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Post-planting treatments and shading effects in a *Fraxinus angustifolia* Vahl. silvopastoral system

G. Klossas, A.P. Kyriazopoulos, Z. Koukoura

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Abstract. Silvopastoral systems present difficulties in their management due to their complexity. When trees are planted into grasslands, they need protection from livestock to prevent damage from trampling or browsing, especially during early years of establishment. One of the common post-planting protective treatments is the protection of individual trees with shelters. Trees also need protection from competition from herbaceous vegetation. The aim of present study was to evaluate the effects of using different types of tree shelters and of controlling competing herbaceous vegetation on the growth of planted young trees and, to assess the effects of heavy shading on the herbage production and composition. The study was conducted in a *Fraxinus angustifolia* silvopastoral system of a 2 x 2.5 m spacing plantation in northern Greece. The effects of solid-walled (tubex and handmade by greenhouse nylon) and wire mesh tree shelters as well as of herbicide application and mechanical removal of the competing herbaceous vegetation on tree height, height increment and the crown surface area of the trees were tested. The effects of artificial shading (80%) on the production of the natural herbaceous vegetation were also investigated. All measurements were recorded three years after plantation. The use of solid wall tubex shelters resulted in higher tree height and higher crown surface area in comparison to the other tested shelters. The solid wall Nylon shelters were more beneficial to the above growth parameters than the wire mesh ones. Both vegetation control treatments proved beneficial to all the growth parameters of *Fraxinus angustifolia*. The artificially applied heavy shading reduced herbage production by 54% compared to the control. The results indicated that post planting treatments in the Mediterranean droughty conditions are essential for the success of this tree species establishment. Furthermore, the later thinning of the dense spacing is important to maintain high herbage production.
Keywords herbage production, Mediterranean region, tree growth, tree shelters, vegetation control.

Authors. Giorgos Klossas, Apostolos P. Kyriazopoulos (apkyriaz@fmenr.duth.gr) Zoe Koukoura - Laboratory of Range Science (236), School of Forestry and Natural Environment, Aristotle University of Thessaloniki, 54124 Thessaloniki, Greece.
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Introduction

Human population growth intensified the pressure on food production (Zhao et al. 2003). As a result, agricultural areas expanded and livestock population increased to meet the human needs (Baig et al. 2008). The agricultural development however, has led to environmental degradation and deforestation. Sustainable agroforestry systems can provide solutions to such problems, with the application of intensive land use management practices that optimize the benefits (physical, biological, ecological, economic, social) from biophysical interactions created when trees combined with crops and/or livestock (Garrett et al. 1994). The silvopastoral systems are a complex type of agroforestry systems, in which wood production and pasture production are combined (Lopez-Diaz et al. 2009). The management of these systems, which are characterized by the interactions among trees, pasture and animals, poses difficulties.

Trees planted into grasslands need protection from livestock (Bendfeldt et al. 2001), reed as serious damage from trampling or browsing to be prevented, especially during early years of establishment (Sibbald et al. 1999). Protective measures include the removal of livestock from the site for a certain period, the use of electrified fencing to protect rows of trees and the use of protective tube shelters or cages to individual trees (Fike et al. 2004). The downside to the otherwise effective methods of the removal of grazing and the use of electrified fencing is the loss of grazing land. Solid-walled and mesh tree shelters can protect trees from grazing animals while they allow livestock to graze among young trees. Moreover, solid-walled shelters create a warmer, more humid microclimate (Potter 1988, Burger et al. 1992), which can benefit the growth rates of many tree species (West et al, 1999, Dubois et al. 2000). There is evidence though that their effects on trees are species dependent (Ponder 2003).

