Effects of tree shelters on young olive tree growth and physiology

Dipartimento di Scienze Agrarie e Ambientali
Università degli Studi di Perugia
Borgo XX Giugno, 74
06121 Perugia, Italy

Dipartimento di Biologia Vegetale e Biotecnologie Agroambientali e Zootecniche
Università degli Studi di Perugia
Borgo XX Giugno, 74
06121 Perugia, Italy

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* Author for correspondence:

Abstract A 3-year study was conducted to evaluate the effects of tree shelters on young olive-tree growth. The trial was carried out in the Apulia region in southern Italy using 1-year-old plants of the cultivar Coratina. Four different types of Tubex (UK) shelters were tested: 75 cm high brown; 90 cm high brown; 75 cm high green; 120 cm high vented (with holes in the basal part of shelters) green. Shelters increased the vertical growth of the trees. In general, the effects were greater with green shelters, especially with green 120 cm vented shelters. Initially, a tendencially lower diametrical growth of the trunk was observed in sheltered plants, with respect to control. However, once growth commenced outside of the shelters, sheltered trees recovered. Shelters did not increase the amount of dry-matter produced, but they modified its allocation within the tree, favouring vertical growth and the development of shoots in the distal parts of the trees.

Key words Acclimation; leaf anatomy; photosynthesis; pruning.

INTRODUCTION

Tree shelters were originally developed in the United Kingdom to increase the survival of newly transplanted forest plants by protecting them from animal browsing. In their basic form they are individual net or plastic protections that are placed around the trees at planting. They are usually constructed from plastic-based material (usually polypropylene) that may be translucent or coloured. The shape can be either cylindrical, square, triangular or poliedric and the height is usually in the range of 40 to 150 cm.

As a result of their use, it was soon observed that, other than merely protecting trees, they also enhanced height tree growth of several species, with effects that appeared to be species-dependent (Frearson and Weiss, 1987; Potter, 1988; Burger et al., 1992; Buresti and Sestini, 1994; West et al., 1999). For example, height increases of 60% and 600% were observed with cherry and oak seedlings, respectively (Frearson and Weiss, 1987; Potter, 1988). Shelters have subsequently been successfully used for nursery plant production and tree establishment in arboriculture for wood production, reforestation, landscape revegetation and urban environments (Buresti and Sestini, 1994; Burger et al., 1992; West et al., 1999).

Growth increases have been attributed to the creation of a more favourable microenvironment around the plants that improves conditions for photosynthesis. Increases in temperature, relative humidity and CO_2 concentration within the shelter have all been suggested as probable causes for the increased growth (Frearson and Weiss, 1987; Tuley, 1985; Potter, 1988, 1991; Burger, 1992). However, the nature of the relationship between these environmental characteristics and their effect on physiology and growth of sheltered trees is not clear. A positive effect on growth could also be related to increased leaf area, the chlorophyll retention promotion and reduced water-use observed in sheltered plants (Burger, 1992; Minter et al., 1992; Kjelgren, 1994). Moreover, shelters tend to reduce weed competition and to prolong the net effective growing season, giving plants an extended period of more suitable temperatures (Ponder, 1994).

However, negative effects have also been observed in some studies. The taller plants produced with shelters often showed reduced stem calipers (Tuley, 1981; Lantagne et al., 1990; Smith, 1983; Kjelgren, 1994; Burger et al., 1996). Sometimes a smaller root-system, that could cause stability problems for the plants after the shelter is removed, was produced (Potter, 1991; Mayhead and Jenkins, 1991; Burger et al., 1992; Mayhead and Boothman, 1997). Shelters reduce light intensity and can also be responsible for conditions leading to suboptimal air temperatures and decreased winter hardiness (Kozlowski, 1979; Mebrahtu and Hanover, 1991; Kjelgren, 1994; Kjelgren and Rupp, 1997; Kjelgren et al., 1997; Swistock et al., 1999).

Very little data is available evaluating the mechanism through which shelters determine their effects on plant physiology. Shelters were reported to reduce water-use but not drought avoidance (Kjelgren, 1994; Kielgren et al., 1997), to increase specific area of leaves growing inside them and to have an effect on photosynthesis that was dependent on the tree species (Kjelgren, 1994; Kjelgren et al., 1997). Data on the relationships/interactions between initial plant size and shelter dimension and colour is also sparse (Buresti and Sestini, 1994; Kjelgren et al., 1997).

In the last decade, the effects of shelters have also been evaluated on agriculturally important plant species, such as coffee and, more recently, grape (Kjelgren, 1994; Lavezzi et al., 2001). In grape, shelters enhanced vine survival, shoot and root growth, disease avoidance and improved weed control and pruning (Lavezzi et al., 2001). These positive results have stimulated an interest in evaluating the use of shelters on other fruit species to accelerate initial growth and fruiting of new plantations as well as to simplify the application of common cultural practices.

The two objectives of this work were, a) to evaluate the effects of shelters on olive tree growing, b) to better understand the mechanism through which the shelters modify tree growth and assimilate availability.

MATERIALS AND METHODS

The trial was carried out in the Apulia region in southern Italy. The Apulia region is the area of highest olive production in Italy, representing 35-40% of total Italian olive production. It is a relatively flat and low-lying region characterised by mild temperatures during winter, high temperatures during summer and an annual rainfall of about 600 mm.

The experiment was carried out in low-lying flat land where the soil is clay-like. In February 2002, a new olive orchard was established at this location using 1-year-old of the Coratina cultivar, one of the main olive cultivars in the Apulia region.

Four different types of shelters produced by Tubex (UK) were tested: 75 cm high brown; 90 cm high brown; 75 cm high green; 120 cm high green. The latter included an integral ventilation system consisting of a series of holes at the base of the tube that created a "chimney effect"; in addition, the manufacturer treated the material of which the tube is made of in a particular way in order to improve the light transmission properties of the shelter. For purposes of clarity, this product, known as the Tubex Ventex [EU Patent No. 0558386], will be described as green 120 cm vented shelters throughout the text. Unsheltered plants were established as control groups. Forty plants were used for each treatment. They were randomly distributed as rows in groups of five, with a spacing of 3 x 3 m. Immediately after planting, shelters were placed over the plants and the base was inserted 5 cm into the ground. Shelters were then firmly attached to supporting stakes placed on the north side of the tube.

For the first two years of the study temperature (T), relative humidity (RH) and photosynthetically active radiation (PAR) inside and outside the shelters (control plants) were measured periodically at both locations, using a thermoigrometer for T and RH and a sensor/LICOR LI-185 apparatus for PAR.

Tree height and basal stem diameter about 10 cm above the collar were measured and recorded at planting time and periodically thereafter.

The number of nodes and the length of internodes on the stem were recorded at planting and at the end of the first vegetative season, in control plants and in plants with green 120 cm vented shelters.

