Adv. Hort. Sci., 2011 25(4): 232-238

Effects of mulching with compost on growth and physiology of *Acer campestre* L. and *Carpinus betulus* L.

A. Fini, F. Ferrini
Dipartimento di Scienze delle Produzioni Vegetali, del Suolo e dell'Ambiente Agroforestale, Università degli Studi di Firenze, Viale delle Idee, 30, 50019 Sesto Fiorentino (FI), Italy.

Key words: chlorophyll fluorescence, leaf gas exchange, mulching, soil respiration, soil temperature, SPAD.

Abstract: The aim of this work was to evaluate the effects of mulching with compost on growth and leaf gas exchange of two widely-used ornamental trees in comparison to local nursery management standards. In addition, effects on soil respiration, soil temperature and water evaporation from soil were determined. An equal number (180 each) of uniform hedge maple (*Acer campestre* L.) and 180 hornbeam (*Carpinus betulus* L.) were planted in an experimental plot located in Pistoia. Treatments compared were: 1) chemical weeding by herbicides; 2) natural grass cover, mowed twice per year; 3) harrowing once a year; and 4) mulching with mixed compost (50% green+50% from household waste, 5 to 10 cm thick). Over a two-year period, stem diameter, shoot extension and leaf gas exchange were measured. In the second year leaf chlorophyll content, chlorophyll fluorescence, soil respiration, soil evaporation content and soil temperature were also recorded. Mulching with compost influenced shoot extension and stem diameter growth of field maple and white hornbeam. Plants grown with natural grass cover had, generally, smaller stem diameters and shoot growth than the other treatments. Leaf gas exchange, chlorophyll content and chlorophyll fluorescence were influenced by the different treatments. Soil respiration was unaffected by the different treatments while soil temperature was significantly lower in mulched plots.

1. Introduction

A key to success for the planting of new trees, both in open-field nursery and in the urban environment, is the protection of young plants from non-crop plant species (including some hardwoods, shrubs, grasses, and forbs). These fast-growing plants often kill or greatly suppress desired trees by competing with them for light, water, and nutrients. As a result, nurserymen, arborists and urban forest managers generally use herbicides to suppress non-crop vegetation.

However, the use of herbicides in the urban environment may be limited or even banned in certain countries and/or municipalities. As a consequence, to protect young trees, environmentally sound, effective, cost-efficient, and socially acceptable techniques for managing non-crop vegetation are needed.

In this scenario, we focused on the need for the establishment of environmentally friendly and low cost management methods for nurseries and urban green areas. Mulching and its skilled use can contribute to such a development by improving organic matter content in the soils and by affecting other soil characteristics (Harris *et al*., 2004).

Received for publication 5 August 2011
Accepted for publication 9 November 2011

For tree management in the urban landscape, especially in the first years after planting, mulching with organic materials can be advantageous. Organic mulching with different materials (mainly shredded wood, chipped wood, pine bark and composted materials), when skillfully applied, is an environmentally friendly way of establishing, protecting and managing young trees at a low cost in a new plantation. A recent review compared the costs and benefits of landscape mulches as reported in the technical and scientific literature, underlining how plants and soil can both benefit in terms of weed suppression, evaporation reduction and other environmental modifications (Chalker-Scott, 2007).

Even if mulching is a world-wide practise in urban green areas and different materials (as noted above) can be used for this purpose (Rakow, 1989), little research has been done in Italy to determine its effectiveness.

Positive effects following organic mulch application have been obtained in previous research, demonstrating beneficial effects on soil physical and chemical properties (Fraedrich and Ham, 1982; Litzow and Pellett, 1983; Watson, 1988; Appleton *et al*., 1990; Himelick and Watson, 1990; Smith and Rakow, 1992; Iles and Dosmann, 1999; Dahiya *et al*., 2007; Tiquina *et al*., 2007) and on plant growth and physiology (Watson, 1988; Green and Watson, 1989; Appleton *et al*., 1990; Himelick and Watson, 1990). However, sometimes the results from mulching are variable as they are affected by different environmental conditions and different tree species (Whitcomb, 1979; Iles and Dosmann, 1999). Moreover, if the quality of the mulching materials supplied by the producers is not satisfactory, tree performances can be affected in a negative way. This fact can be related either to quality or misuse, i.e adding too much material which can negatively affect soil oxygen content (Gilman and Grabosky, 2004; Hanslin *et al.*, 2005), although Watson and Kupkowski (1991) found no detrimental effect from the application of 0.45 m of wood chip mulch over soil in which the roots of trees were growing. The application of bark mulch can sometimes decrease growth in the first year, but the effects on plant growth are positive when examined in the long term (Samyn and de Vos, 2002). This can be due to a temporary nitrogen depression until the microorganisms are able to decompose a sufficient amount of organic material to provide the needed nitrogen (Craul, 1992). In fact, although this temporary depression mainly affects the interface between mulch and soil, it has been shown that fine roots tend to grow into the organic mulch layer (Watson, 1988; Watson and Kupkowski, 1991), where N-concentration is temporary depressed.