Competition from herbaceous vegetation for light, water and nutrients in the establishment stage of a silvopastoral system may lead to reduced seedling survival and growth (Sibbald 1999). Consequently, the control of the herbaceous vegetation is essential for the successful plantation establishment (Alley et al. 1998). Many researchers have reported that herbaceous vegetation control in agroforestry systems resulted in an increase of tree growth (Paris et al. 1998, Green et al. 1999). Understorey vegetation control can be achieved mechanically or chemically. The degree of protection required is species dependent as some species can be successfully established without any control of the understory vegetation (Fike et al. 2004).

Fraxinus angustifolia Vahl. is among the fast growing tree species that produce high quality timber and can be introduced to agroforestry system (Papanastasis 2007). It occurs naturally in the southern Europe, the Balkans, the Caucasus and Iran (Fraxigen 2005). In the Mediterranean region, *Fraxinus angustifolia* can be found on drier sites, as well as on riverine and wetland sites. Its wood characteristics have many similarities to common ash (*Fraxinus excelsior*) and it produces high quality wood that is especially preferred in the veneer and furniture industry. Yet, despite its relative importance, little is known about the plantation establishment of *Fraxinus angustifolia* (Cicek et al. 2010).

The maintenance of high herbage production in silvopastoral systems is essential as it affects livestock carrying capacity (Fernandez et al. 2002). Competition for light in silvopastoral systems is critical to herbage growth (Braziotis & Papanastasis 1995). Shading affects directly the photosynthesis and indirectly the dynamics of water and nutrient use efficiency and their partitioning between trees and understory vegetation (Bergez et al. 1997). As a result, herbage production decreases as light intensity decreases (Knowles 1991, Devkota & Kemp 1999). In the Mediterranean zone, this occurs mostly only under heavy shading. Koukoura & Nastis (1989) found a higher herbage production under moderate shade (50%) compared to herbage production of the control (0%) or heavier shade (70%, 90%). Shading effect on composition is related to the individual species. It directly affects the photosynthetic ability of the understorey vegetation (Bergez *et al.* 1997). Thus, only the shade tolerant species can grow under heavy shading.

No research thus far has evaluated the post-planting treatments of the successful establishment of a *Fraxinus angustifolia* silvopastoral system. Thus, the objectives of this study were: (i) to evaluate the effects of using three types of tree shelters and of controlling competing herbaceous vegetation on the growth of planted *Fraxinus angustifolia* young trees and (ii) to assess the effects of heavy shading on the herbage production and composition.

Materials and methods

Study area

The study was conducted at the village of Scholari, 43 km northeast of Thessaloniki, located in northern Greece, at an altitude of 100 m. The soil is sandy silt derived from conglomerates of the tertiary period and colluvials from river or torrent deposits. The climate according to the bioclimatogram of Emberger (1942) could be characterized as Mediterranean semiarid with cold winters, with mean annual precipitation of 512 mm and mean annual temperature of 14° C. The natural potential vegetation of the area belongs to the lowest part of the Mediterranean vegetation zone (Dafis, 1973), the association *Coccifero-Carpinetum*, of the alliance *Ostryo-Carpinion*, order *Quercetalia pubescentis*. The experiment was established on a 0.75 ha grassland dominated by perennial herbaceous plant species, mainly grasses and graminoids. Some woody species (elder, blackberry) were also present. The experimental site was lightly grazed by sheep.

Post-planting treatment effects

The selected tree species was *Fraxinus angustifolia* Vahl. Plants were grown from seeds in a nursery. One-year-old seedlings were transplanted in 2 x 2.5 m spacing, corresponding to 2000 plants/ha density, during early February 1996. Post planting treatments included combinations of tree shelters and competing vegetation control. Solid-walled and mesh tree shelters were tested. Solid-walled shelters were polypropylene Tubex shelters (Tubex Limited, South Wales, UK) and handmade greenhouse nylon shelters (both 11 cm diameter, 150 cm height). Mesh tree shelters were constructed from wire mesh (25 cm diameter, 150 cm height). Competing vegetation control treatments were: (1) herbicide application (Roundup) to a radius of 50 cm (2) mechanical removal of the sod layer to a radius of 50 cm and (3) control. The study consisted of a two factorial split-plot design with six replication blocks of 140 m^2 each. Whole plot treatment was the tree shelter (three levels) and subplot treatment was vegetation control treatment (three levels).