At the end of the first two years of field growth, three plants per treatment were extirpated and both fresh- and dry-weight of roots, trunk, branches, shoots and leaves were determined. At the end of the first year, surface and specific-weight of leaves located inside and outside the shelters were also determined on samples of 20 leaves per extirpated tree, by using a leaf area meter (*Hayashi Denkoh Co.*, model *AAM-7*, Tokyo, Japan) and by drying them to a constant mass (dry weight) in a forced-air oven at 105°C.

At the end of winter of each growing season, the amount of pruned material was recorded.

Periodically, observations were made of the overall appearance of the trees, to evaluate possible changes induced by shelters on the susceptibility of plants to biotic and abiotic adversities.

Observations to determine the number of plants damaged by harrowing after tillage of the soil were performed.

Leaf photosynthesis (P_N), transpiration rate (E), stomatal conductance (g_S) and sub-stomatal CO_2 concentration (C_I) were determined periodically for a two-year period. Photosynthesis measurements were taken on cloudless days, from 09:00 to 11:00 in the morning, in three different kinds of leaves: fully-expanded leaves present on the stem at the time of planting (old leaves), fully expanded leaves grown inside the shelters and fully expanded leaves grown outside the shelters. All measurements were made using an LCA-2 portable gas exchange analyser (Analytical Development Co., Hoddesdon, Herts, U.K.) and a Parkinson leaf chamber type PLC. The detached leaf was immediately enclosed in the chamber and exposed perpendicularly to sunrays (incoming PPFD 1400-1600 μmol m^{-2} s^{-1}). Measurements were taken, depending on the treatment and the kind of leaf used, at full light and/or after a piece of shelter, cut from the respective type of shelter used for the considered tree, was placed over the chamber so that the light levels were similar to those inside the shelter. All measurements were taken under steady-state conditions.

To determine blade and palisade thickness, leaves grown inside and outside the shelters and leaves of the control trees were collected, fixed in glutaraldehyde (5% v/v) overnight at room temperature and post-fixed in osmium tetroxide (1% w/v) for 4 hours (both in 0.075 M cacodylate buffer, pH 7.2). After dehydration with a graded ethanol series and propylene oxide, the samples were embedded in resin (Epon, DDSA and MNA mixture) (Loreto et al. 2001). Transversal and longitudinal sections (1.5 μm thick) from each sample were stained with toluidine blue and mounted in Eukitt for light microscopy observation. Photomicrographs were made using a Leica DMR HC photomicroscope.

The image analysis software LEICA IM1000 was used for measuring leaf thickness and palisade parenchyma height.

Data regarding plant growth were statistically analysed by ANOVA, according to a complete randomized design, and the averages were compared by the Student-Newman-Keuls Test. All the other data are reported in figures and tables as means ± standard error.

RESULTS

Higher temperatures were detected inside the shelters than in the control (Figure 1A); in the green 120 cm vented shelters temperatures were lower than in the other shelters and sometimes similar to control. Also the relative humidity within the shelters was higher than in the control, with the exception of the green 120 cm vented shelters which showed values lower or similar to the control (Figure 1B). The ranges of variation of temperature and relative humidity changed over the different seasons. The shelters reduced the light intensity inside them. The green 120 cm vented shelters allowed more light than the others (Figure 2A and B; data not shown for the second year of field growth).

In general, shelters increased the height of the trees (Figure 3). In general, the effects were greater with green shelters. Trees with green 120 cm vented shelters showed the greatest increase in height.. At the end of the first year of field-growth (January 2003) they were taller than control trees after two seasons of field-growth (February 2004) (Figure 3). The shelters determined a higher tree-height increment in the first year of field-growth, with respect to the control, while in the second and third years the general growth and differences among treatments were less marked and shelter-dependent (Figure 3). In the first year of field-growth, all shelters, especially the green ones, determined a higher tree-height increment in spring and summer, with respect to the control (Figure 3). The green 120 cm vented shelters promoted a greater growth also in autumn, showing a longer positive effect on tree-height growth. At the end of the first vegetative season, the number of nodes along the stem of control plants and plants with green 120 cm vented shelters was substantially similar (Figure 4A and B), whereas sheltered plants showed longer internodes in the stem portion grown inside the shelters (Figure 4C).

In the first year of field growth, shelters tended to determine a lower diametrical growth of the trunk, with respect to control (Figures 5). Later, sheltered trees showed increments higher than control and, so, they recovered.

After two years of field-growth the amounts of dry-matter in the different roots, trunk, branches, shoots and leaves of trees grown in green shelters were similar to those of the control, while lower values were observed for trees grown in the brown shelters (Figure 6).

After one year of field-growth a significant proportion of shoots and leaves were still located inside the shelters (38, 55, 24 and 65% of total shoots and 18, 29, 23 and 48% of total leaves, respectively for brown 75 cm, brown 90 cm, green 75 cm and green 120 cm vented shelters), especially in the green 120 cm vented shelters. After two years of field-growth, the proportion of leaves inside the shelters decreased substantially as a result of the growth of the trees outside the shelters (8, 11, 7 and 5% of total shoots and 7, 7, 6 and 6% of total leaves, respectively for brown 75 cm, brown 90 cm, green 75 cm and green 120 cm vented shelters).

The leaves inside the shelters generally showed a larger surface and a lower specific-weight with respect to the leaves outside the shelters (on average +7% and –21%, respectively). Leaves grown inside the shelters had lower blade thickness and palisade height with respect to the control (Table 1). The shelters did not affect the anatomy of leaves grown outside them (leaf thickness and palisade parenchyma height were, respectively, 403±5 μm^2 and 160±8 μm^2 for the control and 416±9 μm^2 and 145±8 μm^2 for the green 120 cm vented shelter).

All leaves inside the shelters had lower photosynthesis values than control (full light) (Figure 7). Leaves inside the green 120 cm vented shelters had higher values than those in the other shelters. No differences, also in the second year of field growth (data not shown), with respect to control were detected for leaves grown outside the shelters. Old leaves and leaves grown inside the shelters, if exposed to full light tended to increase their photosynthetic activity but, in general, they did not reach values as high as those of the control (data not shown). In general, leaves grown inside the shelters showed higher values of *gs* and *Ci* and lower values of *E* (data not shown).

No damage due to high temperatures were observed during the experimental period No significant effects of shelters on biotic adversities were observed. Shelters prevented damage caused by harrow during soil tillage, whereas 6-7% of control trees showed some damage. Occasionally, in spring weeds grew inside the shelters but, in general, they died during summer.

In sheltered trees, pruning was performed by eliminating, pinching off or bending shoots that were in an inappropriate position and this pruning was easy to apply. Shoots which had grown vertically inside the shelters were bent or pinched off, depending upon their particular location on the trunk. Control trees required a more severe pruning than sheltered ones (Figure 8), because they had more vigorous branches inserted in the basal portion of the trunk that had to be removed.

DISCUSSION AND CONCLUSIONS

In general, the profiles of temperature, relative humidity and light observed in the shelters confirmed what has been already reported in other studies (Burger et al., 1992; Sharpe et al., 1999; Kjelgren, 1994; Kjelgren et al., 1997; Lavezzi et al., 2001). However, it is interesting that the green 120 cm vented shelters showed a lower reduction in light intensity, and its integral ventilation system determined a lower increase of temperature and values of RH that were lower than or similar to those of control, showing an opposite behaviour with respect to the other shelters that increased RH.