As far the composted material as concerned, it has to be remarked that it needs to be well characterised for nutrient values, stability and other properties for the support of tree growth and effect against weeds. In a review of the use of composts for mulching and soil amendments, Sæbø and Ferrini (2006) suggest designing the composts to fit the specific effects that are wanted. For example composts for mulching should consist of layers of compost of different particle sizes, so that nutrients can be supplied and weeds are not given good germination conditions.

The purpose of the present study was to investigate the use of mulching materials and their possible influence on growth and physiology of two shade tree species widely grown in the urban environment. In addition, effects on soil respiration, soil temperature and water evaporation from soil were assessed in the second year of the experiments.

2. Materials and Methods

One hundred eighty uniform *Acer campestre* L. and 180 *Carpinus betulus* L. two-year-old seedlings 1.20 m in height from container were planted in an experimental plot located in Pistoia (43°56' N; 10°54' E). Planting density was 1.80 m in-row and 2.50 m between rows. Mean temperature and rainfall over the last 50 years are 14.3°C and 1257 mm/year respectively. However, during the years of the current experiment, a decrease in rainfall and an increase in mean temperatures were recorded: rainfall in the first and second year was 971 and 903 mm, respectively; while in both the first and second year, an extended dry period with no rainfall was recorded from early June to the end of July. Plants were irrigated the first year after planting to help establishment. From the second year no irrigation or fertilization were applied to plants.

After two years from planting, when trees had overcome transplant phase, the experiment was started and the following thesis were compared: 1) weeding by herbicides using glyphosate twice a year (W); 2) natural grass cover, which was mechanically cut twice per year (G); 3) tillage by harrowing at a depth of 15 cm, once per year (T); and 4) in-row mulching with green compost (layer 5-10 cm thick and 1.5 m wide) and natural grass cover soil between the rows (M). The experimental design was a randomized complete block with six blocks and 30 plants per block.

The following year (three years after planting and one year after treatments), biometric and physiological analyses were performed. Stem diameter was measured 5 cm above the root flare on all plants at the end of the growing season. At the same time shoot extension was determined on 10 shoots per plant on three plants per block (18 plants per treatment). During the growing season, leaf gas exchange was measured with an infrared gas analyzer (Ciras-2, PP-System, New Hertfordshire, UK) on six leaves per block (36 leaves per treatment x species) twice during the first growing season and four times during the second. Measured parameters were net assimilation (A, $\mu mol*m^{-2}*s^{-1}$) and transpiration (E, $mmol*m^{-2}*s^{-1}$). Measurements were taken between the hours 8.00 and 13.00 on the first fully expanded leaf from the shoot apex. Measurements were taken under fixed CO_2 concentration (360 ppm) and saturating irradiance (1300 $\mu mol*m^{-2}*s^{-1}$) provided with a built-in red light emitting diode radiation source. Water Use Efficiency (WUE) was calculated as the ratio between A and E as described in a previous work (Ferrini *et al.*, 2008). Leaf greenness index was determined in the second growing season with a Minolta SPAD-meter (Spectrum Technologies, Plainfield, IL, USA) on six leaves per block (36 leaves per treatment x species). For each leaf, the SPAD value was obtained averaging three different measurements made in different points of the leaf blade. This parameter is a good indicator of leaf chlorophyll, N and carotenoid content (Percival *et al.*, 2008). Chlorophyll fluorescence was measured three times in the second year with a portable plant efficiency analyzer HandyPea (Hansatech Ins., King's Lynn, UK) on six leaves per block (36 leaves per treatment x species). Fv/Fm values were obtained by placing leaves in darkness for 30 min by attaching light-exclusion clips to the leaf surface. Fv/Fm is the maximum quantum yield of the PSII and it is a reliable indicator of the occurrence of environmental stress (Maxwell and Johnson, 2000). Soil respiration and evaporation were measured with a soil respiration chamber (SRC, PP-System, New Hertfordshire, UK) at a depth of 5 cm below soil surface. Measurements were taken twice in July around midday on soil exposed to full sunlight (not shaded by the trees). At least 30 days had passed since the last remarkable rainfall

(Fig. 1). Four measurements per treatment per species and per replicate were made. Before measuring respiration and evaporation, the mulch was removed from an area of about 25 cm^2 and the chamber was placed on the soil beneath. After taking the measurements, mulch was spread again. Soil temperature was measured with a temperature probe at a depth of 10 cm below soil surface four times per treatment per species and per replicate.

