

Research Article

Effects of Tree Shelters on the Survival and Growth of *Argania spinosa* Seedlings in Mediterranean Arid Environment

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The argan tree is endemic species of Morocco. It occupies an area of more than 8700 km² and plays essential ecological and economical roles. In spite of their value, the argan woodlands are subject to rapid and uncontrolled degradation during the last decades, mainly due to overgrazing and systematic collection of argan nuts. The present study was carried out to investigate the effects of two types of tree shelters on survival and growth of *Argania spinosa* seedlings planted in the southwest of Morocco in order to improve the results of reforestation programs which usually end by repeated failures. The experiment was conducted in the Mesguina forest for two growing seasons after transplantation in the field. After two years, the use of tree shelters significantly increased tree survival and allowed a gain of 20%. Height growth was positively affected by tree shelters. The use of tree shelters showed no significant decrease in basal diameter. In contrast, the height to diameter ratios of sheltered trees were much higher compared to the control. Thus, the use of the tree shelters could aid the early establishment and growth of *Argania spinosa* under conditions similar to those of the experiment.

1. Introduction

The argan forests (*Argania spinosa* (L.) Skeels) extend over 8700 square kilometers [1]. For centuries, argan tree has shaped the socioeconomic life of the southwestern Morocco, becoming a flagship species for the region and for the country [2]. This space has been declared by UNESCO's Man and the Biosphere (MAB) Programme as biosphere reserve in 1998. The argan tree is the major tree species of Macaronesian formations in a climate characterized by very large occult precipitation [3]. Argan tree is a thermophilic and xerophytic tree species, evolving in warm temperate arid bioclimate (along the coast and in the plains) and in warm temperate semiarid bioclimate (High Atlas and Anti-Atlas), with annual rainfall ranging from 400 mm in the north (Safi), 250 mm in the Souss Valley, and 150 mm in the Anti-Atlas to less than

100 mm in the southern areas of desert nature [4]. This tree, which can live up to 250 years [5], provides multiple uses for the local population: its very hard wood and the shell of the fruit are used for heating, the leaves and the pulp of its fruit and the oil cake are a valuable fodder for the flock, its thorny branches are used as fence for agricultural plots, edible oil and cosmetics are derived from its seed, and finally the rich soil of the forest area is a very favorable area for intercropping.

During recent years, the argan tree faces many constraints that result in the weakening and degradation of natural forest ecosystems. The argan forests face, in recent decades, the changes in climate and many anthropozoogenic disturbances that result in a reduction in area and density and inexorably lead to the weakening and deterioration of the natural forest ecosystems. As part of the global forest resources assessment [6], official figures provided by Morocco and relating to

TABLE 1: Physicochemical characteristics of the plot study soil.

Soil depth (cm)	C (%)	N (‰)	C/N	OM (%)	pH (1:5)	P (mg/kg)
0–20	2.12	0.85	24.89	3.66	7.17	36.17
20–40	0.32	0.08	40.62	0.56	7.36	36.25

the degradation of the argan tree show a decrease of 111 km² of the total area of the argan tree between 1990 and 2005, which corresponds to a decrease of 7.4 km²/year. On the other hand, the argan forests are in almost total lack of natural regeneration [7].

With the aim of preserving this natural resource and to reverse this decline, the Forest Department opted for assisted regeneration in the late 90s and led a large reforestation program. However, successful argan plantations are hard to establish, and many reforestation projects have resulted in repeated failures, depriving local users of a vital space for their flocks for too long periods. Some breeders do not respect the enclosure despite the implementation of a state compensation of 350 Dh/ha (\$ 3600/km²) in favor of users' associations. Infringement of the enclosure by flocks in these areas is one of the main factors of failure of forest regeneration [8]. Added to that is damage by wild animals (hares, gazelles, and boar) and rodents (Barbary ground squirrel and voles) that multiply significantly in these closed spaces where phytomass quickly becomes very important. Under these conditions, individual protection of young seedlings, using tree shelters, is required. Being developed to protect trees from animal damage, these plastic tubes showed their ability to improve early growth by creating a "greenhouse effect" around each tree [9]. Numerous scientific publications have been devoted to the use of shelters in reforestation for several woody species, highlighting many benefits [9–13] but also some of their disadvantages [14–16]. No work has been devoted to the study of the effect of tree shelters on young argan seedlings in the field conditions. The present work aims to test how these techniques can improve the regeneration of argan tree by assessing the effects of individual protection seedlings on its growth parameters under field conditions for the first two growing seasons after transplantation.

