Sexual and asexual propagation of *Artemisia herba-alba*; a native pastoral species highly valued and over-exploited

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Abstract

Artemisia herba-alba is among the most important pastoral species, characterized by a high fodder value, especially for ruminants. However, *Artemisia herba-alba* steppes in Morocco are undergoing continuous degradation. Therefore, understanding the multiplication of this highly appreciated species is essential for its preservation and the rehabilitation of degraded pastures. The present study's objective is to understand techniques of sexual and asexual multiplication of *Artemisia herba-alba*: germination and cutting. For sexual multiplication, three factors were considered: age of seeds, their origins and pre-treatments. For asexual multiplication, two factors were tested, i) the effect of Indole Acetic Acid IAA and ii) the cuttings type effect on the rooting of *Artemisia herba-alba* cuttings. The obtained results showed a high germination rate for freshly harvested seeds (88%), a decrease in the germination rate of seeds over the years, and those of the same year but lately collected (19.78%). Also, there is an increase is observed in the germination rate of seeds soaked for 48 h (21%) compared to the control (17%). In addition, an inhibitory effect of some IAA concentrations on the cuttings rooting was noted. The best rooting rate was observed in herbaceous cuttings control, collected in March (50%). Therefore, it can be concluded that cuttings represent the most efficient and promising technique for the propagation of *Artemisia herba-alba.*

Keywords: *Artemisia herba-alba*, germination, cuttings, degraded rangelands, Eastern Morocco

Multiplication sexuée et asexuée *d'Artemisia herba-alba* Asso ; une espèce pastorale autochtone appréciée et surexploitée

Résumé

Artemisia herba-alba est l'une des espèces pastorales les plus importantes, caractérisée par une valeur fourragère élevée, en particulier pour les ruminants. Cependant. Les steppes à *Artemisia herba-alba* subissent une dégradation continue. La maitrise de la multiplication de cette espèce est indispensable, pour sa préservation et la réhabilitation des pâturages dégradés. La présente étude a pour objectif de maitriser les techniques de multiplication sexuée et asexuée *d'Artemisia herba-alba*: germination et bouturage. Pour étudier la multiplication sexuée, trois facteurs sont considérés: l'âge des graines, leurs provenances et leurs pré-traitements. Pour la multiplication asexuée, deux essais de bouturage sont menés, dans le but de tester l'effet i) du trempage dans une solution d'auxine AIA, et ii) de la nature des boutures (herbacées, semi-ligneuses et ligneuses) sur l'enracinement de ces boutures. Les résultats obtenus ont montré un taux de germination important pour les graines fraichement récoltées (88%), une diminution du taux de germination des graines au fil des années, et celles de l'année en cours, mais provenant du pastoretum et récoltées tardivement (19,78%). Aussi, une augmentation du taux de germination des graines imbibées pendant 48h (21%), par rapport au témoin (17%). Par ailleurs, nous avons noté un effet inhibiteur de certaines concentrations de l'AIA sur l'enracinement des boutures. Le meilleur taux d'enracinement a été observé chez les boutures herbacées témoins, collectées en mars (50%).

Mots-clés : *Artemisia herba-alba*, germination, bouturage, parcours dégradés, Hauts Plateaux du Maroc Oriental

التكاثر الجنسي واللاجنسي ل *Artemisia herba-alba* Asso أحد الأصناف الرعوية الأصلية القيمة والتي تعرضت للاستغلال المفرط

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ملخص

سهوب *Artemisia herba-alba* تخضع لتدهور مستمر. يعد التحكم في تكاثر هذا النوع أمرًا ضروريًا للحفاظ عليه ولإعادة تأهيل المراعي المتدهورة. الهدف من هذه الدراسة هو إتقان تقنيات التكاثر الجنسي واللاجنسي، وهي: الإنبات والقصاصات. لدراسة التكاثر الجنسي، تم اعتماد ثلاثة عوامل: عمر البذور، أصولها ومعالجاتها المسبقة. من أجل دراسة تأثير عمر التخزين، أجريت اختبارات الإنبات على البذور التي تعود إلى أعوام 2008 و2019 و2020 و2021. بالنسبة للأصل، تم استعمال بذور لعام 2021 قادمة من عين بني مطهر وأخرى تم جمعها من المحمية المتواجدة بالمعهد الوطني للبحث الزراعي بوجدة. العلاجات المسبقة المستخدمة هي التشرب لمدة 24 ساعة، والتشرب لمدة 48 ساعة والخدش. بالنسبة للتكاثر اللاجنسي، تم إجراء اختبارين للقص، من أجل الكشف عن تأثير الهرمون النباتي auxin (AIA) بالتركيزات وأوقات النقع التالية: الشاهد، 50 جزء في المليون لمدة 24 ساعة، 1000 جزء في المليون، 3000 جزء في المليون، 5000 جزء في المليون لمدة دقيقة، 3 دقائق و 5 دقائق، وطبيعة القصاصات (عشبية، شبه خشبية، وخشبية) على تجذير قصاصات *Artemisia herba-alba* . أظهرت النتائج التي تم الحصول عليها معدل إنبات مرتفع للبذور المحصودة حديثًا (88٪ لبذور 2021)، وانخفاض في معدل إنبات البذور على مر السنين وانخفاض في معدل إنبات البذور في العام نفسه لتلك القادمة من المحمية والمحصودة متأخرا (19.78٪). كما تبين أن هناك زيادة في معدل إنبات البذور المتشربة لمدة 48 ساعة (21٪) مقارنة بالمجموعة الشاهدة (17٪). إضافة إلئ ذلك، لوحظ وجود تأثير سلبي لتركيزات معينة من AIA على تجذير القصاصات. أفضل تجذير لوحظ في القصاصات العشبية الشاهدة المقطوعة شهر مارس(50 ٪) .

