Disparity in the germination time of Argan nuts (*Argania spinosa* L. Skeels) on the growth of their seedlings in nurseries

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Abstract

The challenges encountered for the propagation of the Argan tree are embryonic and integumentary dormancy, which directly affect the rate and the duration of germination, the standards of aggregation of the plants for the reforestation, and in parallel on the stay time in the nursery. The study was conducted on Argan tree *(Argania spinosa* (L) Skeels) seedlings from two types of experimental germination of the kernels in the nursery: one pre-treatment with hot water and the second without pre-treatment (control). The aim was to see the effect of the duration of germination on the growth of the seedlings. The Argan nuts germinating for a short time gave rise to plants of almost convergent height (varying from 23 to 25 cm), i.e., the average height was very representative and similar to the height of their plants (24.94 cm). On the other hand, the nuts with a long germination period produced seedlings of varying heights (ranging from 09 to 27 cm), with an average height different from their range of seedlings (17.46 cm). Regarding diameter growth, germination time did not affect young plants. When the germination period was short, it was possible to obtain homogeneous seedlings that met phyto-technical standards for reforestation. According to this study, Argan seedlings should not be kept in the nursery for more than 33 weeks (8 months); otherwise, there is a risk of a poorly formed root system.

Keywords: Argan tree, breeding, pre-treatment, plants, nursery

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Introduction

The Argan tree is of great socio-economic and ecological interest, and its exceptional biological adaptability to extreme environmental conditions has been defined as a tool for combating desertification (Kechairi, 2018). In Algeria, the geographical range of the Argan grove is relatively limited, with around 56,644 ha, in the form of degraded stands occupying sandy, gravelly and rocky wadi beds (Kechairi and Abdoun, 2016).

The ageing of the stands and their degradation is very worrying because apart from stump sprouts, there is hardly any young regeneration by natural seedlings in thorny plants close to a wadi, the fruit of which is generally eaten by the Barbary squirrel (*Atlantoxerusgetulus*) (M'hirit et al., 1998). Drought seems to harm the regeneration and development of the Argan tree, especially at a young age (Ould Safi et al., 2015).

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The Argan tree is threatened with extinction. It must be protected in its natural area and replanted in potential areas to combat desertification and as an economical source for local populations. The current issue is to halt the decline of Argan grove and replant some of what has been lost.

The nursery is the place where seedlings are grown for later replanting. The production of seedlings is a significant planting expense. In this case, every effort must be made to produce good quality seedlings at a reasonable cost and when the seedlings intended for planting have reached the desired size, i.e., when they meet planting standards (Kadik, 1978). It is essential to master the techniques of raising Argan seedlings if reforestation is a success and to preserve this genetic capital by creating experimental plots (Fig. I).

According to studies that have been carried out on the propagation of forest species, such as the work of Bellefontaine et al. (2011) on rooting of Argan trees, we have found that seedlings grown in greenhouses survive better than seeds sown directly in situ or by natural regeneration. The young plants are monitored from the time they are buried to become capable of withstanding the problematic conditions they will later encounter in the field.

Among the challenges encountered in propagating these species are embryonic and integumentary dormancy, which directly impact the rate and duration of germination and the length of time the seedlings remain in the nursery. The integumentary hardness of the envelope can delay germination for months or years after sowing (exogenous dormancy), and the property of the embryo (endogenous dormancy) have prompted several specialists to look for more appropriate methods to encourage good germination of the species. Berka and Harfouche (2001) and Berka et al. (2019) researched other methods for germination using hormonal or chemical pre-treatment, as well as germination speed, although thermal pre-treatment remains the most accessible and least expensive.

Fig. I. Argan tree experimental plot at the Baraki experiment station; a: Argan trees, b: branches with inflorescences, fruiting branches, d: nuts

This study aims to determine a simple and inexpensive pre-treatment to ensure optimum germination or to obtain more regular germination in a minimum and maximum proportion.

In this study, we monitored the growth of *Argania spinosa* seedlings from germination pre-treatment and untreated control. The influence of germination time on the development of Argania spinosa plants was studied.

Materials and Methods

The nuts used in the experiment were harvested from mature Argan trees in Stidia (Mostaganem) and were characterized by their elongated shape. Each nut weighed 4.4 g, and there were 396 Argan nuts per 1 kg nuts (Fig I. d).