2. Materials and Methods

2.1. Study Site. The experimental study was carried out at the Mesguina argan forest (9°23'W, 30°25'N, elevation 115 m) in southwestern Morocco, 25 km east of Agadir city. The study site is located in a fenced area and strictly closed to grazing. The climate is Mediterranean with an annual mean rainfall of 232.8 mm. The annual mean temperature is 20.0°C.

Soil samples were collected with auger at depths of 0–20 cm and 20–40 cm. These samples were analyzed by standard methods to determine the granulometric and physicochemical characteristics. The soil of the study site is sandy clay, with neutral pH, and poor in organic matter (Table 1).

2.2. Materials. The plantation was established in mid-March 2010. The seeds used in this study had the same origin, and the harvest was carried out in argan forest of Ida Ou

Moumen region. Argan seedlings were grown in the Oulad Teima forest nursery located 20 km from study area. This nursery produces hundreds of thousands of argan seedlings per year and constitutes the main supplier for the argan tree regeneration programs in the whole region. The seedlings were grown in 500 cm³ and 7 cm square containers filled with 75–25% (v/v) white peat and forest soil and transplanted in the field after 11 months in the nursery. These rigid containers are made of black polypropylene. They have an inverted truncated pyramidal shape with an open base in order to promote root air-pruning. The tree shelter used is a double-walled light green translucent polypropylene vented tube. Openings at the base of the shelter provide ventilation inside the tube. Two heights of the shelters were tested: 120 cm and 150 cm.

2.3. Experimental Design and Treatments. A complete randomized block design with three blocks was used. Each block contained 102 argan seedlings: 34 with 120 cm shelters, 34 with 150 cm shelters, and 34 argan seedlings as control (without shelters). On the plot, seedlings were planted with a density of 204 seedlings/ha, in cubic holes with dimensions of 0.60 m × 0.60 m in surface and 0.60 m in depth. A catchment area of 20 cm high and 1 m around the plant was established. The 204 shelters (sizes 120 and 150 cm) were then placed around the treated plants and 102 argan seedlings were left as control. Until August, every month a regular watering of 30 L per plant was provided during the first year. During the second growing season, no watering was provided to plants.

For each plant and throughout the duration of the study, plant height and basal diameter were measured. In addition to measurements at the planting date, two measurements were made during the first year (October 30 and December 26) and one measurement (October 30) was made for the following year, except basal diameter for which the measurement was performed only during the first year. Indeed, during the second year, the development of plants and their ramifications in the shelters did not allow measuring the extent of the basal diameter.

2.4. Statistical Analysis. Quantitative variables (survival, growth height, basal diameter, and height to diameter ratio) were analyzed with repeated measures. During the growing seasons 2010 and 2011, 3 measurements were made. The initial values of each variable measured just after planting were considered as a covariable. An analysis of covariance (ANCOVA) was then conducted.

The comparison of averages was made using Scheffé test calculated at $P < 0.05$ [17]. Previously, data had undergone logarithmic transformations to satisfy the assumptions required for the covariance analysis. Data for plants survival had undergone an angular transformation arcsine type of the

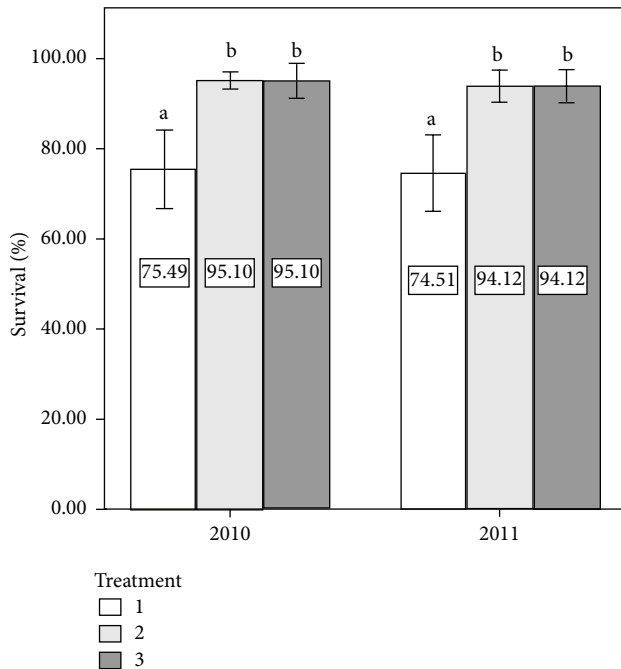


FIGURE 1: Survival rate (%) of argan seedlings for 2010 and 2011. Treatment 1: control. Treatment 2: seedlings with 120 cm shelters. Treatment 3: seedlings with 150 cm shelters. Values sharing the same letter within the same year are not significantly different at 5% level (Scheffé test).

square root ($Y = 2\text{arsin}X^{1/2}$), the raw data being expressed by values from 0 to 1 [18].