Height (total shoot elongation) and height increment (cm) were measured for eight individual randomly selected trees in every block and the crown surface area (m^2) was determined. This was achieved by measuring the maximum radius of the crown from the trunk in all the four cardinal compass directions. The mean radius was used to calculate the area. All the measurements were recorded three years after the plantation was established.

Analysis of variance (ANOVA) was used to evaluate the effects of tree shelter and vegetation control treatment. Statistical analysis was performed using the MSTATC statistical program (Michigan State University, East Lansing, MI). When analyses of variance indicated significant effects, the treatment means were separated by Least Significant Difference

(L.S.D.) at the 0.05 level.

Shading effects

Because the trees in the experimental area were young and provided limited shade (10–20 %) that could not significantly affect the understorey vegetation, artificial shading was created by four shade cloths of 20 m^2 placed randomly in the experimental area. The shade cloths provided 80% reduction of the total radiation, as measured by a LiCor quantum sensor (Li 190 SB). Four similarly-sized areas were assigned next to the shaded ones. Herbage yield was measured by clipping four 0.5 m x 0.5 m quadrats randomly placed in every shaded and control area. All the herbaceous and shrub species plants were harvested at ground level (Cook & Stubbendieck 1986). Biomass was measured at the end of the growing season (end of May). The herbage production samples were then separated into grasses, forbs and shrubs subsamples in order to estimate botanical composition on dry-weight basis. All the samples were oven-dried at 60 °C for at least 48 hours and then weighed. Dry matter production was expressed in kg/ha.

The experiment was laid out in a complete randomised block design. All herbage production data were subjected to single factor analysis of variance (Steel & Torrie 1980). The differences between the mean values of the studied parameters were calculated by Student "t" test.

Results

Significant differences were detected among the tree shelter treatments and the vegetation control treatments for tree height, height increment and crown surface area. Significant interaction between the tree shelter treatments and the vegetation control treatments was not observed for tree height, height increment and crown surface area, indicating that the effect of the tree shelter treatment was consistent. For this reason, the data for these parameters were summarized over tree shelter and vegetation control treatments.

Tree height in the mesh tree shelters was significantly lower (Table 1) compared with the other two treatments. From the two solid walled tree shelter treatments, the tubex resulted in a significantly higher tree height. Vegetation control increased significantly the tree height compared to the control (Table 2). There was no significant difference between the two vegetation control treatments.

Concerning the height increment, no statistical differences were detected among the tree shelter treatments (Table 1). On the contrary, height increment was significantly higher for both the vegetation control treatments compared to the control (Table 2). No statistical differences were detected between the herbicide application and the mechanical removal.

The crown surface area of the solid-walled shelters was significantly greater than the one of the mesh shelters. The tubex tree shelters resulted in a significantly higher crown surface area than the handmade greenhouse nylon

Table 1 Means of height, height increment and crown surface area of trees on three tree shelter treatments

Treatment	Height (cm)	Height increment (cm)	Crown surface area (m^2)
Solid wall Tubex shelter	406.00	73.00	3.02
Solid wall Nylon shelter	329.00	81.00	1.98
Wire mesh shelter	251.00	70.00	1.11
Significance	*	n.s.	*
$LSD_{0.05}$	55.00	-	0.83
CV (%)	12.87	16.21	19.40

Note. * $p \leq 0.05$; n.s. - none significant.

shelters (Table 1). Crown surface area was significantly higher for both the vegetation control treatments compared to the control (Table 2). However, no statistical differences were detected between them.

Shading decreased significantly the total herbage production (Table 3) by 54% compared to the control. It also resulted in a significant decrease of grasses and shrub biomass. In contrast, the forbs were not affected by shading.