الكلمات المفاتيحية: *Artemisia herba-alba*، الإنبات، القصاصات، المراعي المتدهورة، مرتفعات المغرب الشرقي

Introduction

Pastoral ecosystems cover 25% of the land surface and affect between 100 and 200 million of people in the worldwide (SCDC, 2010). However, other sources provide much higher figures. Thus, it is estimated that drylands represent 41% of the earth's surface, 69% of which are grazing land supporting some 2 billion of people and 50% of the world's livestock. (MA, 2005)

In Morocco, rangelands covers an area of 53 million hectares (62 to 65 million hectares including forests), i.e. that is 74% of the national territory (MARA, 1992-95, Laouina, 2003) .

The manageable pastures cover an area of 21 million hectares and extend over several ecosystems that differ in terms of climate, soil and flora.

Mostly, they have collective land tenure system and contribute nearly by third of all the food needs of the national herd. The livestock sector concerns around 1,100,000 rural households and represents 25 to 42% of gross agricultural production. (Berkat, et al., 1992 ; Laouina, 2003). This sector also provides 20% of agricultural jobs and is the exclusive activity for nearly 18% of the farmers. (Laouina, 2003).

The overexploitation of pastoral resources, the negative effects of climate change and recurrent droughts from which Morocco's pastoral ecosystems continually suffer have increased the extent and accelerated the rate of their degradation for several decades. The consequences are a very significant reduction in the area and pastoral production, a significant decrease in floristic diversity and therefore an imbalance between the pastoral fodder supply and the food requirement of the livestock.

The white wormwood steppes exist in several regions of Morocco (Eastern, pre-Sahara, Middle Atlas…) and are among the pastures most appreciated by pastoralists. Unfortunately, they are often overexploited and continually suffer from rapid and large-scale degradation. They occupied 5 million hectares during the 1980s (Hammoumi, et al., 1982), today, they are confined to protected sites such as settlements and seed reserves. (Maatougui et al. 2011, Maatougui et al. 2013)

The Morocco Oriental region covers about 8.8 million hectares and is characterized by a great agroecological diversity (MI, 2015). The high plateaus area of Eastern Morocco constitutes the main pastoral zone covering a large steppe ecosystem of approximately 3.5 million hectares.
The current state of the rangelands in this area is experiencing a marked deterioration resulting from excessive exploitation due to:

- Cultivation, which disturbs the seed stock in the soil, as well as its deterioration by plowing;
- Overgrazing caused by a large number of herds in excess of rangelands capacity;
- Human pressure on pastoral species with various vocations, worsen by sedentarization.

The main objective of the present study is to contribute to the rehabilitation of rangelands and the preservation of their biodiversity. particularly the white wormwood (*Artemisia herba alba*), as a native pastoral species, with a focus on improving of its propagation using sexual and asexual ways.
The specific objectives are:

Methodology

Sexual multiplication: Germination

Germination requires the identification of *Artemisia herba-alba* seeds, with the aim of studying the effect of their age, their provenances and their pre-treatments on their germination (Table 1). All seeds have been stored in the laboratory under ambient conditions in the laboratory.

Table 1. Factors and characteristics of Artemisia herba-alba seeds put to germination

Factors	Harvest date	Origin
Age	2008	Goutitir*
	06/03/2019	Ain Beni Mathar*
	06/03/2020	Pastorum of CRRA Oujda*
	21/02/2021	Ain Beni Mathar
Provenances	21/02/2021	Ain Beni Mathar
	12/04/2021	Pastorum of CRRA Oujda
Pre-treatments: Imbibition for 24 hours; Imbibition for 48 hours; Scarification.	2008	Goutitir

*Goutitir is a rural commune in the province of Taourirt, Oriental region.
*Ain Béni Matha is a municipality in the province of Jerada, Oriental region.
*Pastoretum installed at INRA Oujda

For this study, three tries were carried out:

- **First trial:** Germination of seeds dating from 2008, 2019, 2020 and 2021.
- **Second trial:** Germination of seeds from Ain Beni Mathar collected on 21/02/2021, and those from the CRRA_Oujda pastoretum collected on 12/04/2021.
- **Third trial:** Germination of seeds of 2008: control (without imbibition), with an imbibition for 24 hours, with an imbibition for 48 hours, with a scarification.

Intact and full seeds were placed in Petri dishes with 9 cm in diameter, on a filter disc (5893 Blue ribbon) with a diameter slightly greater than that of the Petri dish. (Figure 1).

