

Net CO₂ storage in mediterranean olive and peach orchards

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Abstract

Agricultural practices can play an important role in atmospheric CO₂ emission and fixation. In this study, we present results on carbon fluxes in the biomass of two typical Mediterranean orchards indicating that proper canopy management coupled with other agricultural techniques could increase the absorption of atmospheric CO₂ and its storage. We also discuss the potential environmental contribution of the orchards to enhancement of both soil and air quality. Trials were carried out in southern Italy on olive (*Olea europaea* L.) and peach orchards (*Prunus persica* L.) at different age and plant densities. At the end of each vegetative season, values of fixed atmospheric CO₂ were calculated by measuring dry matter accumulation and partitioning in the different plant organs. In the early years, sequestered CO₂ was primarily distributed in the permanent structures and in the root system while in mature orchards the fixed CO₂ was distributed in leaves, pruning materials and fruit. Significant differences in amounts of fixed CO₂ were observed in peach orchards cultivated using different planting and training strategies. The results underline the importance of training system, plant density and cultivation techniques in the absorption of atmospheric CO₂ and its storage as organic matter in the soil.

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1. Introduction

Agriculture plays a key role in atmospheric CO₂ emission and fixation (Janssens et al., 2003). Agricultural practices account for one-fifth of annual emissions of CO₂, CH₄ and N₂O (Reicosky et al., 2000). Between 1.5 and 3.0 Gt year⁻¹ of CO₂ could be immobilised worldwide in agricultural soils by the implementation of appropriate management practices to increase productivity (Intergovernmental Panel on Climate Change, 1995). These values are equivalent to 47 and 94% of the CO₂ yearly released into the atmosphere, which amounts to 3.2 Gt CO₂ (Lal, 1997). Anthropogenic factors, such as the combustion of fossil fuels and forests, deforestation, desertification, urbanisation and modern agricultural practices are responsible for the increase in

atmospheric CO₂ concentration (Schlesinger and Lichter, 2001), which reached the value of 370 mmol mol⁻¹ in 2000 (Keeling and Whorf, 2000), and it is estimated that this value would double before the end of this century if corrective actions are not taken accordingly (Arnell et al., 2002).

In agro-ecosystems, any increase of the carbon pool as humus derives almost entirely from the biotic pool of carbon inputs. Soil organic matter (SOM) depends largely on the periodic input of organic materials and the speed of their mineralisation (Kimmins, 1997). Carbon mineralisation, which is the transformation of soil organic carbon (SOC) into CO₂, H₂O and mineral salts is exacerbated by anthropogenic factors (Janssens et al., 2003). The rate of CO₂ fixation is also related to the amount of photosynthetically active radiation intercepted (intercepted photon flux density—PFD_{in}), which plays a key role in determining orchard productivity. For example, in peach orchards, crop systems with different plant densities and canopy shapes

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determine changes in PFD_{in} , and higher yields can be obtained if the tree canopy is as spread out as possible (Loreti et al., 1993; Grossman and DeJong, 1998).

Pedospheric, atmospheric, and biotic carbon pools contain 2400, 750 and 550 Gt of carbon, respectively (Brady and Weil, 2004). In particular, about 80% of the biotic pool of carbon is fixed in plants and fungi (Kimmins, 1997). Modern agricultural practices convert the pedosphere, which is normally a carbon sink, into a significant carbon source, a process which is resulting in significant repercussions on the total amount of CO_2 in the atmosphere. This is the case in modern fruit orchards, especially in areas where rainfall is infrequent during the growing season and the soil is managed with shallow and repeated tillage (Xiloyannis et al., 2002).