Discussion

Like other species (Minter et al. 1992, Bergez et al. 1997, Devine et al. 2007) *Fraxinus angustifolia* responded to solid-walled tree shelters with greater tree height and crown surface area but there was no difference in height increment relative to mesh shelters. This phenomenon is closely related to the reduced VPD (vapour pressure deficit) that has been recorded inside these solid wall tubes with the consequence of reduced transpiration (Noitsakis & Nastis 1995). Tubex shelters had probably a greater effect in transpiration than the handmade greenhouse nylon ones and that resulted in a higher height and crown surface area. Moreover, the grazing herbivores and especially goats, may manage to graze some twigs of the plants growing in the mesh shelters. Although the solid wall tubex shelters were more beneficial to the growth parameters of *Fraxinus angustifolia* than the handmade greenhouse nylon ones, the later could be used as an inexpensive alternative protection method. Nevertheless, the primary function of shelters is protection from grazing, and solid-walled shelters reduce the length of time saplings need to grow above the height of animal browse, in comparison to mesh shelters.

Evans (1997) stated that *Fraxinus* is sensitive to weed competition, especially from grasses. In the Mediterranean region soil moisture is an essential factor affecting young tree growth. The understorey herbaceous vegetation is a strong competitor for soil water and can reduce the growth of young trees. Bendfeldt et al. (2001) found that the control of graminoids significantly increased the soil water content near planted seedlings. The results of this experiment indicated that both treatments of the vegetation control applied (herbicide and mechanical removal) resulted in a significant increase of tree height, height increment and

Table 2 Means of height, height increment and crown surface area of trees on three tree vegetation control treatments

Treatment	Height (cm)	Height increment (cm)	Crown surface area (m^2)
Herbicide application	336.00	83.00	2.21
Mechanical removal	335.00	80.00	2.28
Control	315.00	61.00	1.63
Significance	*	*	*
$LSD_{0.05}$	17.00	9.00	0.54
CV (%)	12.87	16.21	19.40

Note. * $p \leq 0.05$; n.s. - none significant.

Table 3 Herbage production of grasses, forbs, shrubs and total (kg/ha) at the two shading treatments.

Treatment	Grasses	Forbs	Shrubs	Total
Shading 80%	337.1	130.2	54.7	522.0
Control	730.7	105.1	304. 8	1140.6
Significance	*	n.s.	*	*

Note. * $p \leq 0.05$; n.s.- none significant.

crown surface area. These results are in agreement with those reported for other broadleaves as *Quercus petraea* and *Fraxinus excelsior* (Davis 1985), *Coryllus avellana* (de Montant *et al.* 1998), and *Quercus garryana* (Devine et al. 2007). The method of herbicide application of controlling competition with herbaceous vegetation has been reported as more beneficial to tree growth (Bendfeldt et al. 2001, Delate et al. 2005). However, this was not the case in this study. The equally beneficial mechanical removal to the *Fraxinus angustifolia* growth can be used as alternative to herbicides which may cause phytotoxicity in adjacent plants and may reduce soil quality (Pimentel et al. 1995).

