal R (1997) Residue management, conservation tillage and soil restoration for mitigating greenhouse effect by CO₂-enrichment. *Soil Till Res* 43: 81-107
- Lo Gullo AM, Salleo S (1988) Different strategies of drought resistance in three Mediterranean sclerophyllous trees growing in the same environmental conditions. *New Phytol* 108: 267-276
- Mc Graw-Hill (1994) *Dictionary of scientific and technical terms*. McGraw-Hill Inc., New York
- Moreno F, Fernández JE, Clothier BE, Green SR (1996) Transpiration and root water uptake by olive trees. *Plant Soil* 184: 85-96
- Moriana A, Villalobos FJ, Fereres E (2002) Stomatal and photosynthetic responses of olive (*Olea europaea* L.) leaves to water deficits. *Plant Cell Environ* 25: 395-405
- Nabuurs GJ, Päivinen R, Sikkema R, Mohren GMJ (1997) The role of European forests in the global carbon cycle - a review. *Biomass and Bioenergy* (13) 6: 345-358
- Nogués S, Baker NR (2000) Effects of drought on photosynthesis in Mediterranean plants grown under enhanced UV-B radiation. *J Exp Bot* 51 (348): 1309-1317
- Schlesinger WH, Lichter J (2001) Limited carbon storage in soil and litter of experimental forest plots under increased atmospheric CO₂. *Nature* 441: 466-469
- Strong AE (1989) Greater global warming revealed by satellite-derived sea-surface-temperature trends. *Nature* 338: 642-645
- Vitousek PM (1994) Beyond global warming: ecology and global change. *Ecology* 75 (7): 1861-1876
- Xiloyannis C, Pezzarossa B, Jorba J, Angelici P (1988) Effects on soil water content on gas exchange in olive trees. *Adv Hort Sci* 2: 58-63.

Table 1. Isohumic coefficients, humus production and carbon release time in the experimental olive orchard during the 5th year after planting.

	Isohumic coefficient	Humus (t ha ⁻¹ year ⁻¹)	Carbon release time
Fruits	-	~ 0	Short
Senescent leaves	0.20	0.17	Medium
Cover crops	0.15	1.13	Medium
Pruning material	0.35	0.69	Long
Branches and trunk	-	~ 0	Long
Roots	-	Data not available	Long
TOTAL	-	1.99	-

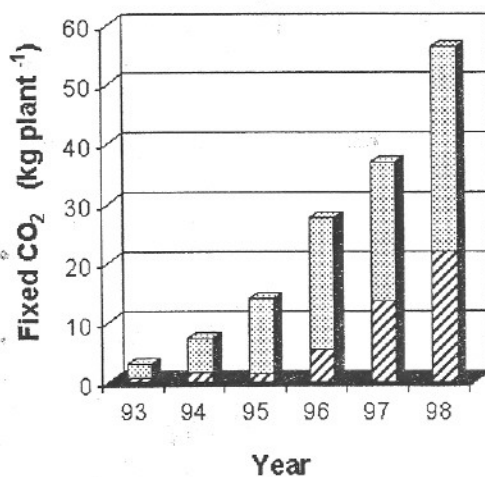


Figure 1. CO₂ fixed in the epigeal (dots) and hypogeal (diagonal lines) part of olive plants during the experimental period. The values were calculated as annual increments.

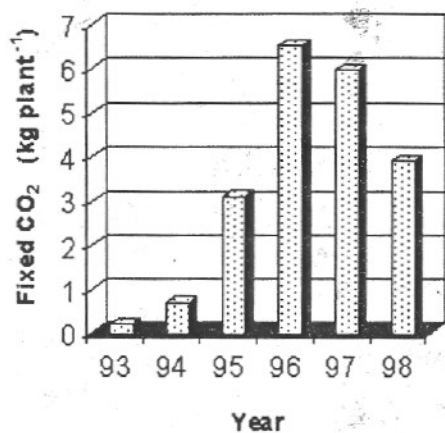


Figure 2. CO₂ fixed in pruning material of olive plants during the experimental period.

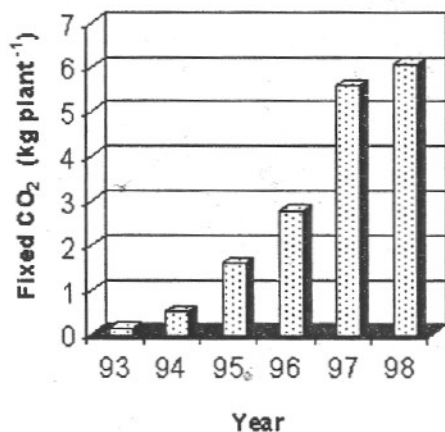


Figure 3. CO₂ fixed in senescent leaves of olive plants during the experimental period.

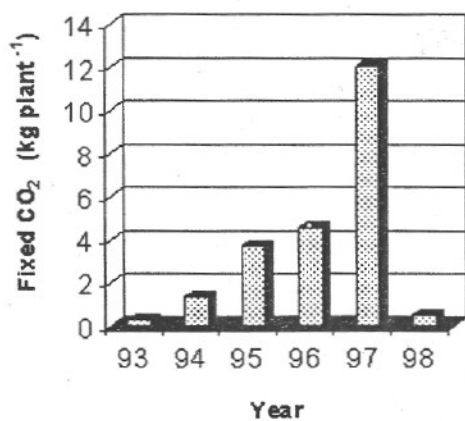


Figure 4. CO₂ fixed in fruits of olive plants during the experimental period.