The Argan nuts used were preceded by germination tests under the effect of hot water, based on the trials of this pre-treatment. In contrast, the nuts were immersed in hot water (80 ℃) for one minute and then put in lukewarm water for 48 hours. They were then germinated in W.M. containers in the nursery.

The aims were reducing the effects of Argan nut dormancy, obtaining an appreciable percentage of successful germination, accelerating germination speed, and reducing mean germination time. Also, the study aimed at determining the effect of germination time on growth in height and diameter at the crown of seedlings, in addition to monitoring root development in Riedacker WM containers (Fig. II).

We used 300 Argan nuts from Mostaganem, including 150 nuts (without soaking, control) and 150 nuts (soaked in hot water 80 ℃.) for one minute and then in lukewarm water for 48 hours. Monitoring was carried out for 34 weeks (09 months) without interruption. Germination rate, height growth, crown diameter, and root system were monitored. Finally, we determined the time the plants had been in the nursery.

The substrate comprised 1/5 topsoil (crumbled and sieved), 2/5 compost collected from the cork oak forest, and 2/5 sand. The mixture was filled into bottomless containers (W.M. by Riedacker, 17 cm deep, and 400 cm^3 in volume). An M-shaped container with 4 dihedral angles of less than 60° allows practically all the lateral roots to be deflected in the direction of the edges (Riedacker, 1978). The absence of a bottom encourages roots to self-nest at the base of the containers, as well as aeration of the roots and leaching of the substrate. These containers are placed in raised boxes to make transporting them to the planting site easier.

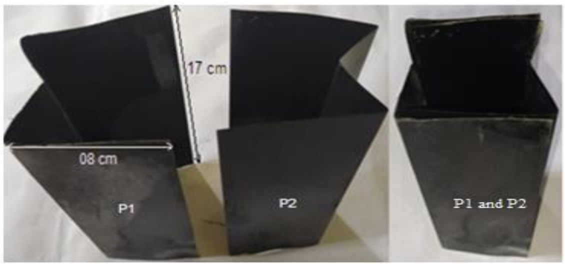

Fig. II. Riedacker W.M. containers openable in two parts (P1 and P2); P_1: party 1 M, P_2: party 2 W, P1 and P2: WM containers

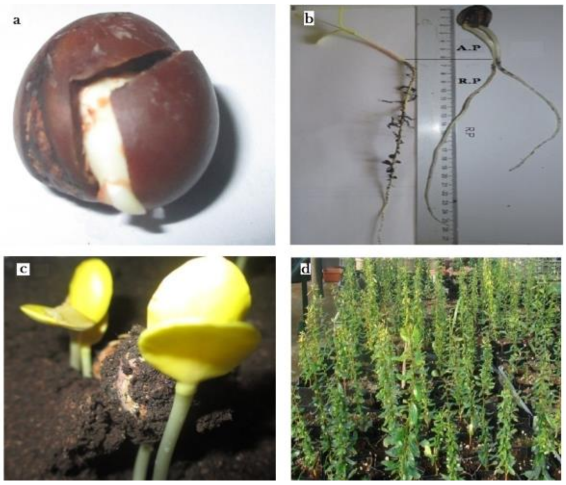

Fig. III. Argan nut germination; A.P: aerial part, R.P: root part, a: tegument bursting; b: growth of the primary root, average PR = 20.45 cm, PA = 4 cm, of Argan seedlings, 15 days after germination, c: sidleengs appearing, d: rearing of Argan seedlings in W.M. Riedacker containers (nursery at the Baraki Experimental Station)

Assays

Germination rate (G.R.) was calculated as the number of germinated nuts (Ni) per the total number of nuts sown (Nt), expressed as a percentage:

$$G.R = \frac{Number\ \text{of germinated nuts}}{Number\ \text{of nuts}\ sown} \times 100 = \frac{Ni}{Nt} \times 100$$

Germinated nuts were counted daily or based on the number of newly sprouted nuts at each observation. All nuts whose stems reached 1cm above the substrate were considered to be germinated (Fig. III. c).

Daily measurements of the height and diameter of plants in the nursery were done using a ruler and a caliper, respectively. The height was expressed in centimeters (cm), and the diameter was expressed in millimeters (mm). We monitored the development of the root system to ensure the production of quality plants.

