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Plant crown traits and carbon sequestration capability by *Platanus hybrida* Brot. in Rome

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Abstract

Measurements of carbon dioxide (CO_2) concentration carried out in the city of Rome in the period January–December 2005 showed a mean yearly CO_2 concentration of 414 ± 45 ppm; polluted sites (P sites) had 21% higher CO_2 concentration than control sites (C sites). The significant ($p < 0.01$) correlation analysis between CO_2 concentration and traffic density measured during the study period at P sites showed that traffic density explained 51% of the CO_2 variation. The CO_2 trend during the traffic limitation days (provision imposed by ordinance of the City Council) did not show significant differences as regards regular traffic days, suggesting the ineffectiveness of this provision. Leaf area index (LAI) of *Platanus hybrida* Brot. was on an average 11% lower at P sites than at C ones associated with a lower total photosynthetic leaf surface area (SPT, 34% lower at P sites than at C ones). *P. hybrida* had a total carbon sequestration of $117 \pm 13\,\mathrm{kg\,year^{-1}}$ (mean value of P and C sites) playing an important role in sequestering CO_2. Thus, the choice of plant species for urban areas may be set out taking into account their own air amelioration capability. Plant traits of each species may be used for urban tree planting programs to ameliorate urban air pollution.

Keywords: *Platanus hybrida*; CO_2 concentration; CO_2 sequestration; Urban area

1. Introduction

The urban carbon dioxide (CO_2) concentration significantly differs from that of natural environment (Koerner and Klopatek, 2002; Gratani and Varone, 2005). Human and automobile activities produce more than 80% input of CO_2 into the urban environment (Koerner and Klopatek, 2002). Moreover, CO_2 is site and time dependent (Nasrallah et al., 2003; Salmond et al., 2005), and it is related to weather conditions and urbanistic characteristics (Gratani and Varone, 2005); freeway roads with high traffic density have CO_2 concentration lower than those characterised by tall buildings on both the sides, the dispersion of gases released at ground level by vehicles being restricted because of tall buildings (Capannesi et al., 1981; Gratani and Varone, 2005). Trees may improve urban life quality (Akbari, 2002; Brack, 2002) by fixing CO_2 during photosynthesis and storing excess carbon as biomass (Nowak and Crane, 2002; Gratani and Varone, 2006). Nevertheless, plants contribute differently to reducing carbon dioxide concentration by sequestration, depending on plant traits and *habitus* (evergreen and deciduous species); taking into account leaf longevity, deciduous species contribute to remove CO_2 from the atmosphere spring to the beginning of autumn, while evergreen species all year long, and also in autumn–winter when the traffic volume is the highest (Gratani and Varone, 2005).

The city of Rome is characterised by a high extension of the urbanised area (1.285 km^2) and a high movement of public and private means of transport (6.1 million daily movements; data from ATAC S.p.A., Mobility Agency, 2004). The urbanisation process in Rome has been increasing during the last years, and many new sub-urban areas have been built by scaling down free areas surrounding the city.

The overall objective of this research was to analyse the carbon sequestration capability by *Platanus hybrida* Brot., largely distributed in Rome and used in parks and green areas since the beginning of the 20th century.

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2. Methods

2.1. Site and plants description

The study was carried out in the city of Rome (41°53′N, 12°29′E), which was under Mediterranean type climate. The average total yearly rainfall was 695 mm, the average minimum air temperature of the coldest month (February) was 5.6 ± 1.9 °C and the average maximum air temperature of the hottest months (July and August) was 30.8 ± 1.0 °C. Most of the total annual rainfall was distributed in autumn, and dry period was from June to the middle of August. There was a constant wind speed (2.2 ± 0.2 m s^{-1}) during the year (data provided by the Meteorological Station of the Collegio Romano for the years 1995–2005).

Measurements of plant structural traits and leaf phenological and physiological traits of *P. hybrida* were carried out during the year 2005. Ten high traffic level sites (P sites) were selected according to Gratani and Crescente (1999), Gratani et al. (2000). Eight control sites (C sites) were selected among urban parks and they were characterised by the absence of vehicle movement.