3. Results and Discussion

3.1. Survival. After two years of experimentation the results showed that the survival rate was 94.12% for sheltered trees versus 74.51% for unsheltered trees. This represents a very high rate that very few regeneration schemes have reached in the region.

Statistical treatments showed highly significant intergroup differences both for the first year ($P = 0.0029$) and for the second year ($P = 0.0043$) for the treatments on survival of argan seedlings. Results showed a positive effect of tree shelters on survival of argan seedlings (Figure 1).

The tree shelters improved significantly the survival rates ($P < 0.05$). The difference with the control was about 20% in both the first and the second year. Survival rates for seedlings under 120 cm shelters as well as 150 cm were not significantly different. After two years, survival rate of 94% in sheltered plants can be considered exceptional in view of the aridity in this region.

The analysis of Figure 1 shows that annual deaths that occurred in unsheltered seedlings are more important than in sheltered ones. Almost all mortalities were observed during the first year. These results confirm the previous findings [13, 19–24] which showed that mortality was higher for unprotected plants compared to sheltered plants. Similar results were found in arid climate for *Eucalyptus* tree [12].

TABLE 2: Effects of treatments on height growth.

Date	Df	F	P
October 2010	2	5.629	0.004
December 2010	2	6.432	0.002
October 2011	2	18.783	<0.001

Df: degree of freedom.

In continental climate, the use of shelters allowed a mean survival gain of 17% for cottonwood and Siberian elm [25]. Indeed, the shelters played likely a decisive role around the seedlings by creating a favorable microclimate by reducing light intensity [26, 27] and plant transpiration [28] during the summer. According to some studies [29], the soil temperature around unsheltered seedlings may exceed the soil temperature registered in tree shelters by 10 to 20°C. Moreover, the shelter protected the plants against attack of many mammals in the fenced plot: hares and Barbary ground squirrel (*Atlantoxerus getulus*) that attacks seedlings' shoots and especially its apical part which greatly hinders in growth and causes the death of the plant in case of repeated assaults on young argan trees. Contrastingly, some authors have shown no effect on survival [16, 30, 31].

Rainfall and temperatures recorded during the two campaigns may explain much of the mortality rates throughout the plot. Thus, the most important mortalities were observed during the first year regardless of the treatment, due to the difficult acclimatization of the argan seedlings. This acclimatization was made all the more difficult by the fact that the field conditions, especially during the 2009/2010 season, have been unfavorable: rainfall has not exceeded 56.2 mm after the planting date and temperatures were above the annual average. Several heat waves have hit the study area between April and September. These temperatures reached extreme values of 47.3°C and 48.3°C, respectively, on August 12 and August 26, 2010. The shelters gave to the seedlings an additional source of protection from the desiccating wind and thus less evapotranspiration losses. Significant environmental benefits arise due to saved irrigation water by the use of tree shelters in establishing trees in semiarid areas [13]. Thus the use of water and nutrients was better managed and utilized by seedlings that were in the shelter [25].

During the second year, which was very wet, the argan trees found favorable conditions for growth and mortalities greatly diminished. The results are consistent with the findings of studies over several tree species [29, 32]. Moreover, the first year is crucial to overcoming the phenomenon of transplanting stress. This stress is resulting from the confinement of root to the planting hole, poor root-soil contact, and low root permeability [33].

3.2. Height Growth. The statistical treatment showed highly significant effects in the first year and very highly significant effects in the second year on the height growth of argan seedlings (Table 2).

Shelters have significantly stimulated the height growth of argan seedlings compared to the control during the two years of experimentation (Figure 2).