All data were analyzed with GLM using the SPSS statistical package for Windows (SPSS Inc., Chicago, IL, USA). Effects of soil management technique and species were analyzed with a random model two-way ANOVA. When no significant interaction between factors was found, differences among soil management techniques were tested with Duncan's multiple range test (P≤0.05 and P≤0.01). Parameters which showed significant interaction between factors were plotted separately in order to compare each level of factor A (soil management) for each level of factor B (species) (Chew, 1976). Data on leaf gas exchange, Fv/Fm and soil parameters were analyzed per single sampling date, merged together and processed again to obtain an average value on annual basis.

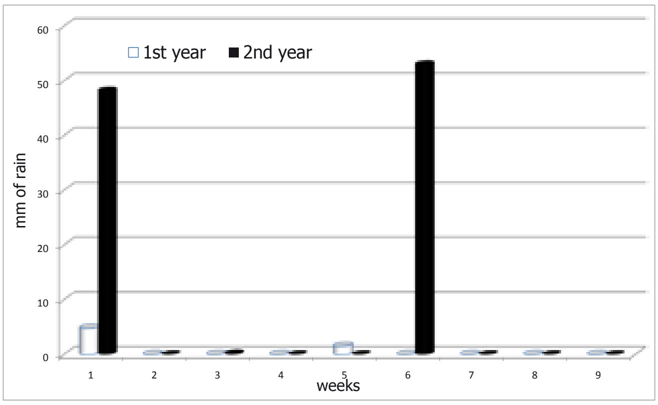

Fig. 1 - Rainfall from 1 June (day 1) to 31 July (day 61) in 2006 and 2007 measured in the experimental centre where the research was carried out.

3. Results and Discussion

Mulching with compost (M) affected shoot growth of *Acer campestre* and *Carpinus betulus* (Table 1). Significant interaction between species and soil management technique was found for shoot growth (Table 1). In the first year of measurements, mulched plants of both species had higher shoot growth than the other treatments (Table 2). In maple, no difference was found among treatments W (herbicide), T (tilling) and G (ground cover). In hornbeam, shoot growth was lower in G than in T and W. In the second year, M *Carpinus* plants had greater shoot growth than W and T which, in turn, had longer shoots than G. In the second year, M and T *Acer* had greater shoot growth than W. Again, the shortest shoots were found in G maples. In the first year and second years, G plants had lower stem di-

Table 2 - Effect of soil management technique on shoot extension in *Acer campestre* and *Carpinus betulus* in the first and second years

Shoot growth (cm)	Acer campestre		Carpinus betulus	
Treatment	1 year	2 year	1 year	2 year
Chem. weeding	70.2 b	58.3 b	70.0 b	44.7 b
Tillage	70.0 b	57.5 b	67.0 b	53.4 a
Grass cover	69.6 b	45.5 c	57.1 c	35.6 c
Mulching	86.0 a	72.0 a	74.0 a	54.4 a

Different letters within the same column indicate significant differences at P≤ 0.01.

Table 1 - Summary table of Two-way ANOVA for the investigated parameters

Parameter	Measurement unit	Management technique	Species	Management x Species
Shoot growth (1 year)	cm	**	**	**
Shoot growth (2 year)	(g)	**	**	**
Stem diameter (1 year)	(g)	**	NS	NS
Stem diameter (2 year)	(g)	**	NS	NS
Leaf greenness index	SPAD unit	**	**	NS
Fv/Fm		**	NS	NS
A (1 year)	µmol m^{-2} s^{-1}	**	**	NS
A (2 year)	µmol m^{-2} s^{-1}	**	**	NS
E (1 year)	mmol m^{-2} s^{-1}	NS	**	NS
E (2 year)	mmol m^{-2} s^{-1}	**	**	NS
WUE (1 year)	µmol CO_2/mmol H_2O	NS	NS	NS
WUE (2 year)	µmol CO_2/mmol H_2O	**	**	NS
Soil temperature (2nd year)	° C	**	NS	NS
Soil respiration (2nd year)	µmol m^{-2} s^{-1}	NS	NS	NS
Soil evaporation (2nd year)	mmol m^{-2} s^{-1}	**	NS	NS