2.2. Carbon dioxide concentration and traffic density

Atmospheric carbon dioxide concentration (CO_2, ppm) was monitored monthly (from the 1st through the 5th day, from 7.00 a.m. to 8.00 p.m., 10 measurement/h at each P and C sites) in the period January–December 2005 by CO_2 gas analysers EGM-1 (PP Systems, UK) at a height of 2 m above the ground, according to Idso et al. (2001). The traffic density (number of cars per minute) at each P sites was monitored in the same time of CO_2 measurements (from 8.00 to 11.00 a.m., peak hours)

CO_2 measurements were carried out also during the traffic limitation days (provision imposed by ordinance of the City Council), on Thursday from 9.00 to 12.00 a.m. and from 3.00 to 8.00 p.m., for the period January–March 2005 (10 measurements per hour).

2.3. Plant structure

Plant structure was analysed for five plants of *P. hybrida* of comparable sizes at each P and C site, for a total of 50 trees at the P sites and 40 trees at the C ones.

Tree diameter at breast height (dbh, cm) was measured by a wheel. Plant (H, m) and crown (h, m) height were measured by a clinometer; the height of the crown was calculated as the difference between plant height and the insertion point of the first coppers.

The projected crown area (P_c, m^2) was measured by projecting the edges of the crown to the ground and measuring the length along an axis from edge to edge through the crown centre (Gratani and Varone, 2006).

Crown volume (V_c, m^3) was calculated by approximating each crown to a simple geometric solid, according to Karlik and Winer (2001).

Leaf area index (LAI) was measured by the "LAI 2000 Plant Canopy Analyzer" (LICOR Inc., Lincoln, USA), and Leaf area density (LAD, m^{-1}) was calculated by the ratio of LAI and crown height (Küppers, 2003).

Total photosynthetic leaf surface area (SPT, m^2) was determined by multiplying each LAI value by P_c of each considered plant (Gratani and Varone, 2006).

Leaf longevity was calculated *in situ*: 10 twigs per each selected plant were randomly obtained and labelled with nylon tape at each P and C sites and leaves were monitored at weekly intervals in the period February–November 2005. Leaf longevity was calculated as the duration between the date of leaf fall and the date of leaf appearance (Kikuzawa et al., 2004).

2.4. Photosynthetic activity

Measurements of net photosynthesis (P_N, μmol m^{-2} s^{-1}) were carried out at P and C sites periodically from May to September 2005 on fully expanded leaves (10 per plant) selected from the external sun exposed portion of the crown.

P_N was monitored by an infrared CO_2 gas analyser ADC-LCA 3 (Hoddesdon, UK) open system, equipped with a leaf chamber (type PLC3). Measurements were carried out early in the morning up to the afternoon (8.00 a.m.–8.00 p.m.) on cloud-free days (PAR > 1000 μmol photon m^{-2} s^{-1}) to ensure that near maximum daily photosynthetic rates were measured (Reich et al., 1995).

The total yearly CO_2 sequestration capacity for *P. hybrida* was calculated by multiplying the photosynthetic rate of the crown (TPCR, μmol CO_2 s^{-1}) by the total photosynthetic activity hours in the year (PTYH). PTYH was obtained by summing the hours in the year with positive P_N; TPCR was obtained by multiplying SPT by the mean yearly photosynthetic rate (YPR, μmol CO_2 m^{-2} s^{-1}), according to Gratani and Varone (2006).

2.5. Statistical analysis

The differences of the means were tested by one-way analysis of variance (ANOVA) and Tukey test for multiple comparisons; ANOVA was performed using a statistical software (Statistica, Statsoft, USA).

3. Results

3.1. Carbon dioxide concentration

P sites exhibited higher CO_2 concentration (454 ± 26 ppm, mean yearly value for the period January–December 2005) than C sites (374 ± 12 ppm) (Fig. 1).

Traffic density at P sites was 55 ± 9 cars min^{-1} (mean value for the period January–December 2005).

The significant ($p < 0.01$) correlation analysis between CO_2 concentration and traffic density measured during the study period at P sites showed that traffic density explained 51% of CO_2 variation (Fig. 2).

Considering the limitation traffic days during the year 2005 (every Thursday from 9.00 to 12.00 a.m. and from 3.00 to 7.00 p.m., in the period January–March), the mean daily atmo-