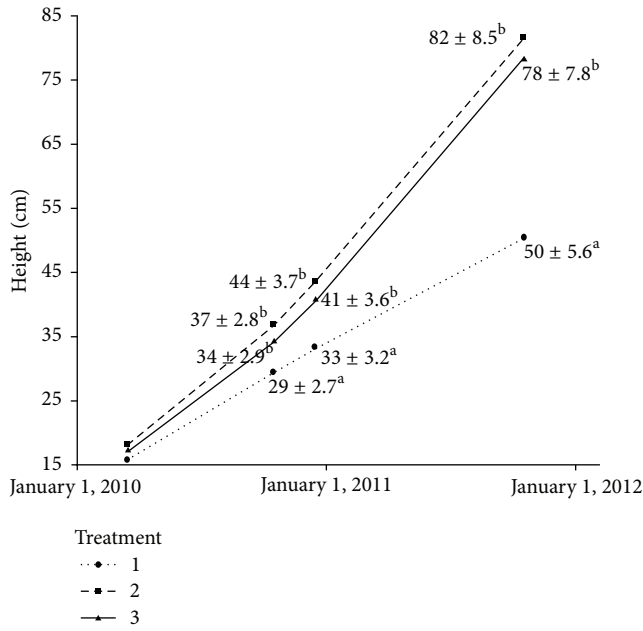


FIGURE 2: Growth height according to tree shelter factor. Treatment 1: control. Treatment 2: seedlings with 120 cm shelters. Treatment 3: seedlings with 150 cm shelters. Values sharing the same letter within same date are not significantly different at 5% by the Scheffé test.

The highest increases were observed for argan seedlings under 120 cm tubes. There was no significant difference compared to the 150 cm shelters. These classic effects of stimulation of height growth of seedlings have been reported by many authors for many tree species and climates [19, 20, 23, 24, 26, 34–38]. Similar results were obtained for oak trees in the south of England [9], for walnut in the south of France [14], and for the argan tree after one growing season under nonlimiting water conditions [39]. On the other hand, tree shelter did not improve the height growth of *Casuarina cristata* and *Eucalyptus moluccana* [30].

During the first year, the growth rates of sheltered argan seedlings were higher compared to the control. The same trend was observed during the second year when watering was not applied, with much sharper dynamics in sheltered trees. This growth's kinetics were stimulated by favorable water conditions: additional watering during the first year and the exceptional rainfall during the 2nd year.

3.3. Basal Diameter. During the first growing season, the measurements showed that the average of basal diameters had become two times higher than its initial value for all treatments (Figure 3). The greatest diameters were observed for the control, however without significant difference with the sheltered trees.

Thus, for control seedlings, the basal diameter increased from 2.91 mm at planting date to 6.98 mm after 9 months, which corresponds to 140% increase (Figure 4). The shelter seedlings had the lowest mean basal diameter. With the exception of publications on two oak species [9] where the tubes allowed good growth of the diameter and the lack of effect on magnolia and oak [34], the results are consistent

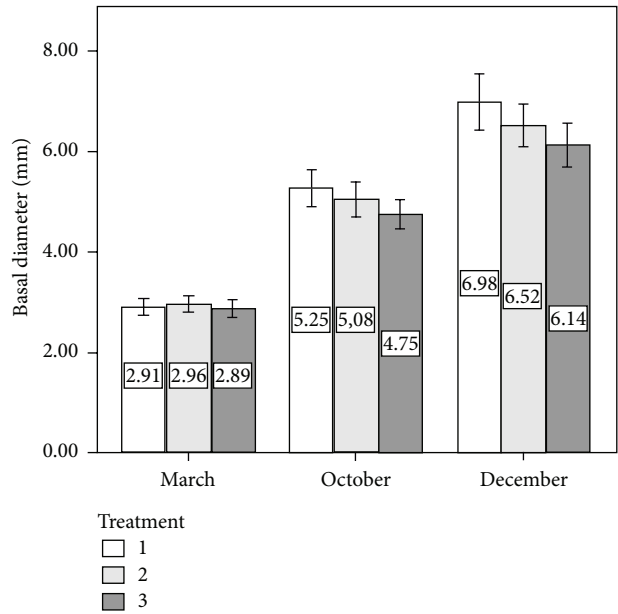


FIGURE 3: Mean basal diameters at planting date (March 2010) and after 7 months (October 2010) and 9 months (December 2010). Treatment 1: control. Treatment 2: seedlings with 120 cm shelters. Treatment 3: seedlings with 150 cm shelters.