The olive tree (*Olea europaea* L.) is a sclerophyllous species of the Mediterranean area presenting a high degree of drought tolerance (Lo Gullo and Salleo, 1988) and a higher specific transpiration in comparison with other fruit tree species in both ideal and water shortage conditions (Nogués and Baker, 2000; Sofu et al., 2004). The peach tree (*Prunus persica* L.) is one of the most common and economically important species of the Mediterranean basin, but most studies have focused on its physiological behaviour (Grossman and DeJong, 1994; Besset et al., 2001; Girona et al., 2002) without considering the environmental impact of peach plantation agricultural practices. In peach orchards, high density systems have been adopted to achieve higher yields and earlier return from the initial investment (Loreti et al., 1993; Grossman and DeJong, 1998).

There is a lack of understanding regarding agricultural management options in typical Mediterranean crops that would ameliorate CO_2 emissions (Robertson et al., 2000). Although not fully understood, CO_2 fixation in fruit orchards is probably higher in comparison to fixation in annual herbaceous crops, such crops having higher carbon outputs and a more rapid mineralisation of organic matter (Robertson et al., 2000; Janssens et al., 2003).

In this study, results of net carbon storage in olive and peach orchards under different training systems are presented. We propose that correct utilisation of appropriate agricultural techniques and land management, important for fruit production and soil preservation, could also contribute to the removal of considerable quantities of atmospheric CO_2 , and simultaneously, improvements in air quality.

2. Materials and methods

2.1. Olive orchards

Trials were conducted using own-rooted 2-year-old *Olea europaea* L. plants, cv. ‘Coratina’, planted in 1992 at distances of 6 m × 3 m, giving a plant density of 555 trees ha⁻¹. The study site was located at Lavello (southern Italy, Basilicata region—N40°38′, E15°48′). The

experimental period ranged from 1993 (year 1 after planting) to 1997 (year 5 after planting).

Irrigation was carried out by microjets discharging 80 L h⁻¹ over a 1 m radius. The soil was a sandy loam (53.3% sand, 29.0% silt and 17.7% clay), and contained 7.4 meq calcium, 1.2 meq magnesium, 1.1 meq potassium and 0.4 meq sodium in 100 g of soil, and 1.2% organic matter, 0.6‰ total nitrogen and 136 kg ha⁻¹ available phosphorus. A fertilisation regime using 248 kg ha⁻¹ of P in the form of triple superphosphate was applied before planting; nitrogen in the form of ammonium sulphate (13.6 kg ha⁻¹) and ammonium nitrate (3.6 kg ha⁻¹) was applied annually in March at the beginning of the vegetative cycle and in May during flowering.

In 2001, the study was also performed in a mature olive orchard (plant age: more than 50 years), cv. ‘Maiatica’, located at Ferrandina (southern Italy, Basilicata region—N40°30′, E16°27′) with a plant density of 156 trees ha⁻¹ (distance of 8 m × 8 m). Olive trees were micro-irrigated. Nitrogen fertiliser was applied by means of fertilisation. Fresh weight of yield and pruned residues were, respectively, 10 and 8.6 t ha⁻¹.

2.2. Peach orchards

The trial was carried out at Metaponto (southern Italy, Basilicata region—40°22′N, 16°48′E) from 1997 (year 1) to 2001 (year 5). Dormant budded trees of *Prunus persica* (L.) Batch ‘Springcrest’, on *P. persica* × *P. amygdalus* ‘GF677’, were planted in two blocks of about 0.50 ha each with rows oriented in a north–south direction and trained to delayed vase and transverse Y. The soil was a sandy–clay (47.8% sand, 11.1% silt and 41.1% clay), and contained 15.7 meq calcium, 0.88 meq magnesium, 0.52 meq potassium and 0.34 meq sodium in 100 g of soil, and 0.9% organic matter, 0.6‰ total nitrogen and 14 ppm available phosphorus (P Olsen). For trees trained to delayed vase, a fertilisation regime using 10.0 kg ha⁻¹ (year 1) to 96.9 kg ha⁻¹ (year 5) of N was applied; 35.5, 6.6 and 15.0 kg ha⁻¹ phosphorus in the form of P₂O₅ were used in year 3–5, respectively. For trees trained to transverse Y, a fertilisation regime using 26.8 kg ha⁻¹ (year 1) to 152.0 kg ha⁻¹ (year 5) of N was applied; 29.9, 2.7 and 10.0 kg ha⁻¹ phosphorus in the form of P₂O₅ were applied in year 3, 4 and 5, respectively. Trees were irrigated with two drip emitters per plant discharging 10 L h⁻¹ each.