Shading reduced significantly herbage production. It is well documented by Boardman (1977) and Koukoura (1987) that plants growing under shade, in their effort to cope with the reduced intensity of solar radiation, exhibit lower overall photosynthetic efficiency because respiration rates exceed the photosynthetic ones. In other studies in the Mediterranean zone (Kyriazopoulos et al. 1999, Koukoura et al. 2009) herbage production was decreased only under heavy shading, while it was not affected or increased under light or moderate shading. This can be attributed to the increased soil moisture under this treatment due to the modification of microclimate (Rao et al. 1997). Soil moisture is the critical factor for plant growth and herbage production in the Mediterranean region (Etienne 1996). In this experiment shading was relatively heavy (80%). By contrast, Dupraz & Newman (1997) found that the heavy natural shading (80%) provided by *Fraxinus excelsior* mature trees, caused only a small reduction in the understorey herbage production. This difference is probably related to the shading tolerance of the species that compose the understorey. Reduced light intensity resulted in a decrease in the biomass production of the grasses and the shrubs while it did not affect the forbs. This could be associated with the fact that forbs species are more shade tolerant than grasses (McConnell & Smith 1965). Lin et al. (1999) have also found reduced production for various grass species when grown under 80% shading. Furthermore, in the study area the dominant grass species were the non shade tolerant *Elymus elongatus* (Shaw & Cooper 1973) and the also non shade tolerant C_4 perennial *Cynodon dactylon*. These significant changes in botanical composition on dry-weight basis might also affect herbage quality as heavy shading resulted in a significant decrease of the less palatable spiny shrubs, while it did not affect the forbs (including legumes). Furthermore, as plants growing under shade reach maturity later than plants under full light intensity (Blair et al. 1983, Koukoura & Nastis 1989) ameliorated herbage quality is expected. Furthermore, it has to be noted that shade and shelter provided by trees can benefit livestock by reducing environmental extremes as it has been reviewed by Fike et al. (2004). The improved environmental conditions in silvopastoral systems allow animals to spare energy for growth, particularly in the warm Mediterranean region.

Conclusions

The results of this study indicate that post-planting treatments are effective for the establishment of a *Fraxinus angustifolia* silvopastoral system. Both the solid-walled shelters provided more increased growth parameters than the wire mesh one. The use of these shelters may reduce the length of time for the trees to reach the sapling stage, above the height of grazing animals. Although the development of *Fraxinus angustifolia* was favoured more by the solid wall tubex shelters, the handmade greenhouse nylon ones could also be used especially when it is essential to reduce the cost. Under the droughty Mediterranean conditions, the control of the understorey competing vegetation proved of primary importance for increasing growth parameters of *Fraxinus angustifolia*. Both treatments proved equally beneficial but mechanical removal should be preferred to herbicide application in the low-input silvopastoral systems. The artificially applied heavy shading significantly decreased the herbage production and altered the botanical composition on dry-weight basis. As the maintenance of high herbage production is a key element of the successful management of silvopastoral systems, the later thinning of the dense 2 x 2.5 m spacing is necessary.

References

Alley J.L., Garrett H.E., McGraw R.L., Dwyer J.P., Blanche C.A., 1999. Forage legumes as living mulches for trees in agroforestry practices - preliminary results. Agroforestry Systems 44: 281-291.

Baig M.B., Ahmad S., Khan N., Khurshid M., 2008. Germplasm conservation of multipurpose trees and their role in agroforestry for sustainable agriculture production in Pakistan. International Journal of Agricultural and Biological 10(3): 340-348.

Bendfeldt E.S., Feldhake C.M., Burger J.A., 2001. Establishing trees in an Appalachian silvopasture: response to shelters, grass control, mulch, and fertilization. Agroforestry Systems 53: 291–295.

Bergez J.E., Dalziel A.J.I., Duller C., Eason W.R., Hoppe G.M., Lavender R.H., 1997. Light modification in a developing silvopastoral system in the UK: a quantitative analysis. Agroforestry Systems 37: 227-240.

Blair R.M., Alcaniz R., Harrell A., 1983. Shade intensity influences the nutrient quality and digestibility of southern deer browse leaves. Journal of Range Management 36: 257–264.

Boardman N.K., 1977. Comparative photosynthesis of sun and shade plants. Annual Review of Plant Physiology 28: 355-77.

Braziotis D.C., Papanastasis V.P., 1995. Seasonal changes of understorey herbage yield in relation to light intensity and soil moisture content in a *Pinus pinaster* plantation. Agroforestry Systems 29: 91-101.

Burger D.W., Svihra P., Harris R., 1992. Treeshelter use in producing container-grown trees. Horticultural Science 27: 30–32.