* and ** indicate significant differences between treatments at P<0.05 and P<0.01, respectively.

ameter than the other treatments (Table 3); no differences in stem diameter were found between species (Table 3). There are several reports on how turf or natural grass cover decrease plant growth (Garrity and Mercado, 1994; Stork and Jerie, 2003; Yao *et al.,* 2005; Chalker-Scott, 2007). In the present experiment, natural grass cover decreased shoot growth and stem diameter in both the species studied. Also, *Carpinus betulus,* whose growth was affected both in the first year and second year, is probably a worse competitor with turf than *Acer campestre.* Mulch increased growth of both species, and mulched plants had shoot growth and stem diameter similar or higher than plants grown in tilled soil. Greater plant growth in response to mulching has been observed by many authors (Sæbø and Ferrini, 2006; Chalker-Scott, 2007; Ferrini *et al*., 2008). Some authors found that mulching decreased growth in the first year after application and most of the authors attributed this reduced growth to temporary immobilization of soil N due to the high C/N ratio of the mulch (Ferrini *et al*., 2009). The mulch applied in this experiment had relatively low C/N ratio (about 30), so no nitrogen immobilization occurred and growth was enhanced even in the first year after application, in agreement with that reported in previous works (Tilander and Bonzi, 1997; Erhart and Hartl, 2003; Sonsteby *et al.*, 2004; Granatstein and Mullinix, 2008).

Table 3 - Effects of soil management technique and species on stem diameter growth in the first and second years

	Stem diameter (cm)	
	1 year	2 year
Effect of different treatments		
Chem. weeding	6.5 a	7.5 a
Tillage	6.1 a	7.6 a
Grass cover	5.6 b	6.7 b
Mulching	6.2 a	7.9 a
Effect of species		
A. campestre	6.1	7.4
C. betulus	6.1	7. 4

Different letters within the same column indicate significant differences at P≤0.01.

Leaf greenness index was affected by the different treatments and species (Table 4). Regardless of the species, mulched plants showed higher values than the other treatments. The lowest readings were found in W and G plants, whereas T plants performed intermediately. Higher SPAD readings following low C/N mulch application were also found by Granatstein and Mullinix (2008), who found a soil N-enrichment due to mulch mineralization. We did not consider the effect of management technique on soil N, however according to Percival *et al*. (2008), the higher SPAD-reading of M plants may reflect a better nutritional status generated by mulch application and its decomposition. Leaf greenness index was also affected by species, with field maple having higher values than hornbeam (Table 4). Fv/Fm was affected by soil management technique but not by species. Fv/Fm measurements of healthy, unstressed plants are associated with values ranging from 0.76 to 0.85 (Percival, 2004; Percival *et al*., 2006). Regardless of the treatment, all plants in this experiment were subjected to some degree of stress because of the very low rainfall during the summer (Fig. 1), since Fv/Fm values were lower than 0.75. In any case, M and T plants had a significantly higher Fv/Fm than G plants (Table 4). Fv/Fm is very sensitive to oxidative stresses, and to drought stress in particular (Angelopulos *et al.*, 1996; Maxwell and Johnson, 2000; Rong-Hua *et al.*, 2006). Thus, the lower SPAD and Fv/Fm observed in G plants must be attributed to grass competition for nutrients and water.

Table 4 - Effects of soil management technique and species on leaf greenness index and Fv/Fm in the second year

	Greenness Index (SPAD)	Fv/Fm
Effect of different treatments		
Chem. weeding	38.7 c	0.721 ab
Tillage	40.2 b	0.731 a
Grass cover	38.8 c	0.701 b
Mulching	42.3 a	0.743 a
Effect of species		
A. campestre	43.0 a	0.728
C. betulus	40.0 b	0.719

Data are the average of two measurement campaigns made in the second year. Different letters within the same column indicate significant differences at P≤ 0.01.

Leaf gas exchange was affected by soil management technique and species (Table 5). In the first year, net assimilation was higher in M plants than in the other treatments. In the second year, M and T had greater assimilation than G and W. Transpiration was not affected by management technique in the first year, while in the second year T plants had greater transpiration than the other treatments. Water Use Efficiency was not affected by soil management technique in the first year. In the second year, M and W had greater WUE when compared to T and G. Leaf gas exchange was also affected by species: hedge maple always showed higher values than hornbeam (Table 5). A significant quadratic relation was found for *Acer* ($P<0.01$; $R^2=0.855$) and *Carpinus* ($P<0.01$; $R^2=0.298$) between leaf greenness index and net assimilation (Fig. 2). Leaf greenness index has shown to be accurate in predicting leaf N content (Follett *et al.*, 1992; Wood *et al*., 1992). In our experiment, the relationship between SPAD and A was much stronger in hedge maple than in hornbeam, suggesting a N limitation to photosynthesis in the case of maple and a less N-dependant limitation in hornbeam.