In general, the shelters increased olive tree height. Therefore, olive can be included among the woody species for which height growth can be significantly increased by using shelters.

The extent of increase in tree-height was related to the type and height of the tree shelter that was used. The greatest increases in height were obtained with the green 120 cm vented shelters. Among the other shelters, the green 75 cm shelter gave better results than the others. This is in contrast with a study concerning Q*uercus robur* in which brown shelters gave better results than green ones (Buresti and Sestini, 1994). During the current experiment, young trees (1-year-old trees) gained at least one-year of growth in height with the green 120 cm vented shelters. The greatest increase in height of sheltered trees was the results of a higher elongation of the internodes grown inside the shelters. This growth advantage persisted in successive years.

As the shelters substantially affected the internode length of the stem portion grown inside them, the shelter influence on height growth decreased once the trees had grown beyond the height of the shelter. At the beginning, in relatively young trees the greater growth in height of sheltered trees was associated with the tendency to reduce the diametrical growth of the trunk, but after 2-3 years of field growth sheltered trees had recovered and, in some cases (i.e. green 75 cm shelters), their trunk cross section tended to be even larger than that of control.

The examination of the amount of dry-matter produced per tree showed that the increased height of sheltered trees is not due to an increase in the dry-matter production, but to a different allocation of assimilates which favoured height growth and development of shoots in the distal part of the trees. In the first year of field growth, the amount of dry-matter produced by sheltered plants was lower than that produced by control plants. This is logical as in the first year a large part of the leaves were located inside the shelters and their photosynthesis was negatively affected by the lower light-intensity within the shelters with respect to outside. Successively, the dry-matter content of sheltered trees tended to recover, particularly with green shelters, as leaves located within the shelters were proportionally less and in control plants more branches and auxiliary shoots were removed with pruning. In this regard, also in other species, no substantial differences were found in biomass production between sheltered and unsheltered plants (West et al., 1999; Lavezzi et al., 2001).

Photosynthesis of leaves inside the shelters was negatively affected by the lower levels of light, although the higher temperature, relative humidity and CO_2 concentration inside the shelters, that have been reported elsewhere as factors that may partly favour the increase of plant growth (Weiss, 1987; Burger et al., 1992), may have had a positive role on photosynthesis of leaves inside the shelters. However, in this study their possible effect has not determined higher values of dry matter production in sheltered trees. In this regard, it has to be considered that the higher amount of light that can pass through green 120 cm vented shelters with respect to the other shelters allows higher P_N values and this could contribute to an increase in the amount of assimilate available for the trees. Moreover, it has to be taken into account that an increase in temperature can have a positive effect on assimilate production up to a certain point and that, beyond this, it can exert a negative effect by increasing respiration. The fact that limitations on photosynthesis were only observed on leaves grown inside the shelters demonstrates that shelters did not present indirect or detrimental effects on the P_N of leaves grown outside them. The higher values of *gs* and lower values of *E* observed in leaves inside the shelters are consistent with other reports (Kjelgren et al., 1997). The higher *Ci* values in the same leaves indicate internal P_N limitations probably due to the anatomical adaptations of leaves grown under low light intensity.

In general, the observed tree growth changes reflect the adaptations and acclimation that plants normally show in conditions of shade. It is known that plants that are put very close to one another, because of the reciprocal shading, compete for the light by privileging the growth in height toward the light and reducing trunk diameter increment, by showing a phototropism phenomenon. Shading inside the shelters has likely produced a similar effect. The tendencially smaller trunk diameter in sheltered trees may also be due to limited trunk movement in the wind-free confines of the shelter (Harris et al., 1976). Considering this, the recovery in trunk-diameter of sheltered trees observed over the time-period of the study could also be due to the fact that once the plants have outgrown the shelters they are subjected to wind movement and revert to normal trunk development dynamics. However, it is also interesting to note that shelters, as time passes, tend to increase the diametrical growth of the trees. This could be also the result of the variations of microclimatic conditions (temperature, RH and light intensity and quality) inside the shelters that could promote a higher cambium activity, also by influencing the hormone balance that regulate the cambium activity. The larger surface area and lower blade and palisade tissue thickness of leaves grown inside the shelters also represent a form of shade acclimatisation (Bjorkman, 1981; Proietti et al., 1988). These adaptations enable leaves to be more efficient when light intensity is low. The results are in agreement with the greater specific leaf area of foliage inside shelters observed in other studies (Kjelgren, 1994; Kjelgren and Rupp, 1997).

The shelters used in this trial did not seem to create conditions that favour the occurrence of biotic or abiotic damage on the plants. To the contrary, in Norway maple (*Acer platanoides* L.) and green ash (*Fraxynus pennsylvanica* Marsh) winter injuries were increased by shelters (Kjegren et al., 1997).

Considering the overall outcome of the study regarding plant growth and the implications for the use of shelters on cultural practices, it is possible to draw some practical indications concerning the potential impact of using tree shelters for olive-tree growing. In olive growing 1- to 2-year-old plants and, less frequently, 3-year-old plants are normally used for the establishment of new orchards (Scaramuzzi, 1977; Barranco et al., 1997; Alfei et al., 2003). Younger trees give good results because they usually show initially a very intense and rapid growth. However, on the other hand, they require more care in the first period of their development, especially for the execution of training pruning, because they tend to branch in the basal portion of the stem. Two and three-year old trees are normally subjected to pruning according to the “vase” system in the nursery so as to make them easier to prune in the field the following year. The use of shelters in combination with young plants (1-year-old) provides an opportunity to increase the initial rapid growth of young trees and at the same time to simplify the training pruning. With older trees (3 year-old) the effect of shelters on their growth is very limited (unpublished data). In all cases shelters prevent or reduce drastically the possible damage to trees during tillage of the soil, facilitate the eventual application of herbicides and do not seem to increase the susceptibility of trees to biotic or abiotic adversities. Obviously, in areas where grazing damage from animals can be a problem to the young trees, the use of shelters in their traditional role can avoid such problems.

The economic convenience in using shelters has to be evaluated taking into consideration the lower price of young plants, and the indirect advantages in terms of pruning, soil management, etc., versus the cost of purchasing and installing the shelter. This research has shown that better results are achieved when green shelters, above all if green 120 cm vented shelters, were used. For optimal results, the choice of tree shelters depends upon the height of the olive trees at planting. As a general recommendation, it is suggested that 75 cm high green shelters are used for plants up to 40-50 cm of height, and that taller shelters (from 75 cm to 120 cm) are used for plants over 50 cm in height. As the “vase” is at the moment the most used olive training system and a free trunk 100-120 cm high is required for the mechanisation of harvesting with trunk shakers, shelters have to be chosen to ensure the trees achieve such trunk height. This height also facilitates the passage and use of machines for the other cultural practices. Also, when other training systems are applied, a free trunk 100-120 cm is usually required for mechanisation.