Trees trained to transverse Y were spaced at 2.5 m in the row with 4.5 m between rows, giving a plant density of 1111 trees ha⁻¹. In the first 5 years, summer pruning and dormant pruning were normally performed to form two scaffolds with an 80–90° wide angle perpendicular to the row direction. Trees trained to delayed vase were spaced at 4.0 m in the row with 6.0 m between rows, giving a plant density of 416 trees ha⁻¹. In both training systems, fruits were thinned in April and the number retained was dependent on the size of the tree and the number of long fruiting shoots remaining after dormant pruning.

Considering the short productive cycle of peach orchards, if compared to that of olive orchards, the plants at year 1 and 2 were considered young trees whereas those from years 3 to 5 were considered mature trees.

2.3. Fixed CO₂ determination

At the end of each vegetative season, in the young olive orchard, dry matter of the whole tree, partitioned among the plant organs, was evaluated on 2 or 3 olive trees, according to Celano et al. (1999). The amount of material removed by pruning was recorded from 10 plants. At harvesting, the yield was recorded from 30 trees. In the mature olive grove, dry matter measurements of pruning material and drupes were carried out on 12 plants. Both in young and mature olive groves, the amount of senescent olive leaves was estimated considering a leaf mean life of 30 months before abscission.

In the peach orchards, above-ground biomass was estimated using specific indexes as reported by Nuzzo et al. (1997). Measurements were performed, at the end of the growth seasons, on peach trees grouped into four experimental units of six plants randomly selected from the grove. Dry matter values were expressed as annual increments.

In both species, the fixed CO₂ was determined from the values of carbon concentration using a molecular weight ratio (1.0 g carbon = 3.66 g CO₂). Carbon concentration in plant organs was calculated according to Grossman and DeJong (1994). The estimated values of humus derived from pruning material and senescent leaves were calculated using an isohumic coefficient of 0.35 and 0.20, respectively, according to Celano et al. (2002).

2.4. Soil mineralisation

The mineralisation coefficient of the soil (k_2) was calculated according to the model of Hénin and Dupuis (1945), using the following equation:

$$k_2 = \frac{(1200 \cdot f_0)}{[(200 + c) \cdot (200 + 0.3 \cdot s)]}$$

where c = clay content (g/kg), s = silt content (g/kg) and $f_0 = 0.2(T - 0.5)$, with T = yearly average temperature (°C).

SOC mineralisation in soil humic fraction was determined at a soil depth of 0–30 cm, which is the most important soil layer for the nutrient supply of agricultural plants and for decomposing organisms.

2.5. Water supply and irradiance level

In olive and peach orchards, for each year of the experimental period, meteorological variables were measured by a standard weather station placed close to the trial fields. From April to October, reference evapotranspiration (ETo) was calculated using the Penman–Monteith method;

irrigation volume and scheduling were determined using a simplified soil water balance (Allen et al., 1998).

In peach orchards, light interception in both training system plots was measured from year 2 to 5 on the same trees of each plot where the fixed CO₂ was estimated. Measurements were taken on sunny days at the end of July, when plants showed high values of leaf area per unit of ground area (LAI). The measurements of transmitted photon flux density (PFD_t) at the base of the canopy (0.2–0.3 m above the soil surface) were carried out using an Accupar Linear Photosynthetically Active Radiation Ceptometer (Decagon Device Inc., Pullman, WA). Measurements were taken at midday across the single tree spacing area on a grid of 0.2 m × 0.2 m. Incident PFD (PFD_i) was measured away from the tree canopies every 5 min. PFD_{in} was calculated for each point of the grid as the difference between PFD_i and PFD_t. Diffuse and reflected components of PFD were not considered as these are generally very small components of PFD and would not significantly affect PFD calculations. The mean value of PFD_{in} was obtained as the average of the various points on the grid below the tree canopies.