Robustness coefficient is used to obtain morphologically good plants in height and diameter with a good MSA/MSR ratio. The robustness ratio is obtained as height/diameter at the crown (H/D) expressed in cm/mm. A sample of raised *Argania spinosa* plants from the nursery was planted in the experimental plot, and their behavior was monitored.

Results

Germination rate of Argan nuts

The germination of Argan nuts pre-treated with hot water exceeded 50% after 7 weeks of sowing, whereas nuts sown without pre-treatment did not exceed 26.66%. After 11 weeks of sowing, the germination rate of the pre-treated nuts reached a maximum value of 62.66%, but the speed of the control had yet to get 50%. At 15 weeks after sowing, the germination rate remained the same for nuts pre-treated with hot water (62.66%) and increased by 1.33% for the control (50.66%), (Table 1).

As a result, the shortest germination time was recorded at 7 weeks for nuts pre-treated with hot water and 15 weeks for nuts sown without pre-treatment. Therefore, the pre-treated nuts had a high germination speed, whereas the control nuts showed a languid germination speed.

Pre-treatment with hot water resulted in a high germination rate over a shorter period, with a difference of 8 weeks between the average germination times of the pre-treated nuts and the control nuts.

Average height of Argan plants

After reseeding, the seedling height developed progressively over time. This increase was very significantly affected by the depth of the container. The evolution of the growth in height and diameter of Argan seedlings during their development cycle in the nursery is illustrated in Table 2.

Measurements taken in the second week after germination showed that 94 plants from the nuts pre-treated with hot water reached an average height of 5.75 cm, compared with an average height of only 1.60 cm for the 76 plants from the control nuts. In fact, the nuts that germinated early produced plants with a more extended average height than the other nuts (Fig. III. d). On the other hand, the germination of nuts sown without pre-treatment (control) took place over an excessively long period, resulting in plants with heterogeneous heights, i.e., the height of the plants was variable (non-homogeneous).

Table 1
Germination rate of Argan nuts 15 weeks after sowing in the nursery

Weeks after sowing	The germination rate of Argan nuts	
	Hot water pre-treatment (T1)	Control(T2)
7 weeks	51,33 %	26,66 %
11 weeks	62,66 %	49,33 %
15 weeks	62,66 %	50,66 %

After 14 weeks of germination, the average height growth of Argan plants grown from nuts pre-treated with hot water was faster and reached 15.40 cm while that of plants grown from control nuts went 9.40 cm. On the other hand, between the 18th and 26th weeks, we noticed a slowdown in the speed of growth of the main stems compared with the previous weeks

Based on monitoring of the plants during their stay in the nursery (34 weeks), it was noted that the average height growth of plants from nuts pre-treated with hot water reached 24.94 cm, compared with 17.46 cm for the control plants.

Moreover, the robustness ratio was 5.21 for seedlings pre-treated with hot water and 4.60 for seedlings from control nuts (Table 2).

Table 2
Average height and diameter of Argan seedlings during 34 weeks (09 months) of rearing

Growth of Argan plants (week)	Plants from nuts pre-treated with hot water (T1)			Plants from control nuts (T2)		
	M.H. (cm)	M.D. (mm)	MH/MD	MH (cm)	MD (mm)	MH/MD
02 weeks (March)	5,75	2,75	2,10	1,60	2,00	0,8
06 weeks (April)	7,91	3,25	2,43	2,25	2,75	1,18
10 weeks (May)	11,28	3,45	3,27	5,00	3,00	2,0
14 weeks (June)	15,40	3,80	4,05	9,40	3,36	3,39
18 weeks (July)	16,70	4,10	4,07	11,38	4,00	3,34
22 weeks (August)	17,51	4,25	4,12	11,84	4,11	3,61
26 weeks (September)	19,82	4,41	4,49	13,60	4,33	3,60
30 weeks (October)	23,35	4,78	4,88	15,33	4,39	3,95
34 weeks (November)	24,94	4,79	5,21	17,46	4,46	4,60

MH: mean height, M.D.: mean diameter

Average diameter at the collar

Analysis of the results showed that the average diameter at the collar of Argan seedlings reached 2.75 mm and 2.0 mm 2 weeks after germination of plants from nuts pre-treated with hot water and the control, respectively.

From the 2nd week to the 18th week of raising the plants in the nursery after germination of the nuts, average diameter at the neck increased at a rapid rate, varying from 2.75 mm to 4.10 mm and from 2.0 mm to 4.00 mm, respectively.