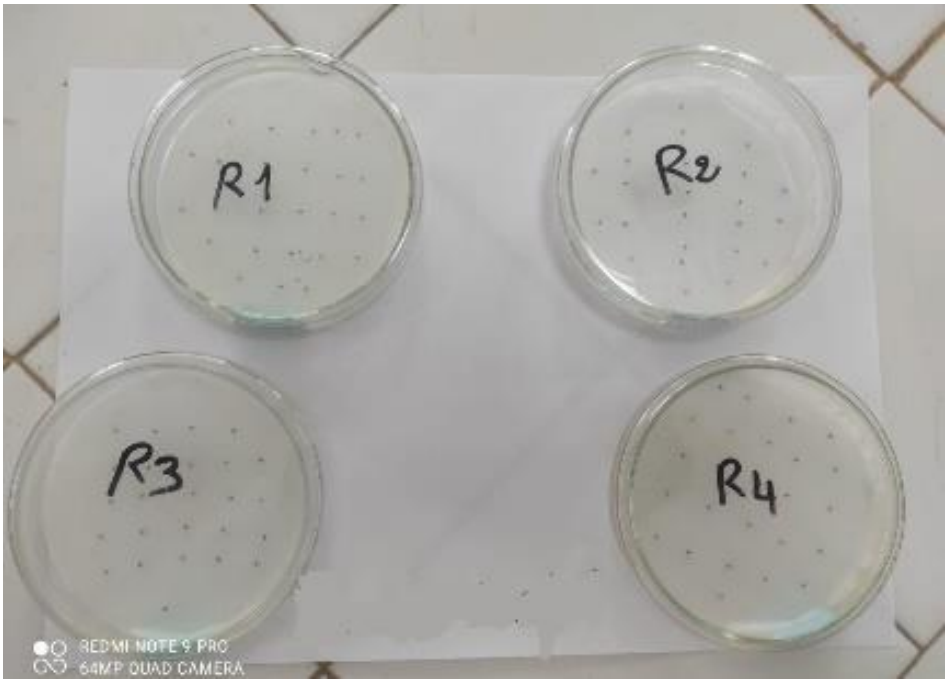

Figure 1. Seeds in petri dishes

Test conditions

- **First trial :** Petri dishes containing seeds dating from 2019, 2020 and 2021 were placed in the laboratory from 17/03/2021 to 17/04/2021 under the following conditions: temperature varying between 11.3°C (22 /03/2021) and 23.5°C (02/04/2021), humidity varying between 22% (01/04/2021) and 32% (30/03/2021), alternating light/dark depending on the day/night duration varies between 12h/12h and 13h/11h

Petri dishes containing the seeds dating from 2008 were placed in the laboratory from 19/05/2021 to 19/06/2021 under a temperature which varies between 21°C (28/05/2021) and 28.3°C (12/06/2021), humidity that varies between 26% (19/05/2021) and 65% (06/06/2021) and a light/dark alternation of 14h/10h.

- **Second trial :** Petri dishes containing the seeds of 2021 Ain Beni Mathar were placed in the laboratory from 17/03/2021 to 17/04/2021 under the following conditions: a temperature which varies between 11.3°C (22/03/2021) and 23.5°C (02/04/2021), a humidity which varies between 22% (01/04/2021) and 32% (30/03/2021), a light/dark alternation which varies between 12h/12h. and 13h/11h.

The seeds dating from 2021 and coming from the pastoretum were also placed in the laboratory from 20/04/2021 to 20/05/2021 under a temperature which varies between 16.2°C (20/04/2021) and 26°C (20/05/2021), a humidity which varies between 26% (18/05/2021, 19/05/2021) and 70% (04/05/2021, 05/05/2021, 06/05/2021), a light/dark alternation that varies between 13h./11h. and 14h/10h.

- **Third trial :** Petri dishes containing the seeds of 2008 (control and with pre-treatments) were placed in the laboratory from 19/05/2021 to 19/06/2021 under a temperature which varies between 21°C (28/05/2021) and 28.3°C (12/06/2021), a humidity that varies between 26% (19/05/2021) and 65% (06/06/2021), and a light/dark alternation of 14h/ 10h.

Observations are taken daily, and the appearance of a small radicle is taken as the germination criterion.

Several other parameters were measured in relation to the germination kinetics, in particular the germination rate, germination speed, latency time. These are extracted from the germination curve.

The experimental device used is a ¨Completely Random Design¨. All tests were performed in four replicates, with 25 seeds in each one. The statistical method used is a single-factor variance analysis using the IBM-SPSS Statistics 23 software. The multiple comparisons of the means are carried out by the STUDENT-NEWMAN-KEULS test at the 5% threshold.

Vegetative propagation: Cuttings

Asexual or vegetative propagation by cuttings requires the collection of herbaceous, semi-woody and woody cuttings of *Artemisia herba-alba* (Table 2). This sampling was carried out on the plants from CRRA Oujda pastoretum, planted in 2012 and having the same origin: Rural commune of Goutitir, Province of Taourirt. These 18 to 20 cm length cuttings were taken from the apical part of the twig and are all in good physiological conditions.

Table 2. Collection date and nature of the Artemisia herba-alba cuttings

Date of collection	Type of cuttings
30/03/2021 31/03/2021 01/04/2021	herbaceous woody
27/04/2021 28/04/2021	Semi-woody woody

All herbaceous, semi-woody and woody cuttings taken from the pastorum were treated with the IAA hormone as follows (Table 3):

Table 2. IAA Hormone Concentrations and Cuttings Soaking Times

IAA Concentrations	Soak times
0ppm (Control)	-
50 ppm	24 hours
1000 ppm	1 min
	3 mins
	5 min
3000 ppm	1 min
	3 mins
	5 min
5000 ppm	1 min
	3 mins
	5 min

For studying the effect of cuttings nature and the treatments on their rhizogenesis of the cuttings, two tests were carried out:

- **First trial:** Placement of herbaceous and woody cuttings treated with the various concentrations of AIA hormone and soaking times, in cubic dimpled plates of dimensions: a = 4.5 cm, H = 7 cm, and filled with peat used as substrate. (Figure 2). They were daily irrigated.
- **Second trial:** Placement of the semi-woody and woody cuttings treated with the same concentrations and soaking times in beakers filled with distilled water which is renewed once a week in order to keep them in good conditions. (Figure 3).

Remark

The difference between the nature of herbaceous and semi-woody cuttings is explained by the fact that the first trial planted in the dimpled plates did not give an indication of the exact day of the first roots emission because of their sinking in the peat.

So, the second test responded to this constraint, by leaving the cuttings in beakers filled with distilled water.

Indeed, the semi-lignification of herbaceous cuttings is the consequence of the temporary lag between the first and second collection.