3. Results

3.1. Olive orchards

The highest value of irrigation in a growing season was 128 mm in year 5 and the annual mean was 81 mm (Fig. 1A).

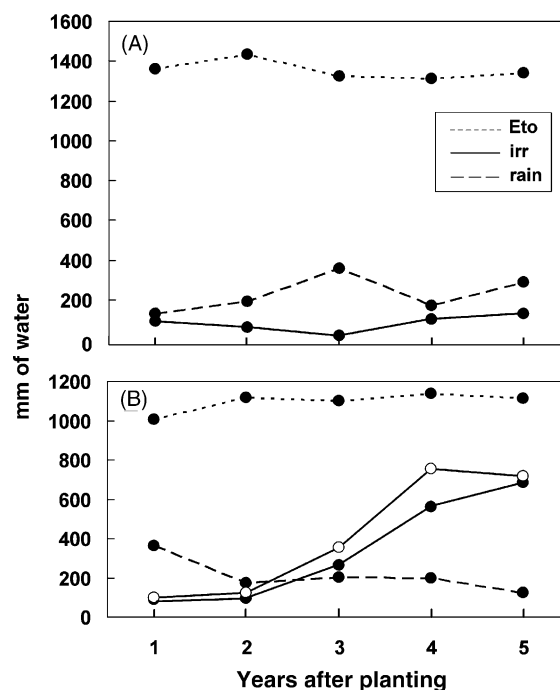


Fig. 1. Trends of irrigation, potential evapotranspiration and rainfall from April to October at the field sites of the young olive orchard (A) and of the peach orchards (B) during the experimental period. The patterns of irrigation in peach plants trained to delayed vase and transverse Y are represented by full and blank circles, respectively.

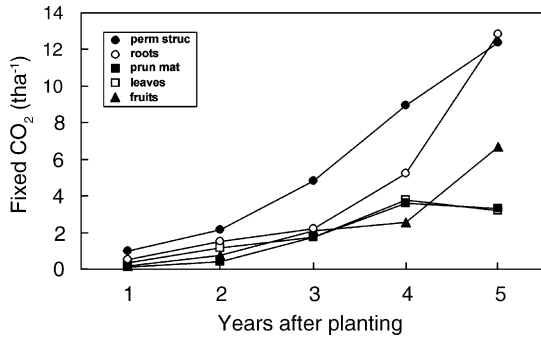


Fig. 2. CO₂ fixed in above-ground permanent structures, roots, pruning material, leaves and fruits of young olive trees. Each data point represents the mean of two or three measurements from plants selected in the orchard.

The accumulated ETo was highest in year 2 (1435 mm) and the overall mean 1354 mm (Fig. 1A). During the entire experimental period the rainfall mean was 228 mm, ranging between 131 and 359 mm (Fig. 1A).

Young trees gradually increased CO₂ fixation during the experimental period in both the above-ground biomass and the root system (Fig. 2). In the 5-year period, olive trees fixed 72.9% of CO₂ in the above-ground biomass of the plants and the remaining CO₂ was fixed in root biomass (Fig. 2). During the whole experimental period, the mean value of fixed CO₂ in leaves of young olive trees was 16.4% of the total fixed CO₂ and decreased from 17.9% in year 1 to 9.0% in year 5 (Fig. 2). In contrast, the mean value of fixed CO₂ in woody parts of young olive plants was 68.9% and increased during the experimental period from 64.9% in year 3 to 71.9% in year 5 (Fig. 2).