Soil temperature was affected by management technique: in July (second growing season) plots mulched with compost were 13°C, 10.8°C and 7.2°C cooler than bare soil, tilled and turf plots respectively (Table 6). This is consistent with previous works, which found that mulching is more effective than cover crops and tillage to reduce extreme summer temperatures and that, in dry climates, mulching can lead to a reduction in soil temperature of up to 10°C (Martin and Poultney, 1992; Zhang *et al*, 2009).

Table 5 - Effect of soil management technique and species on net assimilation (A, µmol*m^{-2}*s^{-1}), transpiration (E, mmol*m^{-2}*s^{-1}) and Water Use Efficiency (WUE, µmol CO_2/mmol H_2O). Data are the average of two (the first year) and four (the second year) measurement campaigns

	A (µmol m^{-2} s^{-1})		E (mmol m^{-2} s^{-1})		WUE (µmol CO_2/ mmol H_2O)	
	1 year	2 year	1 year	2 year	1 year	2 year
Effect of different treatments						
Chem. weeding	8.2 b	6.3 b	2.5	2.0 b	3.6	3.5 a
Tillage	8.4 b	7.5 a	2.5	2.6 a	3.8	2.9 b
Grass cover	7.7 b	6.3 b	2.2	2.1 b	3.8	3.1 b
Mulching	9.3 a	7.5 a	2.5	2.0 b	4.0	3.7 a
Effect of species						
A. campestre	10.3 a	8.3 a	2.9 a	2.4 a	3.8	3.6 a
C. betulus	6.5 b	5.5 b	1.9 b	1.9 b	3.7	2.9 b

Different letters within the same column and factor indicate significant differences at P<0.01.

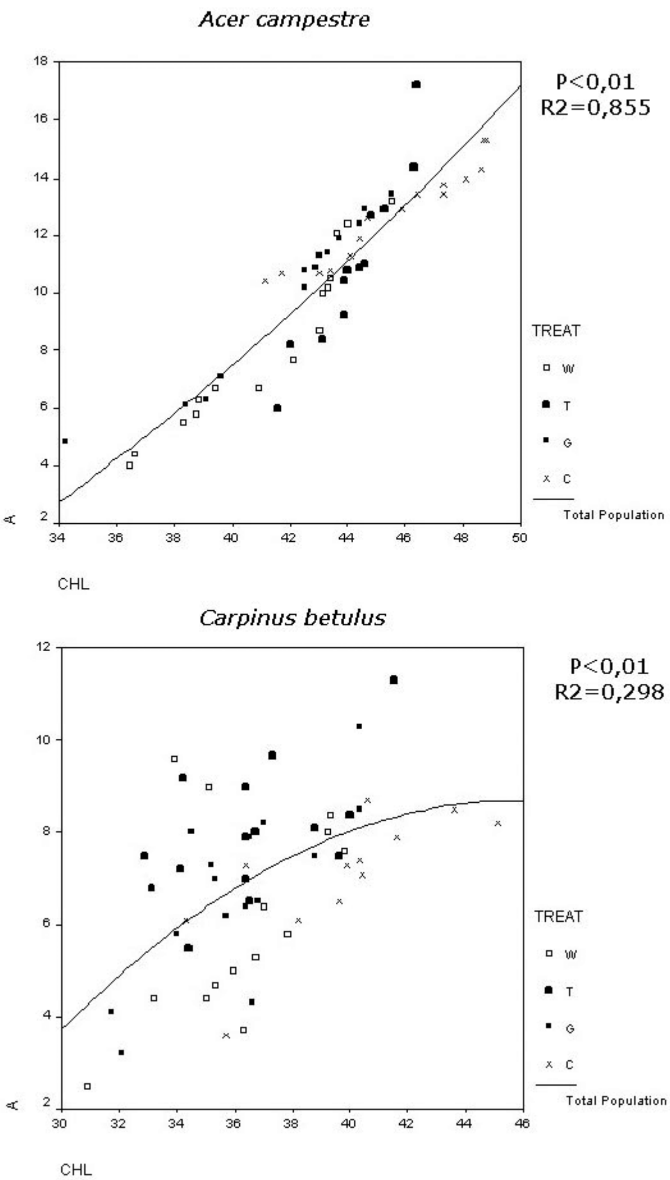

Fig. 2 - Relationship between leaf greenness index (chl, SPAD-units) and net assimilation (A, mmol*m^{-2}*s^{-1}) in *Acer campestre* and *Carpinus betulus.*