Cicek E., Yilmaz F., Tilki F., Cicek N., 2010. Effects of spacing and post-planting treatments on survival and growth of *Fraxinus angustifolia* seedlings. Journal of Environmental Biology 31: 515-519.

Cook C.W., Stubbendieck J., 1986. Range Research: Basic Problems and Techniques. Society for Range Management. Denver, Colorado, 317 pp.

Dafis S., 1973. Classification of vegetation in Greece. Depart. of Forestry and Natural Environment, Aristotle University of Thessaloniki, Vol. IE, Thessaloniki. (In Greek).

Davies R.J., 1985. The importance of weed control and the use of tree shelters for establishing broadleaved trees on grass-dominated sites in England. Forestry 58: 167-180.

De Montard F.X., Rapey H., Delpy R., Massey P., 1999. Competition for light, water and nitrogen in an association of hazel and cocksfoot. Agroforestry Systems 43: 135–150.

Delate K., Holzmueller E., Frederick D.D., Mize C., Brummer C., 2005. Tree establishment and growth using forage ground covers in an alley-cropped system in Midwestern USA. Agroforestry Systems 65: 43–52.

Devine W.D., Harrington C.A., Leonard L.P., 2007. Post-Planting treatments increase growth of Oregon White Oak (*Quercus garryana* Dougl. ex Hook.) seedlings. Restoration Ecology 15(2): 212–222.

Devkota N.R., Kemp P.D., 1999. Morphological aspects of pasture species in the shade in relation to various management practices under silvopastoral systems. Journal of the Institute of Agriculture and Animal Science 19-20: 1-26.

Dubois M.R., Chappelka A.H., Robbins E., Somers G., Baker K., 2000. Tree shelters and weed control: effects on protection, survival and growth of cherrybark oak seedlings planted on a cutover site. New Forests 20: 105–118.

Dupraz C., Newman S., 1997. Temperate agroforestry: the European way. In: Gordon A.M., Newman S.M., (eds.). Temperate Agroforestry Systems [CAB International, Wallingford, UK]. pp. 181-236.

Emberger L., 1942. Un project d' une classification des climats du point de vue phytogeographigue. Bul Soc D' Historie Nuturelle de Toulouse 77: 97–124.

Etienne M., 1996. Research on temperate and tropical silvopastoral systems: a review. In: Etienne, M.(ed.), Western European Silvopastoral Systems. INRA, Paris, France, pp. 5-22.

Evans J., 1997. Silviculture of hardwoods in Great Britain. Forestry 70: 309-315.

Fike, J. H., Buergler, A. L., Burger, J. A., Kallenbach, R. L., 2004. Considerations for establishing and managing silvopastures. Plant Management Network, 1-12.

Fernandez M.E., Gyenge J.E., Dalla Salda G., Schlichter T.M., 2002. Silvopastoral systems in Northwestern Patagonia I: Growth and photosynthesis of *Stipa speciosa* under different levels of *Pinus ponerosa* cover. Agroforestry Systems 55: 27-35.

Fraxigen, 2005. Ash species in Europe: Biological characteristics and practical guidelines for sustainable use. A summary of findings from the Fraxigen project EU project EVKCT00108. Oxford Forestry Institute, University of Oxford, UK.

Garrett H.E., Buck L., 1994. Agroforestry practice and policy in the United States of America. Forest Ecology and Management 91: 5-15.

Green J.J., Alifragis D., Baddeley J.A., Bagnaresi U., Bohne H., Bulfin M., Edwards A.C., Hooker J.E., Watson

C.A., 1999. Impact of understorey vegetation on tree production in European agrofororestry systems. Grassland Science in Europe 4: 171–175.

Knowles R.L., 1991. New Zealand experience with silvopastoral systems: a review. Forest Ecology and Management 45: 251-267.