Figure 2. Cuttings in the dimpled plates

Figure 3. Cuttings in the beakers

Test conditions

- **First trial :**The cuttings were put in dimpled plates containing peat and placed in the greenhouse from 01/04/2021 to 21/05/2021 under a temperature which varies between 13.4°C (20/04/2021) and 39 .6°C (21/05/2021), a humidity which varies between 5% (02/05/2021, 08/05/2021, 09/05/2021, 10/05/2021, 14/05/2021, 15/05/2021, 16/05/2021, 18/05/2021) and 84% (25/04/2021, 26/04/2021, 27/04/2021), a light/dark alternation which varies between 12h /12h. and 13h /11h.
- **Second trial :** The cuttings put in the beakers were placed in the laboratory from 27/04/2021 until 21/06/201 under a temperature which varies between 17.1°C (03/05/2021) and 28.3°C (12/06/2021), a humidity that varies between 26% (18/05/2021 and 19/05/2021) and 70% (04/05/2021, 05/05/2021, 06/05/2021) , a light/dark alternation that varies between 13h./11h. and 14h/10h.

Observations concerned the appearance of the first radicle which is taken as the rooting criterion, and were taken weekly for the first one.

Several other parameters were measured in relation to the kinetics of rhizogenesis, in particular the rooting rate, latency time, which were extracted from the rooting curve.

The experimental design used is a ¨Completely Random Design. The first trial includes 264 herbaceous cuttings and 264 woody cuttings; 3 repetitions of 8 cuttings for each treatment. The second trial includes a total of 330 semi-woody cuttings and 330 woody cuttings; 3 repetitions of 10 cuttings for each treatment.

The statistical method used is a two-factor variance analysis (Nature of cuttings and Treatment) using IBM-SPSS Statistics 23 software.

Results and discussion

Sexual multiplication: Germination

Study of age effect on germination

The analysis of variance showed that the seeds age has a very highly significant effect on germination rate (P<0.001).

The means comparison allowed the discrimination of four homogeneous groups; the first group represents year 2008 (17%), the second group contains year 2019 (31%), the third group represents year 2020 (75%) and the fourth group contains year 2021 (88 %).

Total germination percentage

Germination rate of seeds dating from 2021 is the highest (88%), while that of 2008 is the lowest (17%). The germination rate decreases from year to year. (Figure 4).

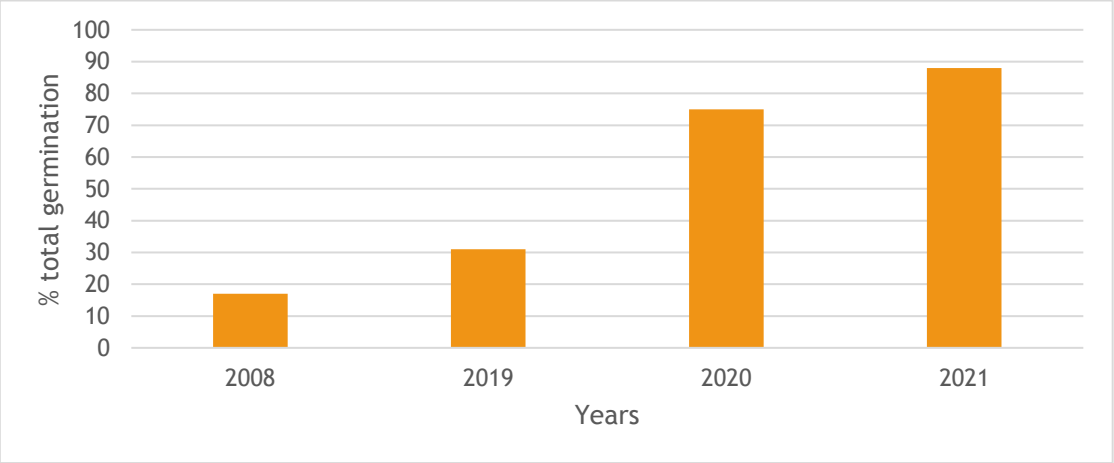

Figure 4. Total germination percentage of Artemisia herba-alba seeds according to their collection years

Seed age effect on germination rate and latency time

The 2021 seeds have the shortest latency time (2 days) and reach 50% of the total germination rate on the 5th day. While the 2008 seeds have the slowest latency time (4 days) and reach 50% of the total germination rate on the 9th day (Figure 5).

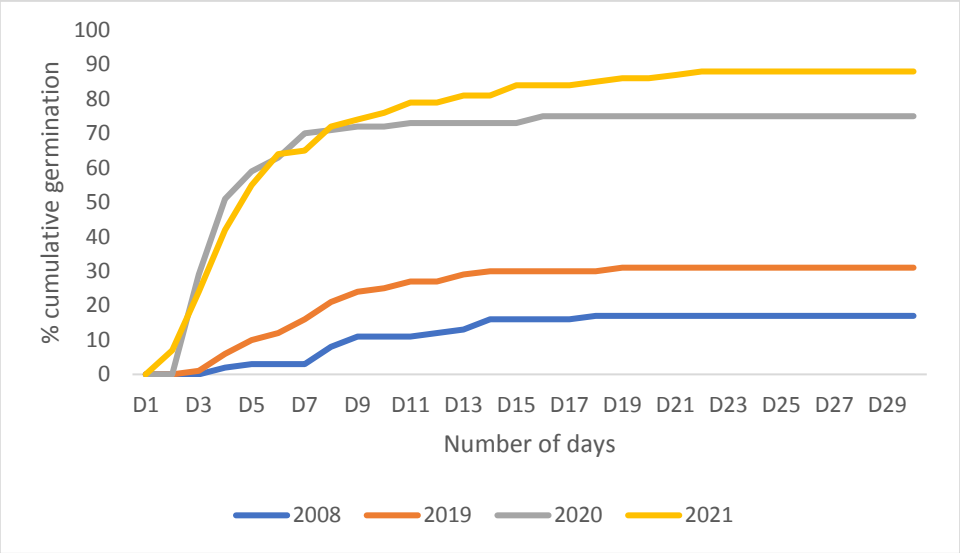

Figure 5. Germination curve of Artemesia herba-alba seeds according to their collection years

This difference between the obtained results can be explained by the impact of the storage duration of seeds on their germination, knowing that they were all stored under ambient conditions, and their germination capacity decreases with time. We can, then, conclude that the viability of these seeds can reach up to 13 years, so they are mesobiotic seeds, like what was quoted by Djuvara (2013).