The significant reduction in soil temperature contributed to create a more favourable environment for root growth: soil temperature in mulched plots did not exceed 35°C, which is considered the threshold temperature above which root growth is hampered and root mortality increases (Coder, 1996; Fini and Ferrini, 2007). The reduction of soil temperature under mulch is due to the low albedo and thermal conductivity of woody mulches (Montague and Kjelgren, 2004). This finding means that the radiation reaching the mulch was not reflected, but the mulch acted as insulation and prevented energy from being conducted to the soil. Soil temperature under natural grass cover was lower than tilled and bare soil, but higher than mulch. The cover crop acted as a barrier which absorbed solar energy and shaded soil surface, but it also transpired soil water, reducing soil water content and, by consequence, its buffering capacity (Zhang *et al.*, 2007, 2009). This is confirmed by water evaporation from soil (Table 6). Evaporation was measured 30 days after the last rainfall. In the mulched plot, the mulch layer was temporary removed and the measurement taken on the soil below. The lowest evaporation was found in G plots and the highest value was found in M plots. In absence of irrigation and natural rainfall, the higher value measured in mulched soil provides further confirmation of the effectiveness of mulching to reduce evaporation: after 30 days of drought, soil was very dry

Table 6 - Effect of the different treatments on soil temperature (measured 10 cm below soil level), soil evaporation (measured 5 cm below soil level), and soil respiration (measured 5 cm below soil level). Data are the average of two measurement campaigns made in the second year

Treatment	Soil temperature (°C)	Soil evaporation (mmol m^{-2} s^{-1})	Soil respiration (μmol m^{-2} s^{-1})
Chem. weeding	43.4 a	28.0 b	0.3
Tillage	41.2 a	29.7 b	0.4
Grass cover	37.6 b	18.3 c	0.3
Mulching	30.4 c	94.2 a	0.5

Different letters within the same column indicate significant differences at P≤ 0.01.

in treatments G, W and T and no further evaporation was possible. On the contrary, moisture was still available under the mulch so that, after mulch removal, evaporation was higher than in the other treatments. Soil respiration was somewhat higher in M and T plots, but differences were not significant (P=0.172).

Most of the parameters measured showed that plants performed better when mulching was used and there are probably multiple causes which determined these results. The effect of mulching in reducing soil temperature which can allow a higher root growth is probably the most important under the conditions of this study, also because it might have prevented dehydration. Compost mineralization might also have increased soil nutrient content. These effects could have allowed a greater root growth and, as a consequence, greater water and nutrients absorption. Unfortunately we did not analyze the soil and this might be a potential shortcoming of this research.

4. Conclusions

The use of compost as mulching material had great impact on plant growth and physiology. In agreement with the results obtained in a previous work (Ferrini *et al.*, 2008), the present study confirms that mulching with compost is a useful practice to improve plant growth, leaf gas exchange and leaf chlorophyll content. Positive effects of organic mulching on soil organic matter, soil water holding capacity and weed suppression have already been revealed in previous works (Sæbø and Ferrini, 2006; Chalker-Scott, 2007; Granatstein and Mullinix, 2008; Mulumba and Lal, 2008). The present investigation provides the evidence that mulching also has positive effects on plant growth and physiology, comparable or even superior to tillage. Despite being inexpensive and very effective in weed control, the use of chemical herbicides reduced shoot growth and gas exchange when compared to mulching. An even greater reduction in growth and carbon assimilation and a significant increase of oxidative stress on PSII was found in plants growing with natural grass cover, mechanically cut twice per year. Considering that mulching is cheaper than tillage and mechanical weeding (Zhang *et al.*, 2009), it can be considered an environmentally-friendly and sustainable alternative for managing plants in the forest, in the nursery and in the urban environment.

Acknowledgements

We thank Regione Lombardia Project "Progetto di Sperimentazione Regionale sul Florovivaismo Tecniche eco-compatibili di gestione del vivaismo e del verde ornamentale" (acronym TECOGEST). Support for this project also came in part from the Regione Toscana (Italy) within the research project SOFILVU.

References

ANGELOPULOS 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.