Further studies would be useful to evaluate the long-term influence of tree shelters on olive trees, including the fruiting phase, as well as how tree shelters could be best applied to improving olive tree husbandry and nursery growing practices. In particular, the application of tree shelters for supporting rapid growth of olive trees in nurseries could be valuable.

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Table 1 Comparison of characteristics of leaves grown inside the shelters and in corresponding positions in control trees at the end of the first year of field-growth. Each value is the mean of 5 replicates ± standard error.

	Leaf thickness (μm^2)	Palisade parenchyma height (μm^2)
Control (no shelter)	415 ± 9	150 ± 5
Brown 75 cm high	355 ± 5	118 ± 6
Brown 90 cm high	352 ± 6	115 ± 4
Green 75 cm high	375 ± 5	123 ± 8
Green 120 cm high	380 ± 6	125 ± 4

Figure legends

Fig. 1 Effects of different types of shelters on air temperature (A) and relative humidity (B) around the trees. Each value is the mean of 30 + 30 replicates taken for each season in the first two years of experiment ± standard error.

Fig. 2 Effects of different types of shelters on light-intensity in empty shelters (A) and in shelters with plants inside (B). Each value is the mean of 30 + 30 replicates taken in spring and summer of the first year of experiment ± standard error.

Fig. 3 Effects of different types of shelters on tree-height growth. For each time of measurement, means accompanied by the same letter are not significantly different at $P \leq 0.05$.

Fig. 4 Effects of green 120 cm vented shelter on the tree height growth (A), number of nodes (B) and internode elongation (C) evaluated at the end of the first year of field-growth. Each value is the mean of 10 replicates ± standard error.

Fig. 5 Effects of different types of shelters on trunk cross-section growth. For each time of measurement, means accompanied by the same letter are not significantly different at $P \leq 0.05$.

Fig. 6 Effects of different types of shelters on dry-matter allocation in the different organs of trees at the end of the first two years of field-growth. Each value is the mean of 3 replicates ± standard error.

Fig. 7 Effects of different types of shelters on leaf photosynthesis during the first year of field growth. Each value is the mean of 4 replicates ± standard error.

Fig. 8 Effects of different types of shelters on the cumulated amount of material cut with pruning in the first three years of field growth. Each value is the mean of 30 replicates ± standard error.

Fig. 1

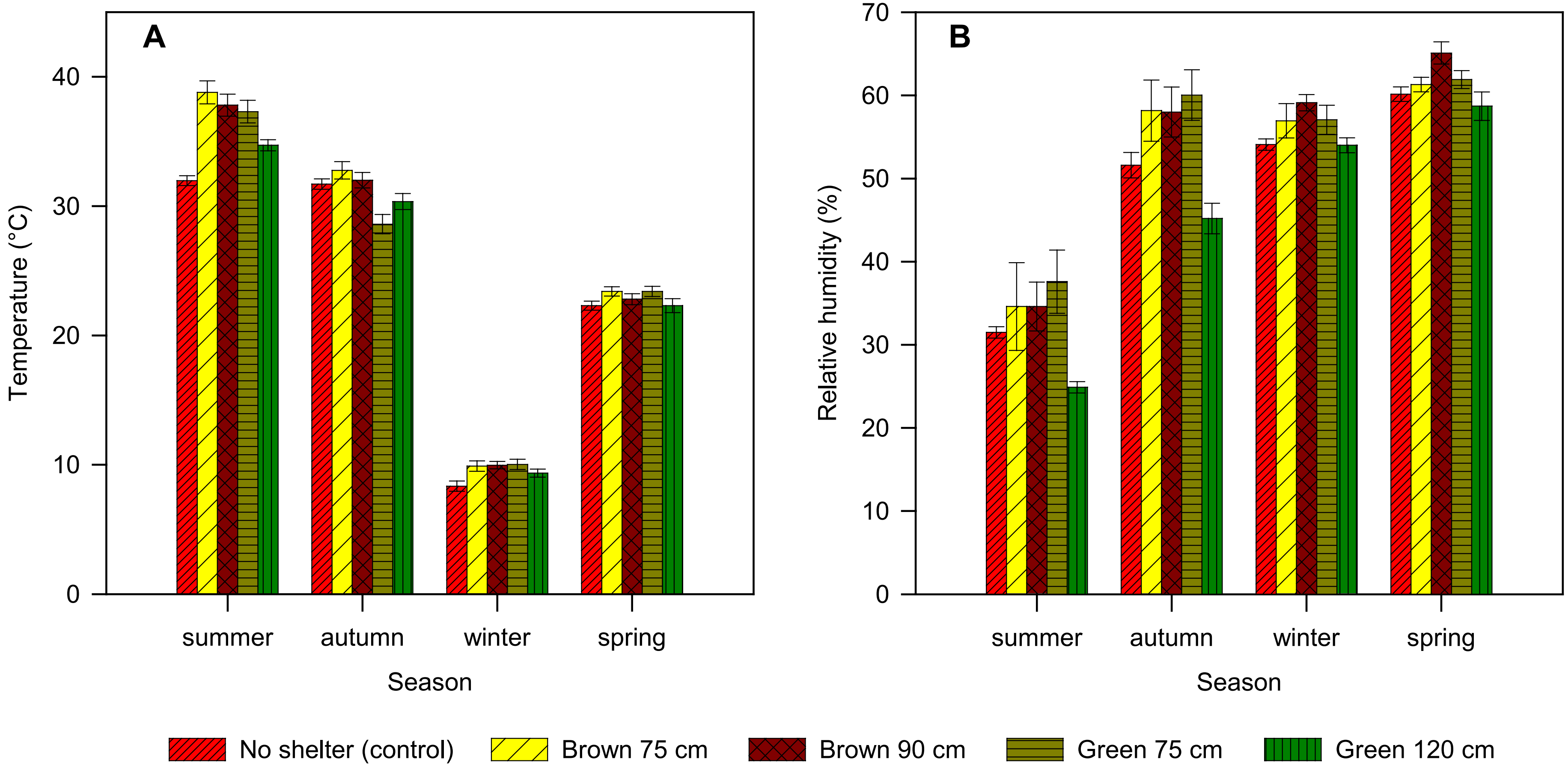

A
B
Temperature (°C)
Relative humidity (%)
0
10
20
30
40
50
60
70
summer
autumn
winter
spring
Season
No shelter (control)
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm

Fig. 2

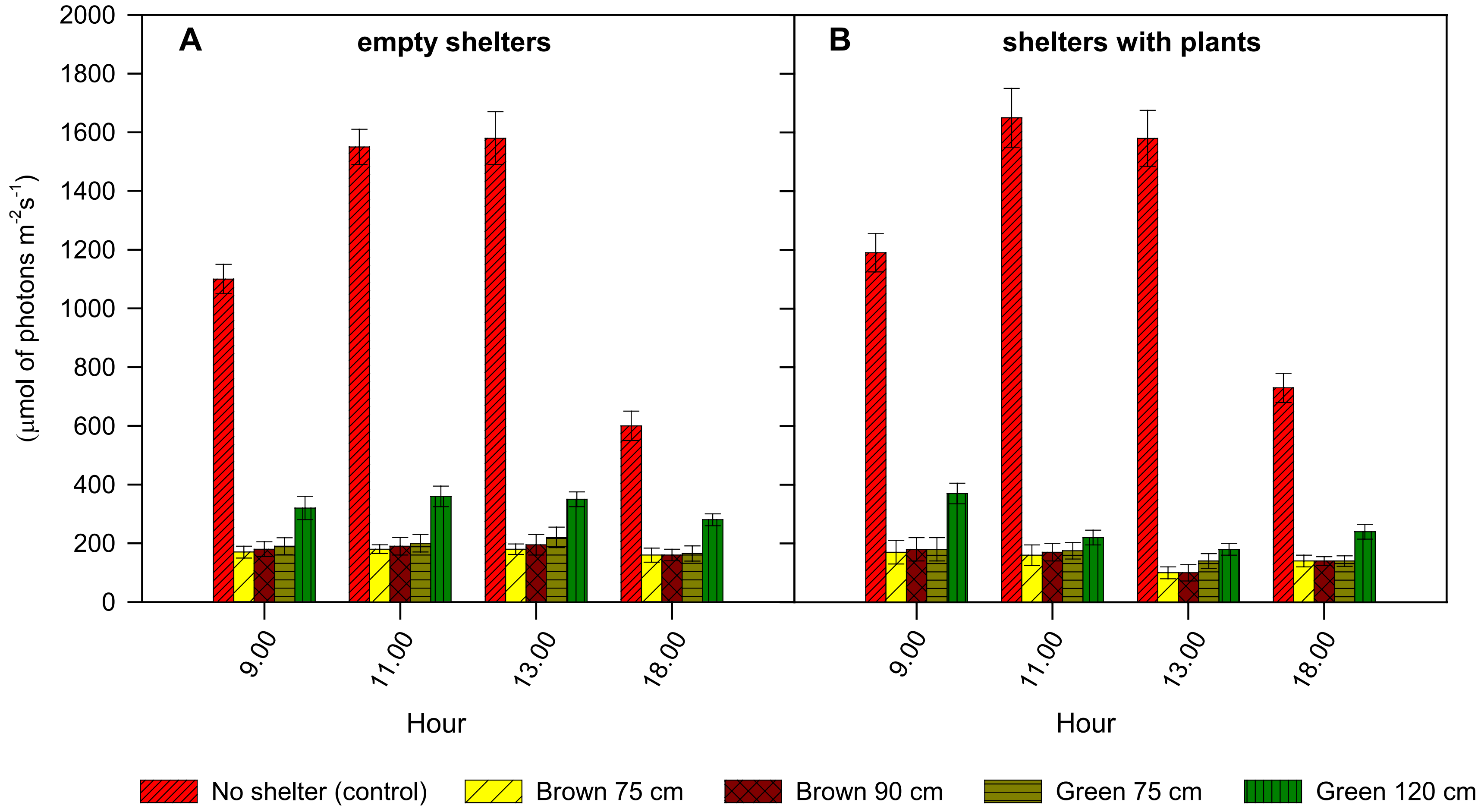

A
empty shelters
B
shelters with plants
2000
1800
1600
1400
1200
1000
800
600
400
200
0
(µmol of photons m-2s-1)
9.00
11.00
13.00
18.00
Hour
Hour
No shelter (control)
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm

Fig. 3

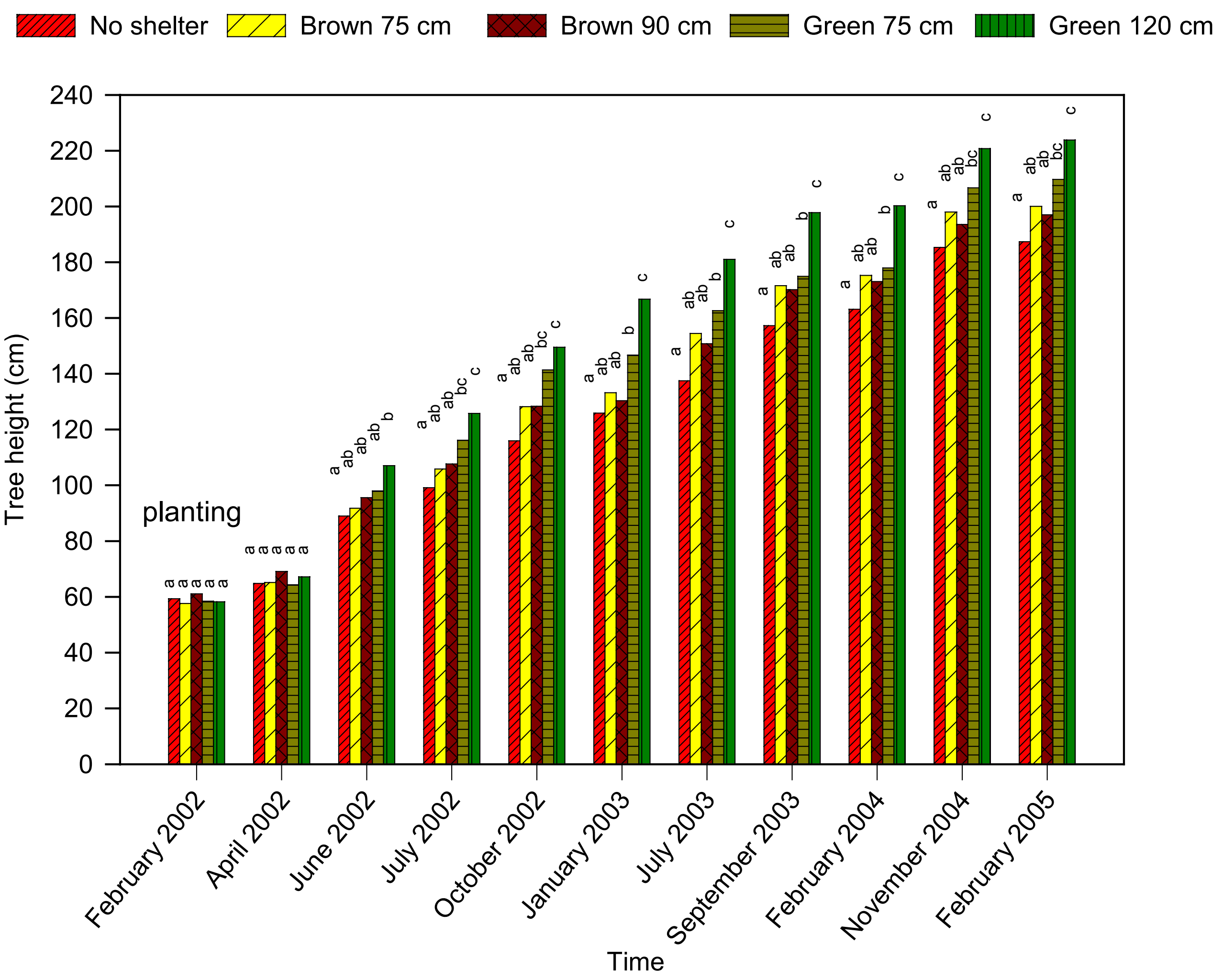

No shelter
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
Tree height (cm)
Time
planting
February 2002
April 2002
June 2002
July 2002
October 2002
January 2003
July 2003
September 2003
February 2004
November 2004
February 2005