In addition, the variation in germination conditions (temperature, humidity and light) between seeds dating from 2019, 2020, 2021, and 2008 may also influence the studied parameters (germination rate, germination speed and latency time). This is consistent with what has been noted by (Kaul et al., 1974) and Pourrat (1975).

Contrary to what has been shown by (Pourrat, 1975), the 88% germination rate for 2021 seeds harvested in February suggests that sagebrush does not require post-harvest dormancy.

The 88% germination rate achieved by *Artemisia herba-alba* seeds is much higher than the results obtained by Gseyra (1995)

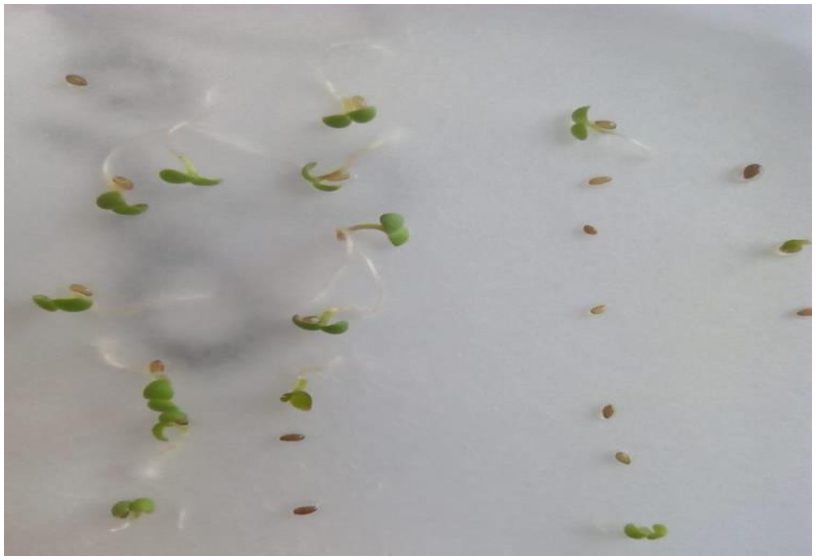

Figure 6. Sprouted seeds of Artemisia herba-alba

Seed provenance effect on germination

The analysis of variance showed that the provenance has a very highly significant effect on the germination rate ($P<0.001$).

Total germination percentage

From the graph, we see that the seeds of 2021 Ain Beni Mathar have a much higher germination rate of 88% than that of 2021 pastoretum (Figure 7).

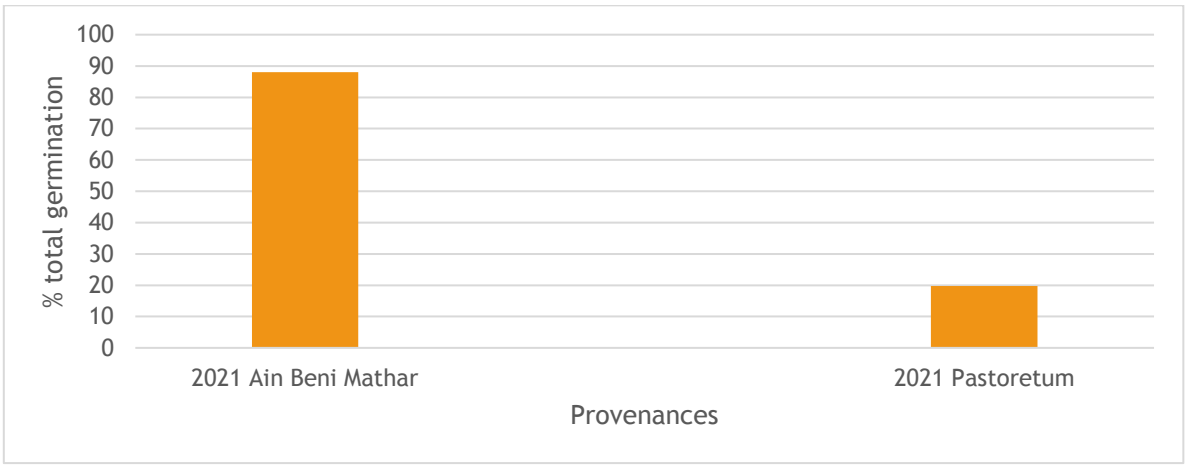

Figure 7. Total germination percentage of Artemisia herba alba seeds according to their provenance

Seed provenance effect on germination rate and latency time

Latency time of the 2021 Ain Beni Mathar seeds was shorter (2 days) than 2021 pastoretum seeds (5 days), and reaches 50% of the total germination rate on the 5th day faster than for pastoretum seeds (13th day) (Figure 8).