APPLETON B.L., DERR J.F., ROSS B.B., 1990 - *The effect of various landscape weed control measures on soil moisture and temperature, and tree root growth*. - J. Arboric., 16: 264-268.

CHALKER-SCOTT L., 2007 - *Impact of mulches on landscape plants and environment - a review*. - J. Environ. Hort., 25(4): 239-249.

CHEW V., 1976 - *Uses and abuses of Duncan's Multiple Range Test*. - Proc. Fla. State Hort. Soc., 89: 251-253.

CODER K.D., 1996 - *Tree heat stress syndrome*. - University of Georgia, School of For Res, Athens, GA, USA, pp 11.

CRAUL P.J., 1992 - *Urban soil in landscape design*. - John Wiley and Sons, Inc., New York, USA.

DAHIYA R., INGWERSEN J., STRECK T., 2007 - *The effect of mulching and tillage on water and temperature regimes of a loess soil: Experimental findings and modeling*. - Soil and Till. Res., 96: 52-63.

ERHART E., HARTL W., 2003 - *Mulching with compost improves growth of blue spruce in Christmas tree plantations*. - Eur. J. Soil Biol., 29: 145-156.

FERRINI F., FINI A., FRANGI P., AMOROSO G., 2008 - *Mulching of ornamental trees: effects on growth and physiology*. - Arb. Urban For., 34(3): 157-162.

FERRINI F., FINI A., PELLEGRINI S., AGNELLI A., PLATINETTI M., FRANGI P., AMOROSO G., 2009 - *Effects of two organic mulches on soil physical, chemical and biological properties.* - Proceedings of the 3rd symposium "The Landscape Below Ground", Morton Arboretum, Lisle-IL, USA, pp. 31-39.

FINI A., FERRINI F., 2007 - *Influenza dell'ambiente urbano sulla fisiologia e sulla crescita degli alberi*. - Italus Hortus, 14(1): 9-24.

FOLLETT R.H., FOLLETT R.E., HALVORSON A.D., 1992 - *Use of chlorophyll meter to evaluate the nitrogen status of dry land winter wheat*. - Comm Soil Sci Plant Analysis, 23: 687-697.

FRAEDRICH S.W., HAM D.L., 1982 - *Wood chip mulching around maples: Effect on tree growth and soil characteristics*. - J. Arboric., 8: 85-89.

GARRITY D.P., MERCADO Jr. A.R., 1994 - *Nitrogen fixation capacity in the component species of contour hedgerows: how important?* - Agrofor. Syst., 27: 241-258.

GILMAN E.F., GRABOSKY J., 2004 - *Mulch and planting depth affect live oak (*Quercus virginiana *Mill.) establishment*. - J. of Arbor., 30: 311-317.

GRANATSTEIN D., MULLINIX K., 2008 - *Mulching options for northwest organic and conventional orchards*. - HortSci., 43(1): 45-50.

GREEN T.L., WATSON G.W., 1989 - *Effects of turfgrass and mulch on the establishment and growth of bare root sugar maples*. - J. Arboric., 15: 268-271.

HANSLIN H.M., SÆBØ A., BERGERSEN O., 2005 - *Estimation of oxygen concentration in the soil gas phase beneath compost mulch by means of a simple method*. - Urb. For. and Urb. Greening, 4: 37-40.