The patterns of fixed CO₂ in leaves and pruning material were similar, showing the highest value in year 4 (3.78 and 3.62 t ha⁻¹, respectively, Fig. 2). Olive fruits contributed to the immobilisation of important quantities of CO₂ that fluctuated from 0.18 to 6.70 t ha⁻¹ in year 1 and 5, respectively (Fig. 2). During the entire experiment, young olive trees lost 0.91 t ha⁻¹ of the fixed CO₂ as senescent leaves and 1.83 t ha⁻¹ of the fixed CO₂ as pruning material. Leaves and pruning material produced 0.10 and 0.35 t ha⁻¹ of humus, derived from their decomposition (Table 1).

ETo measured in Ferrandina during 2001, a very dry year, was of 1003 mm. Irrigation water, supplied to the mature olive trees from May to October, was of 314.4 mm.

The amount of fixed CO₂ accumulated as senescent leaves and pruning material in mature olive trees was higher if compared to the values found in young plants. In the mature orchard, the mean values of fixed CO₂ in senescent leaves and pruning material were 1.67 and 7.87 t ha⁻¹, respectively (Table 1). The humus derived from the decomposition of senescent leaves and pruning material was 0.18 and 1.51 t ha⁻¹, respectively (Table 1), which corresponds to 1.8 and 4.3 times those found in the young orchard.

The mineralisation coefficient of the soil was 0.032 year⁻¹ and the amount of CO₂ related to SOC mineralisation was 3.09 t ha⁻¹ year⁻¹ (Table 4).

3.2. Peach orchards

The highest amount of seasonal irrigation in plants trained to delayed vase and transverse Y were 683 and 716 mm, respectively, in the 5th year after planting (Fig. 1B). The seasonal ETo was highest in year 4 (1137 mm) and the overall mean 1095 mm (Fig. 1B). During the entire experimental period, the rainfall mean was 212 mm, showing a range between 125 and 362 mm (Fig. 1B).

During year 1, the largest amount of fixed CO₂ in both training systems was primarily accumulated in the permanent structures of the above-ground biomass (branches and trunk) and considerably less in the root system (Fig. 3). During the entire experiment, the fixed CO₂ was largely accumulated in the above-ground biomass. The carbon accumulated in woody biomass (branches, trunk, stump and roots) of trees trained as delayed vase and transverse Y increased every year; with mean percentage values of 61.3 and 63.7% of the total CO₂ fixed, respectively (Fig. 3).

Between 1.60 and 6.00 t ha⁻¹ of the CO₂ fixed in leaves of young and mature peach trees trained to delayed vase were removed and placed on the orchard floor, contributing to the production of 0.16 and 0.66 t ha⁻¹ of humus, respectively (Table 2). In peach trees trained to transverse Y, 2.76 and 9.96 t ha⁻¹ of the CO₂ fixed in leaves were removed, resulting in the production of 0.30 and 1.09 t ha⁻¹ of humus, respectively (Table 3). Yield in year 2 was lost due to frost damage during flowering (Tables 2 and 3). During years 3, 4 and 5, the amount of CO₂ in fruit was higher in the transverse Y plants than in the delayed vase plants (Tables 2 and 3).

Table 1

Carbon content and humus production from the decomposition of senescent leaves and pruning material of a young and a mature olive orchard. Each value represents the mean of 10 (young orchard) and 12 measurements (mature orchard)

Orchard	Plant organ	Dry matter (t ha ⁻¹ year ⁻¹)	Fixed CO ₂ (t ha ⁻¹ year ⁻¹)	Isohumic coefficient	Humus (t ha ⁻¹ year ⁻¹)
Young	Senescent leaves	0.50	0.91	0.20	0.10
	Pruning material	1.00	1.83	0.35	0.35
	Total	1.50	2.74	–	0.45
Mature	Senescent leaves	0.91	1.67	0.20	0.18
	Pruning material	4.30	7.87	0.35	1.51
	Total	5.21	9.54	–	1.69