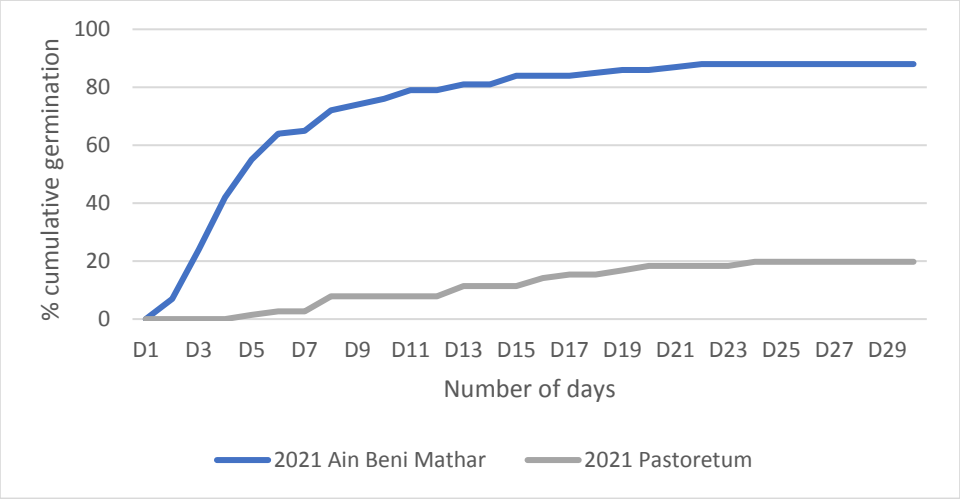

Figure 8. Germination curve of Artemisia herba alba seeds according to their provenance

This difference would be due to climatic conditions: drought could affect the flowering and maturity of seeds as well as their germination capacity, the date of harvesting the seeds; those of Ain Beni Mathar were in full maturity (21/02/2021), while those of the pastoretum were late (12/04/2021).

In addition, the variation in germination conditions (temperature, humidity and light) between the two tests may also influence the studied parameters (germination rate, germination speed and latency time).

In general, germination takes place from February to April, as obtained by Berkat (1986).

Pre-treatments effect on germination

The analysis of variance showed that the effect of the pre-treatments on the total germination percentage is not significant (P>0.05).

Total germination percentage

We noted that the 2008 seeds soaked for 48 hours have the highest total germination rate (21%), slightly higher than that of the control (17%), while that of the scarified seeds is the lowest (8%). (Figure 9).

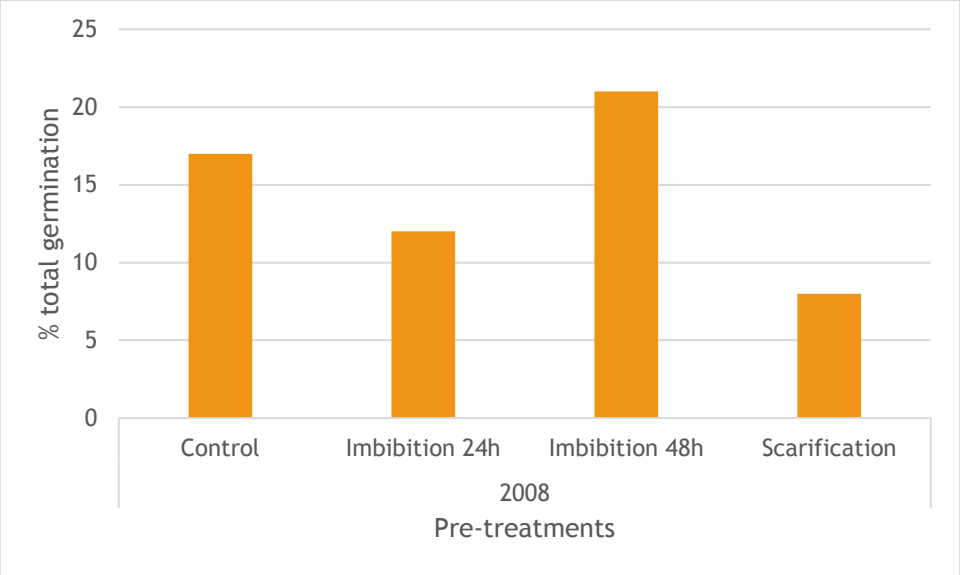

Figure 9. Total germination percentage of Artemisia herba alba seeds according to their pre-treatments

Effect of pre-treatments on germination rate and latency time

Seeds soaked for 48 hours germinated on the day of germination and reached 50% of the total germination rate on the 7th day. However, seeds soaked for 24 hours reached it on the 16th day (Figure 10).

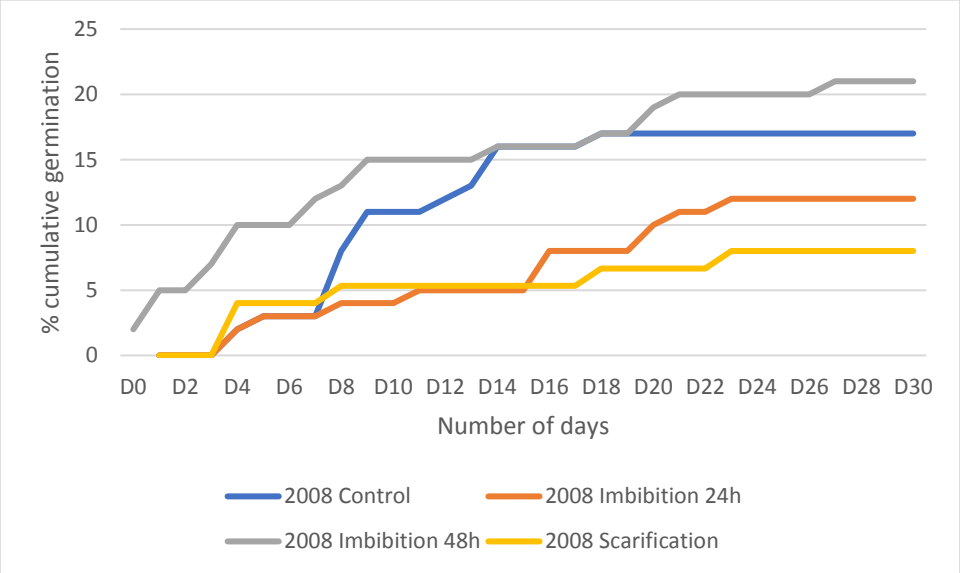

Figure 10. Germination curve of Artemisia herba alba seeds according to their pre-treatments

The results of this test revealed the absence of the tegumentary germination inhibitors, as the imbibition for 48 hours made it possible to slightly increase the total germination percentage compared to the control. It also eliminated the time of latency because we observed the germination of two seeds in water after 48 hours (the day of germination). These are results that could be considered from a practical point of view.