Fig. 4

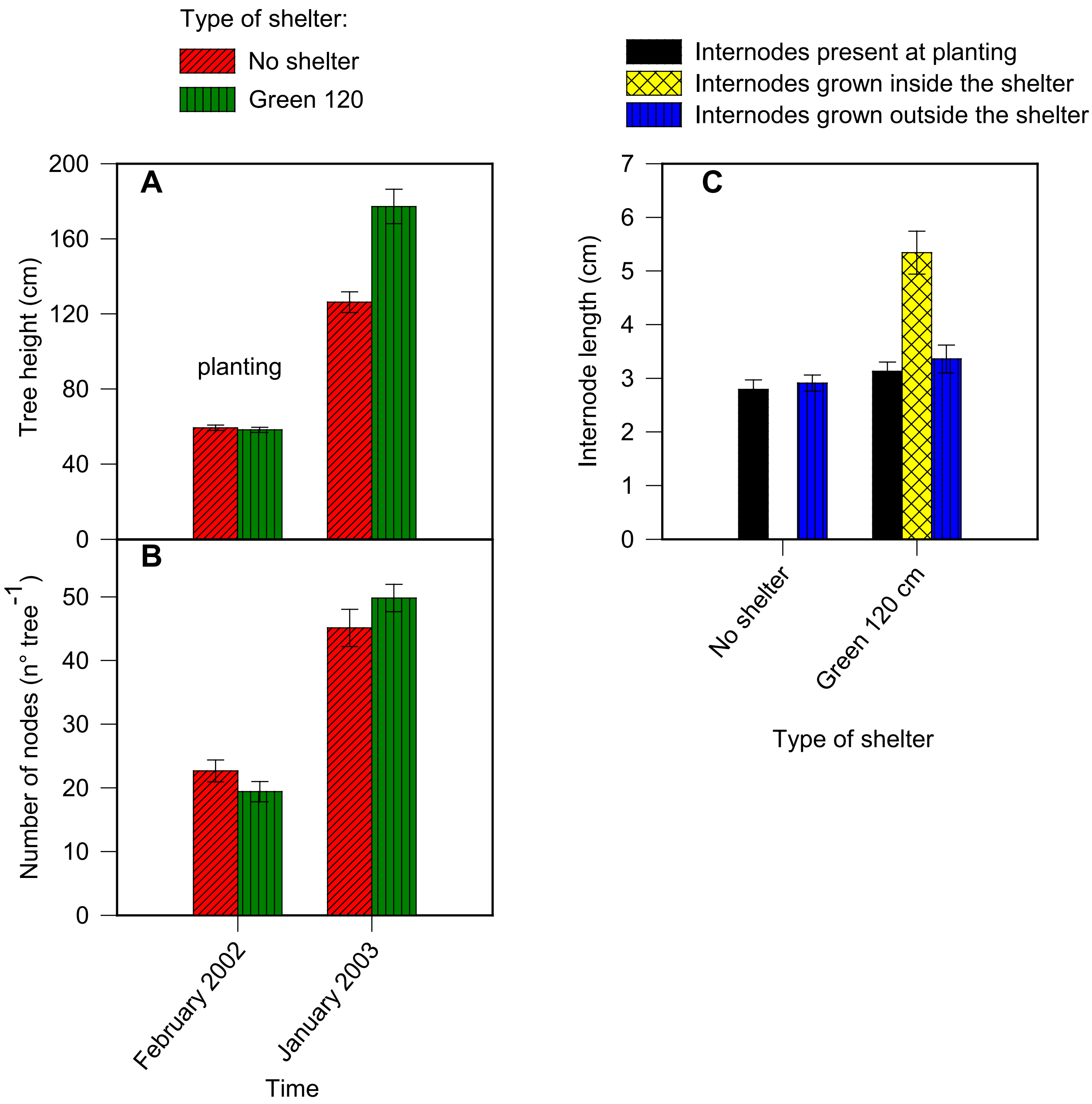

Type of shelter:
No shelter
Green 120
Internodes present at planting
Internodes grown inside the shelter
Internodes grown outside the shelter
A
B
C
planting
Tree height (cm)
Number of nodes (n° tree^{-1})
Internode length (cm)
February 2002
January 2003
Time
No shelter
Green 120 cm
Type of shelter