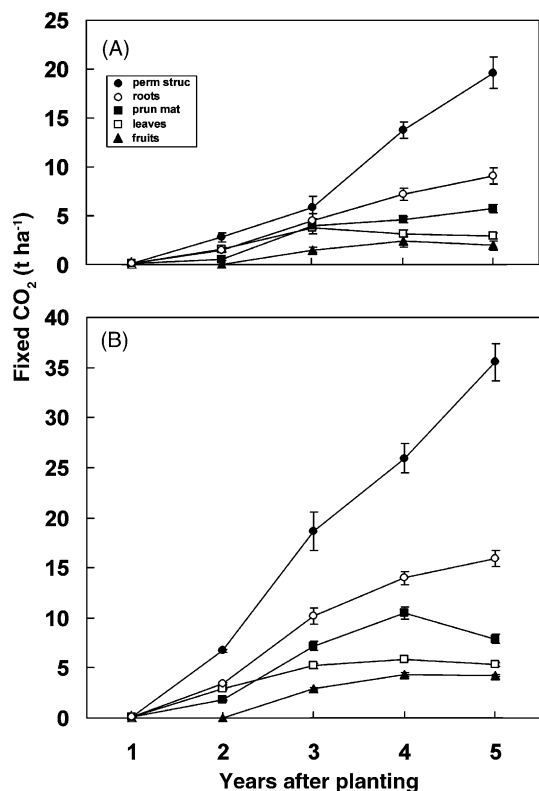


Fig. 3. CO₂ fixed in above-ground permanent structures, roots, pruning material, leaves and fruits of peach trees trained to delayed vase (A) and transverse Y (B). Each data point represents the mean of six measurements (\pm S.E.) from plants randomly selected in the orchard.

The mineralisation coefficient of the soil was 0.024 year⁻¹ and the amount of CO₂ released by SOC mineralisation was 1.57 t ha⁻¹ year⁻¹ (Table 4).

PFD_{in} increased during the experimental period both in plants trained to delayed vase and transverse Y, showing in year 5 values of 51 and 88%, respectively (Fig. 4A). PFD_{in} was directly related to the amount of total above-ground biomass, with a $R^2 = 0.9775$ in plants trained to delayed vase and a $R^2 = 0.9971$ in plants trained to transverse Y (Fig. 4B).

4. Discussion

During the experimental period, fixed CO₂ in young olive and peach trees accumulated primarily in the permanent structures of the above-ground biomass of the trees and in the root system, while the rest was fixed in short-life organs, such as leaves and fruit (Figs. 2 and 3). The permanent structures of the plants represent important pools of fixed CO₂ extracted from the atmosphere during a period equivalent to the life of the tree. In contrast, the carbon immobilised in short-life organs like fruit and leaves has a different fate. The carbon from fruit is lost from the orchard system through harvesting while the carbon from leaves is converted to SOC when leaves fall to the ground and decompose (Celano et al., 2002).

Pruning materials may count as carbon loss from the orchard system if removed from the grove (Figs. 2 and 3;

Table 2

Carbon content and humus production from the decomposition of senescent leaves and pruning material of a young (years 1 and 2) and a mature (years 3–5) peach orchard trained to delayed vase

Orchard	Plant organ	Dry matter (t ha ⁻¹ year ⁻¹)	Fixed CO ₂ (t ha ⁻¹ year ⁻¹)	Isohumic coefficient	Humus (t ha ⁻¹ year ⁻¹)
Young	Senescent leaves	0.80	1.60	0.20	0.16
	Pruning material	0.33	0.60	0.35	0.12
	TOTAL	1.13	2.07	–	0.28
Mature	Senescent leaves	3.28	6.00	0.20	0.66
	Pruning material	4.76	8.71	0.35	1.67
	TOTAL	8.04	14.71	–	2.33

Each value represents the mean of six measurements from plants randomly selected in the orchard.