Vegetative propagation: Cuttings

Cuttings nature and treatments effects on their rooting

First trial

The analysis of variance table showed that the effect of cuttings nature, the treatments as well as their interaction are very highly significant (P<0.001).

Total rooting percentage

After 7 weeks in the plates, the herbaceous and woody cuttings were repotted in bags to ensure their good root development. At this time, we took care to count the number of rooted cuttings. The obtained results show from one hand that the highest rooting rate is observed in herbaceous cuttings not treated with IAA (Control) (50%). The woody cuttings which present the high percentage of rhizogenesis are those treated with a concentration of 3000 ppm of the phytohormone in which they were soaked for one minute (12.5%). On the other hand, some cuttings don't have rooting rate: herbaceous and woody cuttings treated with 50 ppm for 24 hours, 1 000 ppm for 1 minute and 5 000 ppm for 3 minutes, woody cuttings treated with 1 000 ppm for 3 minutes , 3 000 ppm for 3 minutes and 5 000 ppm for 5 minutes (Figure 11).

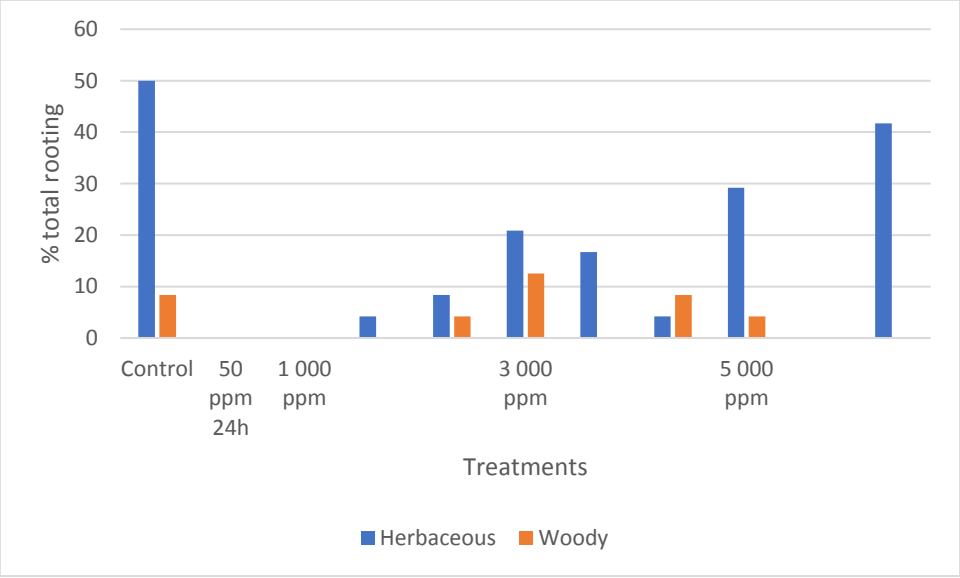

Figure 11. Total rooting percentage of herbaceous and woody cuttings planted in peat

These results show that herbaceous cuttings have a greater rooting ability than woody cuttings.

Second trial

Total rooting percentage

None of the semi-woody cuttings sent roots. In contrast, hardwood cuttings evolved as follows:

The total percentage of high rooting is that of the control (50%). This percentage is canceled in the cuttings treated with 1 000 ppm for one and three minutes and those treated with 3 000 ppm for one, three and five minutes (Figure 12).

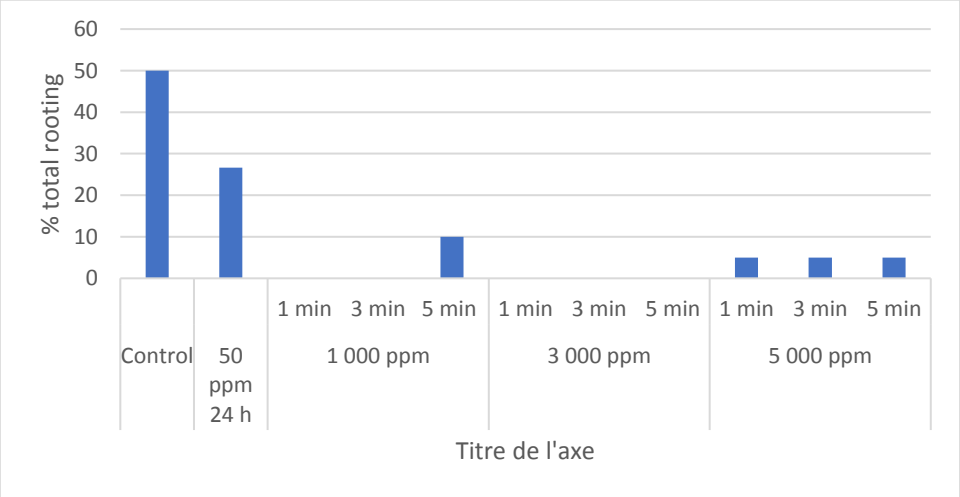

Figure 12. Total rooting percentage of woody cuttings in beakers

Cuttings nature and treatments effect on the latency time.