Fig. 5

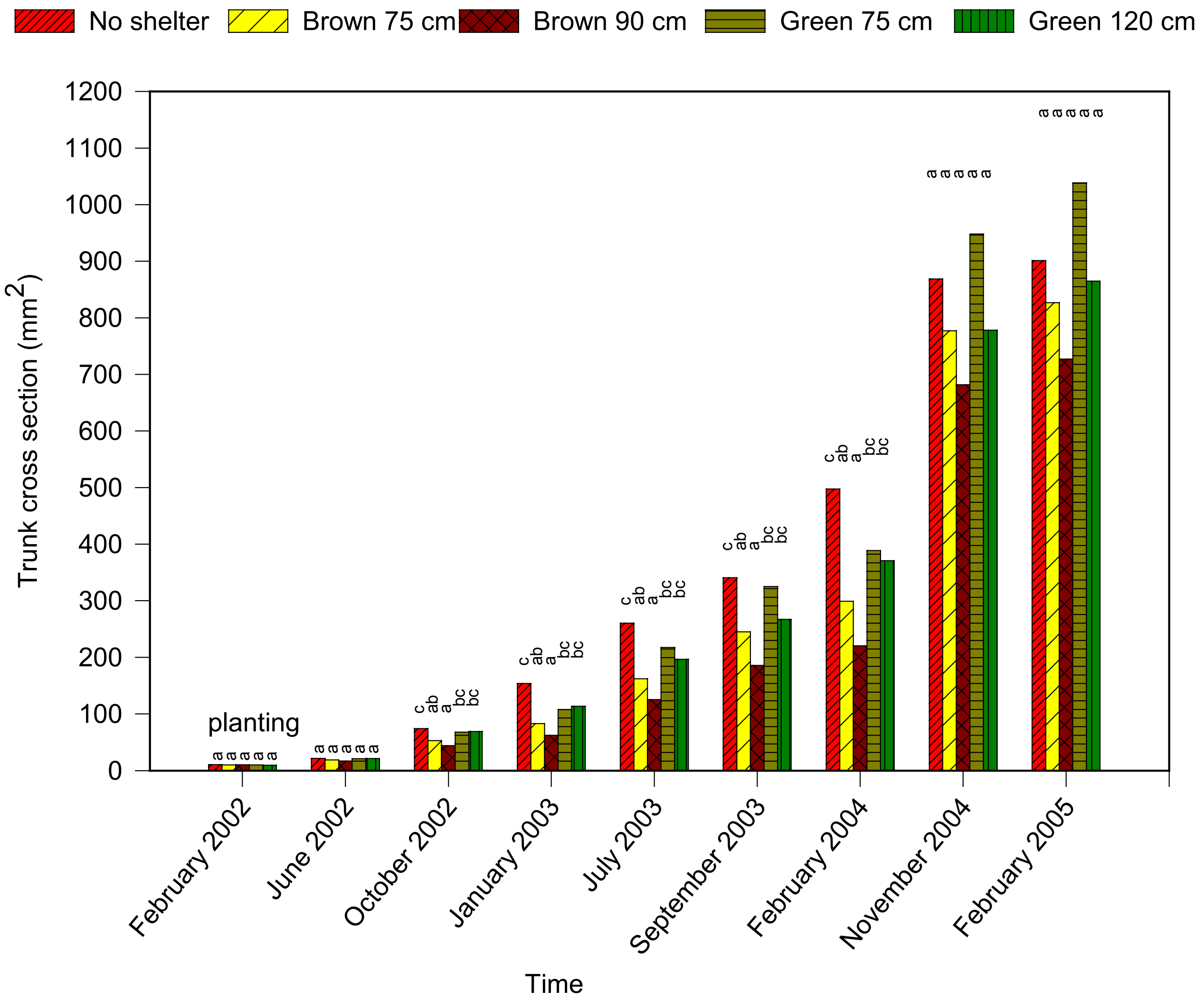

No shelter
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
Trunk cross section (mm2)
1200
1100
1000
900
800
700
600
500
400
300
200
100
0
planting
February 2002
June 2002
October 2002
January 2003
July 2003
September 2003
February 2004
November 2004
February 2005
Time

Fig. 6

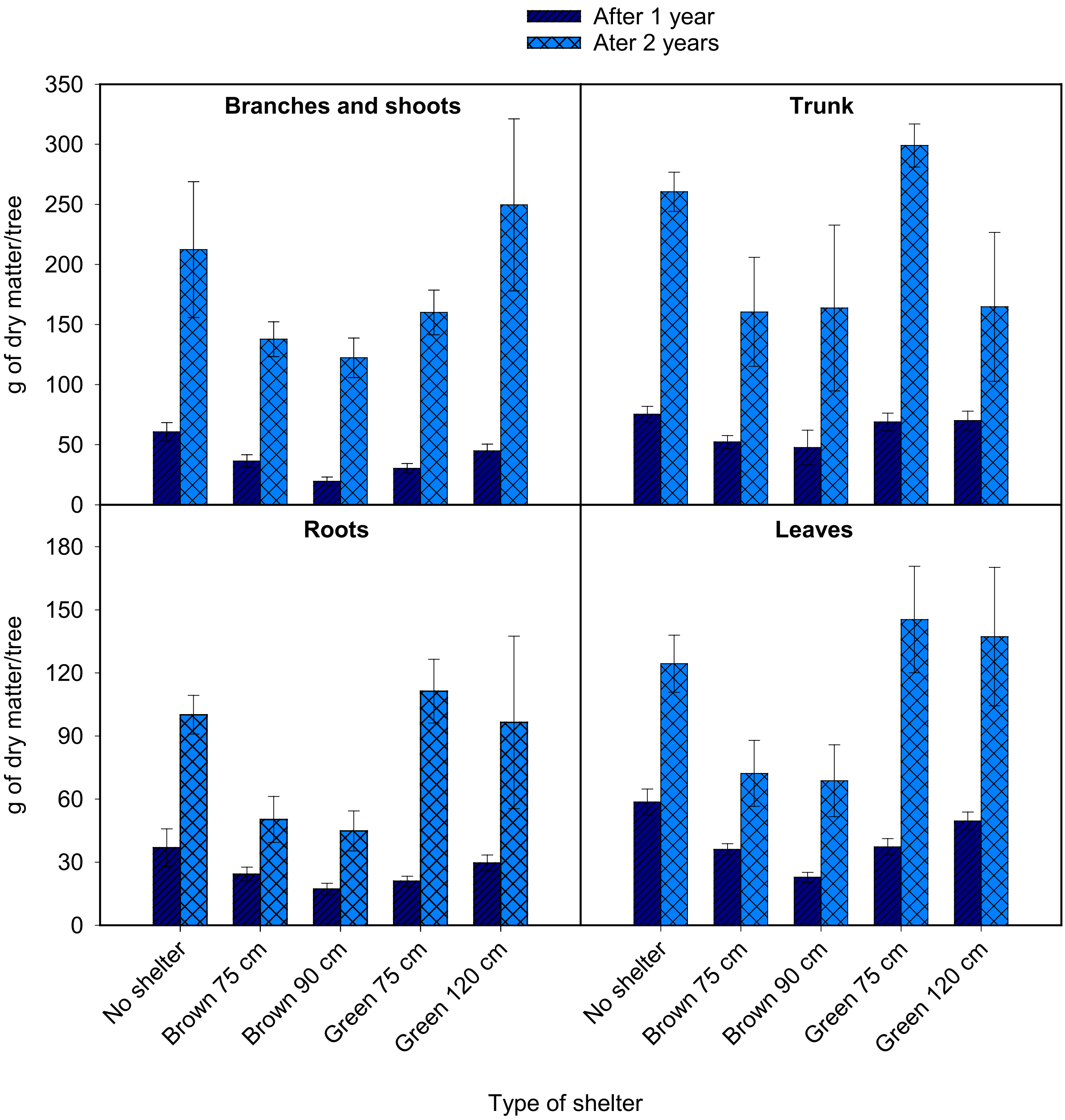

After 1 year
Ater 2 years
Branches and shoots
Trunk
Roots
Leaves
g of dry matter/tree
g of dry matter/tree
0
50
100
150
200
250
300
350
0
30
60
90
120
150
180
No shelter
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
No shelter
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
Type of shelter