Table 3

Carbon content and humus production from the decomposition of senescent leaves and pruning material of a young (years 1 and 2) and a mature (years 3–5) peach orchard trained to transverse Y

Orchard	Plant organ	Dry matter (t ha ⁻¹ year ⁻¹)	Fixed CO ₂ (t ha ⁻¹ year ⁻¹)	Isohumic coefficient	Humus (t ha ⁻¹ year ⁻¹)
Young	Senescent leaves	1.51	2.76	0.20	0.30
	Pruning material	0.93	1.70	0.35	0.33
	Total	2.44	4.47	–	0.63
Mature	Senescent leaves	5.44	9.96	0.20	1.09
	Pruning material	8.52	15.59	0.35	2.98
	Total	13.96	25.55	–	4.07

Each value represents the mean of six measurements from plants randomly selected in the orchard.

Table 4
Soil carbon content and mineralisation in olive and peach orchards

Orchard	Organic carbon (%)	Organic carbon (t ha ⁻¹ year ⁻¹)	Mineralisation coefficient (year ⁻¹)	Mineralised carbon (t ha ⁻¹ year ⁻¹)	Released CO ₂ (t ha ⁻¹ year ⁻¹)
Olive	0.684	26.27	0.032	0.84	3.09
Peach	0.513	17.54	0.024	0.43	1.57

Values were estimated at a soil depth of 0–30 cm. The mineralisation coefficient of the soil was calculated according to the model of Hénin and Dupuis described in the text.

Tables 1–3). Pruning material left to decompose naturally represent an efficient mean of long-term CO₂ immobilisation (Lal, 1997). In fact, 1 year after plant residues are added to the soil, most of the carbon returns to the atmosphere as CO₂, but one-fifth to one-third remains in the soil either as live biomass or as soil humus (Brady and Weil, 2004).

Both in olive and peach trees, the ratio of leaf biomass to total biomass decreased during the years whereas the ratio of woody biomass to total biomass increased during the experimental period (Figs. 2 and 3). These results indicate that in young trees net accumulation of dry matter and CO₂ fixation occurs during the growth period. In productive orchards, where plants have reached maturity, the annual increment of dry matter decreases (Kimmins, 1997).

Conservative soil management (green manure, cover crops) can increase CO₂ fixation in the peach orchard system. The adoption of species with a high biomass production is recommended. A *Vicia faba*/Avena sativa mixture, with a dry matter of 7.5 t ha⁻¹, equivalent to 13.73 t ha⁻¹ of CO₂, can produce 1.13 t ha⁻¹ of humus

every year (Celano et al., 1998). Moreover, in rain fed conditions, it is beneficial to sow cover crops in autumn and mow them just before spring in order to avoid water and nutrient competition (Celano et al., 2002). The use of green manure enhances SOM accumulation and can also stabilise organic compounds already present in the soil. Integrating a sound crop residue management approach, conservation tillage, soil restoration and other sustainable agricultural practices would allow the soil to maintain reduced levels of mineralisation and soil erosion (Lal, 1997). Pruning materials and dead leaves could be used to improve the soils physical, chemical and biological properties, including greater water holding capacity and availability of plant nutrients. Lesser soil disturbance as a result of using conservation tillage and keeping crop residues as mulch also reduces microbial respiration; therefore, reducing soil carbon losses to the atmosphere in the form of CO₂.

The values of CO₂ released into atmosphere by SOC mineralisation (Table 4) indicates that this, independently from the biotic inputs, is largely affected by the initial characteristics of the soil, and in particular by soil composition and SOM content. The carbon contained in the humus derived yearly by plant residues (Tables 1–3) is 31, 85 and 148% of the carbon released yearly by SOC mineralisation (Table 4) in the mature olive orchard, and in the peach orchard trained to delayed vase and to transverse Y, respectively. These results show that carbon fluxes from plants to soil are considerable when leaves and pruning materials of olive and peach trees are converted to SOM (Tables 1–3).