The shortest latency time is that of woody cuttings control (7 days) (Figure 13).

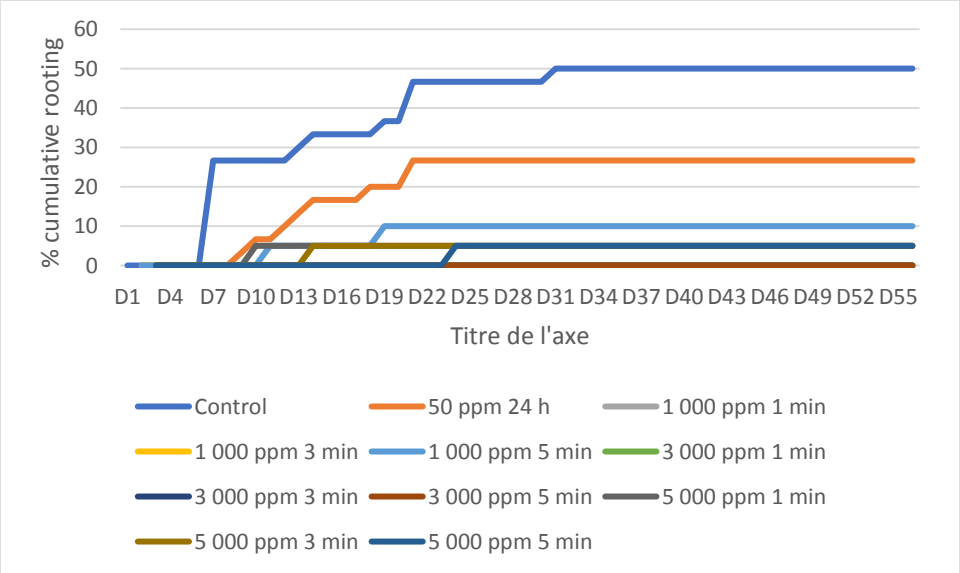

Figure 13. Rooting curve of woody cuttings in beakers

We notice that the capacity of root emission exists in woody cuttings, but is absent in semi-woody cuttings.

Following these two tests, we can deduce that:

- IAA can act positively by promoting the rhizogenesis of cuttings, as it can have a negative effect by totally inhibiting the emission of roots. In this case, it turned out that the cuttings of *Artemisia herba-alba* achieve a better rooting rate without resorting to these hormone treatments.
- Water and peat also have an effect on rhizogenesis; the fragility of the roots in water facilitates their detachment, and therefore the cuttings placed in peat are more vigorous.

According to these obtained results, and in terms of comparison between the two multiplication methods:

Germination requires the collection of seeds from *Artemisia herba alba*; a rather delicate step because of their small size, which requires a considerable time for their detection.

It is also influenced by several factors including the climatic conditions of the year, the stage of maturity of the seeds, the storage conditions, the duration of storage, etc.
However for the cuttings, obtaining a new seedling is faster. We have observed the emission of roots by the cuttings from the 7th day, making a valid plant to be transplanted in the field.

Moreover, this method is very feasible and us sufficient to make a judicious choice of cuttings and the moment of their collection.

Finally, the best rooting is observed in untreated cuttings, which means that the IAA hormone is not useful for this species.

Figure 14. Growth of an Artemisia herba-alba seedling from a seed

Figure 15. Growth of a cutting of Artemisia herba-alba

Conclusion and recommendations

The results of this study led to the production of new seedlings of *Artemisia herba-alba* suitable to be transplanted in the field, both sexually (germination) and asexually (cuttings). Our results could constitute a potential lead to the achievement of the great objective of contribution to the rehabilitation of degraded plateaus to the study shows that the germination of the seeds of *Artemisia herba alba* could reach high rates exceeding 80%. Nevertheless, the germination power could be affected by several parameters:

-The age of the seeds: the seeds of *Artemisia herba-alba* lose their viability with the age of storage. Although 2008 seeds stored at ambient conditions remain viable.

-The collection period: the seeds collected in February-March germinate better than those collected later.

-The provenance: the 2021 seeds collected in Ain Béni Mathar have a higher germination power than that of the seeds collected the same year at Oujda. The difference between localities would be due to climatic conditions: drought could affect the flowering and maturity of seeds as well as their germination capacity.

In addition, scarification is ultimately not indicated for white wormwood whose achenes do not have hard teguments and this treatment seems to damage the seeds, the smallness of this species seeds barely visible to the naked eye and the difficulty of collecting seeds in the field (scaling of maturity, annual variability according to climatic conditions, labor), make multiplication by seed impractical on a large scale.

In addition, propagation by cuttings seems more promising and more feasible to us. Nevertheless, for the mastery of this technique, it is undeniable to deepen knowledge by carrying out studies on the period of cuttings, the types of cuttings and the products that can better improve the rooting and the production of plants.

Indeed, it should be remembered that the best technique to proceed for the multiplication of *Artemisia herba-alba* is the production of apical herbaceous cuttings, collected in March and not treated with the IAA hormone.

Finally, far from providing a definitive final solution to the problem of degradation of this key pastoral species, our study highlighted several supreme aspects that can contribute to the control of the multiplication and production of *Artemisia herba alba* plants suitable for transplantationed.

For all these reasons we recommend to proceed by asexual way for the propagation of *Artemisia herba alba particularly by using* herbaceous apical cuttings collected around the end of March without using IAA,

We also recommend the use of other phytohormones that can stimulate rooting, such as IBA and NAA.

It is therefore very interesting to study the effect of other provenances and other pre-treatments (especially stratification) on the germination of this species. Finally, the use of a germination chamber is also encouraged in order to better understand the role of temperature, humidity and light on the germination of this species.

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