HARRIS R.W., CLARK J.R., MATHENY N.P., 2004 - *Arboriculture*. - Prentice Hall Inc., 4th ed., Upper Saddle River, NJ.
HIMELICK E.B., WATSON G.W., 1990 - *Reduction of oak chlorosis with wood chip mulch treatments*. - J. Arboric., 16: 275-278.
ILES J.K., DOSMANN M.S., 1999 - *Effect of organic and mineral mulches on soil properties and growth of fairview flame red maple trees*. - J. Arboric., 25: 163-167.
LITZOW M., PELLETT H., 1983 - *Influence of mulch materials on growth of green ash*. - J. Arboric., 9: 7-11.
MARTIN P.J., POULTNEY R., 1992 - *Survival and growth of clove seedlings in Zanzibar. 1. Effect of mulching and shade crop*. - Trop. Agric., 69: 365-373.
MAXWELL K., JOHNSON G.N., 2000 - *Chlorophyll fluorescence. A practical guide*. - J. Exp. Bot., 51: 659-668.
MONTAGUE T., KJELGREN R., 2004 - *Energy balance of six common landscape surfaces and the influence of surface properties on gas exchange of four containerized tree species*. - Sci. Hortic., 100: 229-249.
MULUMBA L.N., LAL R., 2008 - *Mulching effect on selected soil physical properties*. - Soil Till. Res., 98: 106-111.
PERCIVAL G.C., 2004 - *Evaluation of physiological tests as a predictor of young tree establishment and growth*. - J. Arboric., 30(2): 80-92.
PERCIVAL G.C., 2005 - *The use of chlorophyll fluorescence to identify chemical and environmental stress in leaf tissue of three oak* (Quercus*) species*. - J. Arboric., 31: 215-227.
PERCIVAL G.C., KEARY I.P., AL-HABSI S., 2006 - *An assessment of drought tolerance of Fraxinus genotypes for urban landscape plantings*. - Urb. For. and Urb. Greening, 5: 17-27.
PERCIVAL G.C., KEARY I.P., NOVISS K., 2008 - *The potential of a chlorophyll content SPAD meter to quantify nutrient stress in foliar tissue of sycamore (*Acer pseudoplatanus*), English oak (*Quercus robur*), and european beech (*Fagus sylvatica). - Arb. Urban For., 34(2): 89-100.
RAKOW D.A., 1989 - *The types and uses of mulches in the landscape*. - Cornell Coop. Ext. Fact Sheet, pp. 700-710.
RONG-HUA L., PEI-GUO G., BAUM M., GRANDO S., CECCARELLI S., 2006 - *Evaluation of chlorophyll content and fluorescence as indicators of drought tolerance in barley*. - Agr. Sci. in China, 5(10): 751-757.
SÆBØ A., FERRINI F., 2006 - *The use of compost in urban green areas. A review for practical application*. - Urb. For. and Urb. Greening, 4: 159-169.
SAMYN J., DE VOS B., 2002 - *The assessment of mulch sheets to inhibit competitive vegetation in tree plantations in urban and natural environmen*t. - Urb. For. and Urb. Greening, 1: 25-37.
SMITH A.M., RAKOW D.A., 1992 - *Strategies for reducing water input in woody landscape plantings*. - J. Arboric., 18: 165-170.
SONSTEBY A., NES A., MAGE F., 2004 - *Effect of bark mulch and N-P-K fertilizer on yield, leaf nutrient status, and soil mineral nitrogen during three years of production*. - Acta Agr. Scand., section B 54: 128-134.
STORK P.R., JERIE P.H., 2003 - *Initial studies of the growth, nitrogen sequestering, and dewatering potential of perennial grass selections for use as nitrogen catch crop in orchards*. - Aust. J. Agr. Res., 54: 27-37.
TILANDER Y., BONZI M., 1997 - *Water and nutrient conservation through the use of agroforestry mulches, and sorghum yield response*. - Plant & Soil, 197: 219-232.
TIQUINA S.M., LLOYD J., HERMS D.A., HOITINK H.A.J., MICHEL F.C. Jr., 2007 - *Effects of mulching on soil nutrients, microbial activity and rhizosphere bacterial community structure determined by analysis of TRFLPs of PCR-amplified rRNA genes*. - App. Soil Ecol., 21: 31-48.
WATSON G.W., 1988 - *Organic mulch and grass competition influence tree root development*. - J. Arboric., 14: 200-203.
WATSON G.W., KUPKOWSKI G., 1991 - *Effects of a deep layer of mulch on the soil environment and tree root growth*. - J. Arboric., 17: 242-245.
WHITCOMB C.E., 1979 - *Factors affecting the establishment of urban trees*. - J. Arboric., 5: 217-219.
WOOD C.W., REEVES D.W., DUFFIELD R.R., EDMISTEN K.L., 1992 - *Field chlorophyll measurement for corn nitrogen status*. - J. Plant Nutr., 15: 487-501.
YAO S., MERWIN I.A., BIRD G.W., ABAWI G.S., THIES J.E., 2005 - *Orchard floor management practices that maintain vegetation or biomass groundcover, stimulate soil microbial activity and alter soil microbial community composition*. - Plant & Soil, 271: 377-389.
ZHANG S., LÖVDAHL L., GRIP H., JANSSON P.E., TONG Y., 2007 - *Modelling the effects of mulching and fallow cropping on water balance in the Chinese Loess Plateau*. - Soil Till. Res., 93: 283-298.
ZHANG S., LÖVDAHL L., GRIP H., TONG Y., YANG X., WANG Q., 2009 - *Effects of mulching and catch cropping on soil temperature, soil moisture and wheat yield on the Loess Plateau of China*. - Soil Till. Res., 102: 78-86.