In Mediterranean regions drought is a limiting factor for fruit production; thus, increasing the water use efficiency through the choice of a proper training system, canopy management and irrigation technique may represent a viable option to enhance plant growth (Xiloyannis et al., 2002) and indirectly CO₂ fixation. During period of water deficit, characterised by high levels of ET_o and low rainfall (Fig. 1) olive and peach plants significantly reduce their net photosynthetic rate (Nogués and Baker, 2000; Besset et al., 2001).

Our results show differences in fixed CO₂ in peach organs between the two training systems (Fig. 3), largely influenced by plant density, which is also a factor affecting yield as suggested by Loreti et al. (1993) and Grossman and DeJong (1998). The results from the peach orchard suggest a close relationship between total above-ground biomass and intercepted radiation (PFD_{in}, Fig. 4B), as observed by

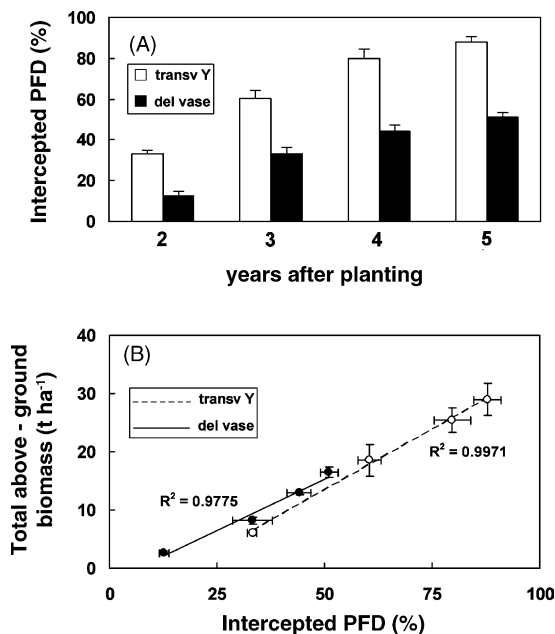


Fig. 4. (A) Intercepted PFD at the end of July in peach trees trained transverse Y and delayed vase from year 2 to 5. (B) Correlation between intercepted PFD and total above-ground biomass in peach trees trained transverse Y and delayed vase from year 2 to 5. Each data point represents the mean of six measurements (\pm S.E.) from plants randomly selected in the orchard.

Grossman and DeJong (1998). Moreover, the specific orchard design of transverse Y resulted in a smaller amount of radiation transmitted to the base of the canopy; consequently, a higher amount of CO₂ was fixed if compared to plants trained to delayed vase (Fig. 4).

In the overall carbon balance of an orchard, it is very difficult to estimate the carbon fluxes due to other factors such as natural drop of flowers and fruits, microbial respiration and rhizodeposition. Roots of higher plants are responsible for a quarter to a third of the respiration occurring in a soil, and rhizodeposition accounts for 2–30% of total dry matter production in young plants (Brady and Weil, 2004). Root decomposition and respiration can be estimated from the values of root dry matter in olive and peach orchards (Figs. 2 and 3), which show a net accumulation of carbon throughout the experimental period.

Considering that in the Mediterranean area, 16% of the total cultivable land is occupied by fruit orchards (Olesen and Bindi, 2002) and in Italy alone, peach orchards cover an area of approximately 1.0×10^5 ha (ISTAT, 2000), we can estimate that the different values of CO₂ sequestration in plant biomass and soil humus, for the different cultivation systems, may be very significant. Our results could also be extended to the total land area worldwide involved in olive growing, which amount to 9.8×10^6 ha and contains approximately 1.2×10^9 olive trees (Luchetti, 2002). These results highlight the importance of Mediterranean orchards in mitigating CO₂ releases into the atmosphere by carbon immobilisation and humus production; particularly in Mediterranean countries where olive and peach crops are economically important and widely cultivated.

The results of this study highlight the importance of Mediterranean orchards in fixing atmospheric CO₂. We conclude that the choice of an appropriate training system, plant density and the use of sustainable agricultural practices with a sound irrigation regime can enhance the capacity of an orchard system to transform significant amounts of CO₂ into biomass and humus.

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