From the 18th week onwards, there was a slowdown in the growth of the diameter at the neck, which varied from 4.10 mm to 4.79 mm for plants grown from nuts pre-treated with hot water and from 4.0 mm to 4.46 mm for plants grown from controls (Table 2). Furthermore, a direct relationship was found between growth in height and diameter, i.e., with a growth in height, there was also a progressive growth in diameter. Finally, changes in diameter at the crown of seedlings varied according to the time and duration of germination.

Development of the root system in W.M. containers

The evolution of the root system in the raised Riedacker W.M. bottomless container was monitored after germination. The vertical root grew faster and reached the bottom of the containers, but the elongation of the aerial part did not yet exceed 04 cm in height (Fig. III. b). In other words, the taproot grew 4 times longer than the aerial stem.

The vertical root reached the limit of the depth of the W.M. bottomless container, came into the air and rapidly dried out, becoming non-functional and forming a weld. Subsequently, rootlets grow all around the vertical root (Fig. IV. a).

Discussion

In this study, Argan nuts sown without pre-treatment had some difficulty germinating 8 weeks after sowing. However, it has been noted that the nuts soaked in hot water can readily grow and exceed the average (Maamar-Kouadri, 2004).

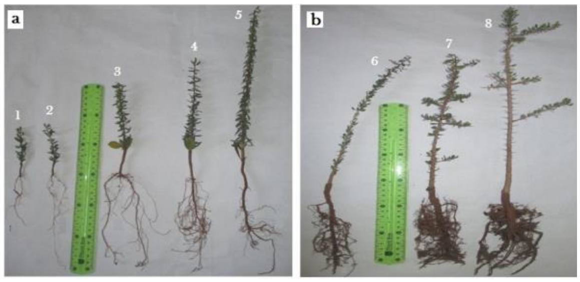

Fig. IV. Root system of Argan seedlings aged 2 to 9 months in W.M. containers (a); Roots of Argan seedlings cut at the bottom in containers between 18 and 30 months old (b); Plant 1: 2 months; Plant 2: 3 months; Plant 3: 5 months; Plant 4: 6 months; Plant 5: 9 months; Plant 6: 18 months; Plant 7: 24 months; Plants 8: 30 months

The thermal shock causes the integuments to crack and then the shell to soften, allowing water to seep inside the nut, which encourages sufficient water to be absorbed and oxygen to diffuse through the living tissues. This speeds up the germination. The nut bursting gives the embryo access to oxygen and consequently triggers germination (Berka and Harfouche, 2001 Côme, 1970), (Fig. III. a).

Sowing without pre-treatment had no apparent influence on germination speed, as the integumentary envelopes retained their original hardness and act as a barrier to germination. The yield was, therefore, insufficient, but in this case, pre-treatment was required to remove the inhibition.

Our results agree with those of Miloudi (2006), who showed that the germination of argan nuts was affected by the duration of soaking in water for 4 days, sufficient to obtain a high germination percentage. Furthermore, Nouaim and Chaussod (1993) reported that soaking argan nuts in water for three or four days promoted a high germination rate. Benaouf (2009) said that soaking the nuts in water for 96 and 120 hours before sowing positively affected how early they germinated. Given these results, the Argan nut is acceptable with proper dormancy.

The mean height growth in nuts pre-treated with hot water was faster than that of control nuts after 14 weeks of germination. This change in growth was due to the increase in temperature during this period. However, between the 18th and 26th weeks, a slowdown was recorded in the speed of growth of the main stems; this slowdown is due to the increase in summer temperature and the high insolation; it provokes the development of axillary buds and slows down apical budding. From the 30th week onwards, the height growth of the plants resumes its regular growth rate.

According to these results, the height growth of *Argania spinosa* plants increases with age. After 34 weeks (9 months) of rearing Argania spinosa seedlings, we found that the average height of seedlings grown from nuts pre-treated with hot water was more significant than the average height of control seedlings, with a difference of 7.48 cm compared with control seedlings. Average height growth is, therefore, directly related to the germination time of the Argan nuts.

The robustness ratio of the Argan seedlings pre-treated with hot water in this study higher than control nuts. According to Lamhamedi et al. (2000), this coefficient should be less than 8 when the plant reaches a target of 28 to 40 cm and the diameter at the collar varies between 4 and 5 mm.