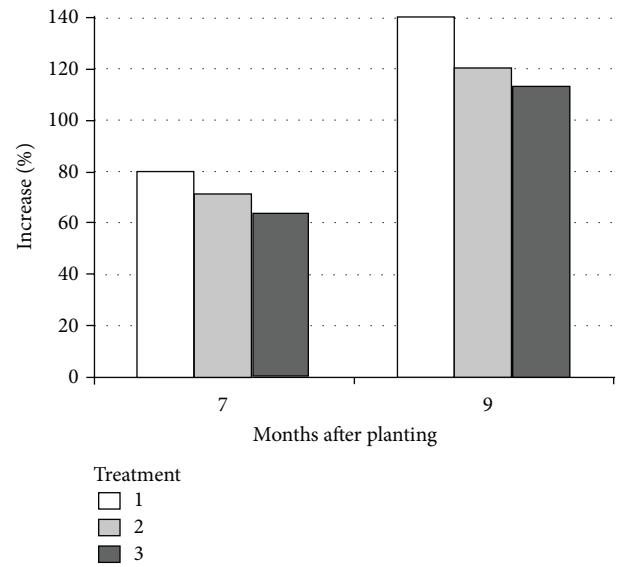


FIGURE 4: Increases of basal diameters for the argan tree seedlings. Treatment 1: control. Treatment 2: seedlings with 120 cm shelters. Treatment 3: seedlings with 150 cm shelters.

with those found for several tree species [14–16] and also for *Argania spinosa* under nonlimiting conditions [39].

3.4. Height to Diameter (H/D) Ratio. The results showed a highly significant effect of treatments on the H/D ratio ($P < 0.001$) both for October and December 2010.

The height to diameter ratio (H/D ratio) is an important factor, which describes the type of stem that each tree develops [40]. A lower ratio means a more vigorous tree [39].

TABLE 3: H/D ratio mean of argan seedlings for October and December 2010. Values sharing the same letter within the same date are not significantly different at 5% by Scheffé test.

Date	Treatment	Mean	SD
October 2010	Control	56.31 ^a	14.17
	T120	72.82 ^b	16.06
	T150	72.96 ^b	21.16
December 2010	Control	47.88 ^a	12.42
	T120	66.68 ^b	16.36
	T150	66.82 ^b	21.96

At seven months as well as nine months, the H/D ratio of the control was statistically much lower than that for the sheltered trees (Table 3).

A low H/D ratio is the sign of a stable tree with vigorous and powerful roots [40]. It has also been reported that shelter promotes rapid and vigorous root growth immediately after planting for *Quercus ilex* and *Pinus halepensis* seedlings under nonlimiting water availability conditions in Mediterranean climate [41].

On the other hand, the height to diameter ratio decreased with the length of the tube, but with no significant difference. These results show that H/D ratio has decreased between October and December. This decrease generally results in more vigorous trees. These results confirm those found for argan trees under nonlimiting water conditions [39], where the H/D ratio had a value of 53 for the control versus 74 to 104 for the sheltered trees depending on the type of shelter.

4. Conclusions

Two years after planting, the results have shown the beneficial effect of shelters on the survival rate of argan seedlings with a gain of 26%.

Tree shelters have, also, stimulated the height growth of the argan trees. Thus, the argan seedlings began to emerge from their shelters one year after planting. Seven months after planting, growing height showed a gain of 28% and 64%, respectively, for the first and second year for sheltered trees (120 cm). This result is very important as it may reduce the duration of deferred grazing. Diameter growth basal was not significantly affected by the introduction of tree shelters. Tree shelters (120 cm) induced a ratio H/D 69% higher compared to the control but which can still be considered acceptable.

Survival rate is the decisive parameter for the success or failure of a regeneration project. The use of tree shelter showed survival rates of 94% after two years. This can be considered exceptional on harsh conditions in southwestern Morocco with irregular rainfall and extreme summer temperatures that sometimes exceeded 48°C. The use of tree shelters should be considered one of the most effective ecotechnological treatments to enhance both seedling survival and growth [23].

With regard to the height of tree shelters, the results showed no significant differences for the studied parameters. Therefore, the use of 120 cm tree shelters would be suitable

since it would allow a faster emergence of the plants from their shelters and a better H/D ratio.

This study is one of the first field trials with *Argania spinosa* in its natural distribution area. Two growing seasons after planting, tree shelter, designed initially to protect against browsing, could enhance the establishment and growth of argan trees planted on harsh conditions in southwestern Morocco.

Conflict of Interests

The authors declare that there is no conflict of interests regarding the publication of this paper.

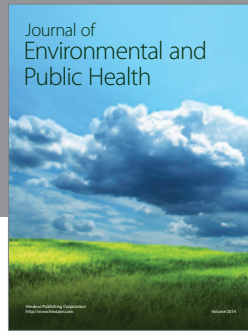
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