Fig. 7

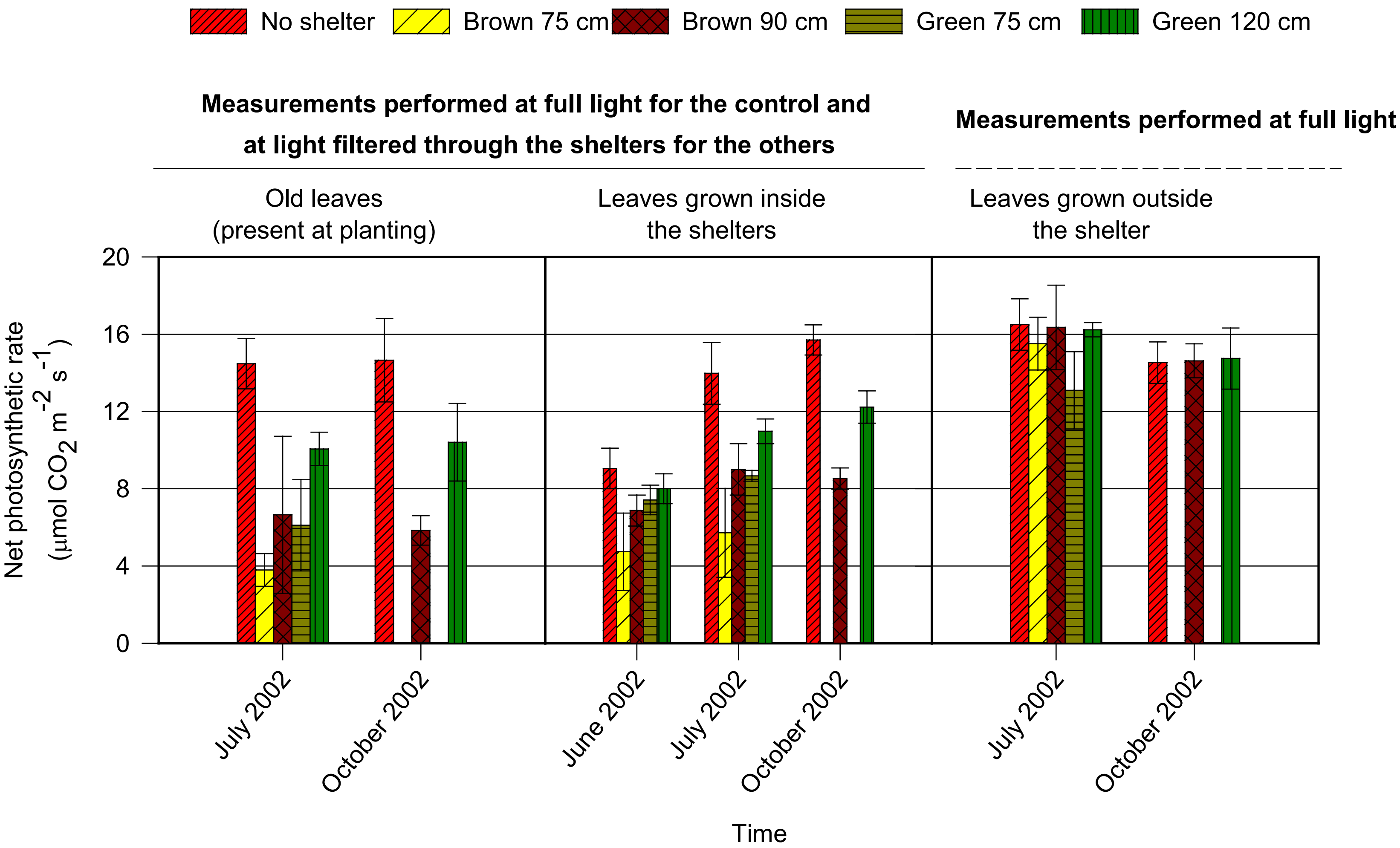
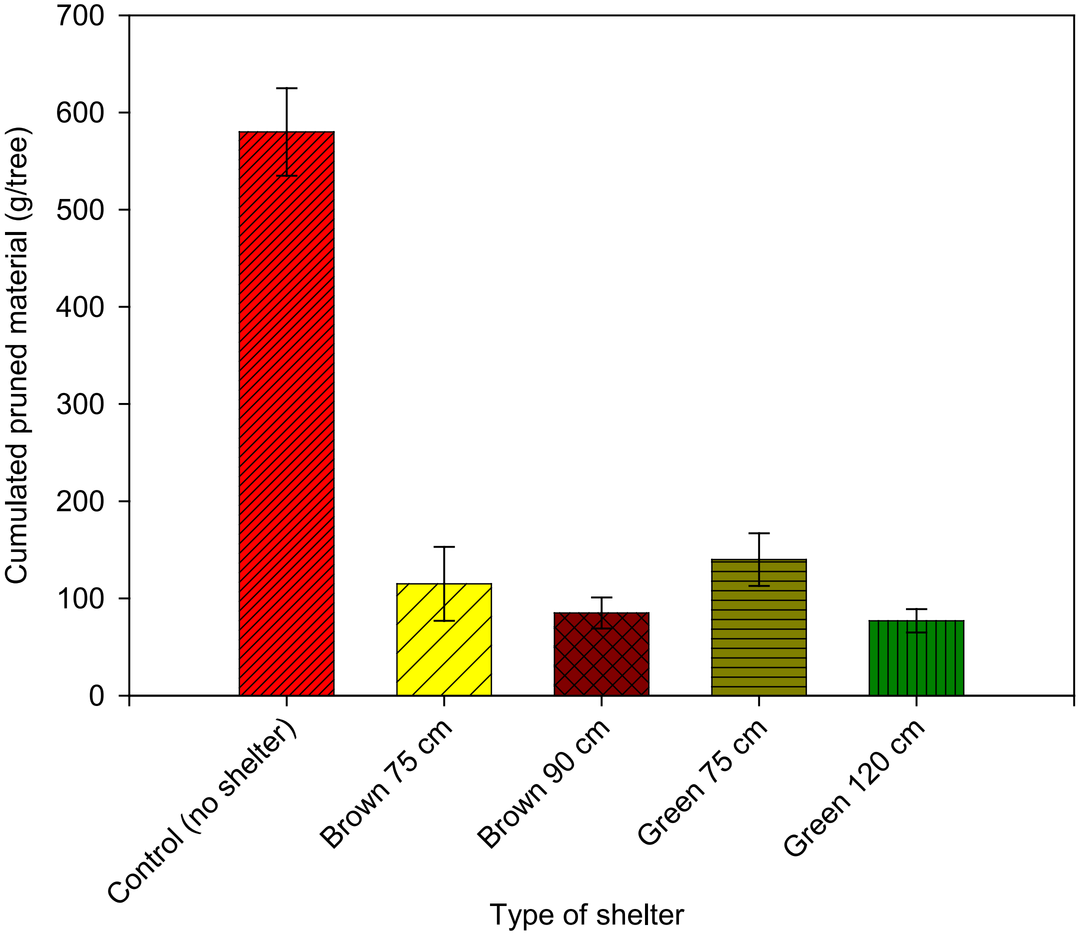

No shelter
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
Measurements performed at full light for the control and at light filtered through the shelters for the others
Measurements performed at full light
Old leaves (present at planting)
Leaves grown inside the shelters
Leaves grown outside the shelter
Net photosynthetic rate (µmol CO2 m-2 s-1)
0
4
8
12
16
20
July 2002
October 2002
June 2002
July 2002
October 2002
July 2002
October 2002
Time

Fig. 8



Cumulated pruned material (g/tree)
700
600
500
400
300
200
100
0
Control (no shelter)
Brown 75 cm
Brown 90 cm
Green 75 cm
Green 120 cm
Type of shelter