A careful scrutiny of the root system of the Argan trees grown in bottomless Riedacker W.M. containers showed that the taproots grew 4 times longer than the aerial stem. According to Bellefontaine et al. (2011), in a traditional nursery with plastic bags 20-30 cm deep and 7 to 8 cm in diameter, the growth of the Argan tree is characteristic of dryland species: shortly after the cotyledons appear, the taproot reaches 5 to 8 cm with no hair or lateral roots.

In Morocco, monitoring the growth of the root system in a minirhizotron revealed very rapid growth of the root part, compared to the aerial part, of more than one cm per day. After 38 days, the aerial parts of the two plants were 8 and 12 cm high, and their primary roots reached 48 and 52 times the length of the aerial part (Nouaim, 1994).

The raised Riedacker WM Container contributes to the juxtaposition of containers without wasting space. It also allows acceptable lateral root development without deformation for eight months (Mihoubi, 1993); after this period, we note that the volume of the root system begins to exceed the capacity of the Riedacker WM container, which subsequently causes root deformation. Riedacker WM container will therefore solve the problem of root deformation, which remains the primary source of rejection of seedlings in the nursery (Chebouti et al., 2020). Therefore, seedlings are preferred to stay in the nursery for no longer than eight months.

The work of Ferradous et al. (2017) on identifying the most suitable rigid containers and substrate mixes showed that the 400 ml container is satisfactory for producing quality Argan seedlings after a seven-month stay in the nursery. In addition, we have appreciated the influence of bottomless W.M. containers on the delimitation of vertical root growth and minimization of the bun system, which will be used for soil fixation by their dominant branching. They can directly contribute to the success of our reforestations, which will produce vigorous stands resistant to unfavorable conditions. Kadik (1978) showed that root malformations remain limited if the nursery rearing time is short. It has been noted that this type of root in *Argania spinosa* seedlings is the best adapted to arid zone environments due to its robust taproot system and well-developed root hairs.

In the plants that remain in the nursery for a long time, the root system takes up all the space in the container and can coil (spiralize) at the bottom and start to create the bun. Nurserymen resort to cutting the bottom of the roots with a sharp, clean knife to avoid deforming the roots and encourage the development of lateral roots (Fig. IV. b). Cutting the roots at the bottom of the container will also ensure the success of the plants after replanting. Under favorable growing conditions, young plants stay in the nursery for around eight months. We obtained plants with an average height of over 20 cm, which can withstand water stress after transplanting to the field.

Root malformations can be observed if the Argan plants are left in the nursery for a long time (beyond the period under consideration). It is crucial to reduce irrigation. To this end, good nursery husbandry will enable the production of quality seedlings, considering the economic, health and environmental benefits of protecting the physical environment

Conclusion

Soaking the Argan nuts in hot water is still the most suitable and inexpensive pre-treatment method for solving the germination problem. Monitoring the development of seedlings from pre-treated nuts shows that pre-treatment affects not only the duration and rate of germination but also the growth of the seedlings.

Pre-treated nuts germinate quickly, producing plants of almost uniform height. In this respect, the average size is representative of the height of this range of seedlings. However, the seedlings from the field of non-pre-treated nuts (control), were characterized by their long germination time and resulting in seedlings with an average height different from most other seedlings. Therefore, the germination period does not significantly impact the neck of the plants, especially in our case, where the age of the plants is at most nine months.

From a scientific and economic point of view, Riedacker WM containers increase the length of stay of seedlings in the nursery while they do not prevent lateral root coiling; but this does not exceed the threshold, which is equivalent to 08 months of rearing after germination, beyond which period the capacity of Riedacker WM containers cannot support the root volume, and root deformation begins to emerge, so planting is recommended.

The period after germination of the nuts in the nursery should be extended at most 8 months to avoid root curling and the formation of characteristic bunches, especially for species with rapid initial growth, such as the Argan. Planting should be done early (October and November) to give the plant time to develop its root system and avoid the risk of spring frost and summer drought.

Monitoring the growth of plants of this species in their natural state has yielded appreciable and encouraging economic and ecological results. This motivates research into improving techniques for raising seedlings in nurseries to control the various propagation methods, guarantee the production of good-quality seedlings, develop programs to safeguard genetic resources, create Argan orchards, and experimental plots in various potential areas on a national scale, and eventually, encouraging international cooperation to finance multiple plantation projects.

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