Koukoura Z., 1987. Light intensity effects on dynamic growth of kermes oak (*Quercus coccifera* L.). Journal of Mediterranean Ecology 13: 19-25.

Koukoura Z., Nastis A.S., 1989. Effect of shade on production and forage quality of herbaceous species. Geotehnika Epistimonika Themata 1: 17-25 (In Greek, English summary).

Koukoura Z., Kyriazopoulos A.P., Parissi Z.M., 2009. Growth characteristics and nutrients content of some herbaceous species under artificial shade and fertilization. Spanish Journal of Agricultural Research 7(2): 431 - 438.

Kyriazopoulos A.P., Koukoura Z., Nastis A.S., 1999. Effects of wild cherry (*Prunus avium*) and grazing on the herbaceous understorey and its crude protein content. Grassland Science in Europe 4: 187-190.

Lin C.H., McGraw R.L., George M.F., Garrett H.E., 1999. Shade effects on forage crops with potential in temperate agroforestry practices. Agroforestry Systems 44: 109–119.

Lopez-Dıaz M.L., Rigueiro-Rodrıguez A., Mosquera-Losada M.R., 2009. Influence of pasture botanical composition and fertilization treatments on tree growth. Forest Ecology and Management 257: 1363–1372.

McConnell B.R., Smith J.G., 1965. Understory response three years after thinning pine. Journal of Range Management 18: 129–132.

Minter W.F., Myers R.K., Fisher B.C., 1992. Effects of tree shelters on northern red oak seedlings planted in harvested forest openings. Northern Journal of Applied Forestry 9: 58–63.

Noitsakis B., Nastis A.S., 1995. Seasonal changes of water potential, stomatal conductance and transpiration in the leaf of cherry trees grown in shelter. Cah Options Mediterr. 12: 267-270.

Papanastasis V.P., 2007. Land abandonment and old field dynamics in Greece. In: Cramer V.A. and R.J. Hobbs (eds). Old fields: Dynamics and restoration of abandoned farmland. pp: 225–246. Island Press, Washington, USA.

Paris P., Olimpieri G., Todaro L., Pisanelli A., Cannata F., 1998. Leaf-water potential and soil-water depletion of walnut mulched with polyethylene and intercropped with alfalfa in central Italy. Agroforestry Systems 40: 69-81.

Pimentel D., Harvey C., Resosudarmo P., Sinclair K., Kurtz D., McNair M., Crist S., Shpritz , Fitton L., Saffouri R., Blair R., 1995. Environmental and economic costs of soil erosion and conservational benefits. Science 267: 1117-1123.

Ponder F. 2003. Ten-year results of tree shelters on survival and growth of planted hardwoods. Northern Journal of Applied Forestry 20: 104-108.

Potter M.J., 1988. Treeshelters improve survival and increase early growth rates. Journal of Forest 86: 39–41.

Rao M.R., Nair P.K.R., Ong C.K., 1997. Biophysical interactions in tropical agroforestry systems. Agroforestry-Systems 38: 3-50.

Shaw A.F., Cooper C.S., 1973. The interagency forage, conservation, and wildlife handbook. Montana State University Extension Service Bozeman, 205 pp.

Sibbald A.R., 1999. Silvopastoral agroforestry: soil–plant–animal interactions in the establishment phase. Grassland Science in Europe 4: 133–144.

Steel R.G.D., Torrie J.H., 1980. Principles and procedures of statistics. 2nd edn. McGraw-Hill, NY, USA, 481 pp.

West D.H., Chappelka A.H., Tilt K.M., Ponder H.G., Williams J.D., 1999. Effects of tree shelters on survival, growth, and wood quality of 11 tree species commonly planted in the southern United States. Journal of Arboriculture 25: 69–74.

Zhao W., Russell J.Q., Pedro R.B., 2003. Modelling of the short wave radiation distribution in an agroforestry system. Agricultural and Forest Meteorology 118: 185-206.