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Technical note

Variation in seed biometry and early seedling growth from northeastern Algerian *Quercus suber* L. provenances

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ABSTRACT This study aimed to assess the effect of provenance on seed biometry and early seedling growth of *Quercus suber* L. The acorns used for the study conducted in the regional forest research station of Jijel, were collected from thirty healthy mother trees representing six provenances in Jijel. After seed collection, a subsample of acorns from each mother tree was used in a laboratory experiment including biometric characterization and cold storage behavior assessment throughout moisture content and germination measurement. Additionally, a nursery experiment was carried out with acorns stored for three months to assess the effects of the seed source on seedling growth traits including height, collar diameter, biomass and leaf biomass and surface. The results revealed significant differences at 5% probability level among *Q. suber* seed provenances and mother trees with respect to seed morphology, seed storage, seed germination and seedling growth parameters. Despite the absence of a clear effect of the environmental conditions of the studied provenances, the Kissir provenance was the superior for all the studied parameters. Regardless of provenance, the favorable environmental conditions of the nursery along with favorable cultivation conditions, including proper seed handling and storage, growing mixture, and irrigation could enhance the desirable seedling quality for reforestation purposes.

KEYWORDS: *Quercus suber* L., provenance, seed biometry, seedling growth.

Introduction

Quercus suber L., also known as cork oak, is a sclerophyllous evergreen tree species belonging to the *Fagaceae* plant family. It is one of the major tree species of the western Mediterranean basin where it occupies areas of high socioeconomic and ecological relevance, extending over 2 million hectares (APCOR 2020, Montero-Muñoz et al. 2021), and spreading across 7 countries (Portugal, Spain, Algeria, Morocco, Tunisia, France, and Italy). In Algeria, cork oak is the most common forest tree species, covering 357,582 hectares after Aleppo pine (FAO 2007), but it is the most contributor to the national economy through the sale of cork products, nonwoody products and other services. Unfortunately, this patrimony continues to deteriorate under the effects of many abiotic and biotic factors including climate change, wildfires, land use changes, invasive species, inappropriate cork stripping, and pests (Messaoudene 2000, Bouhraoua et al. 2002, Younsi et al.2021, Younsi et al. 2022, Bendjebbar et al.2023), along with a lack of management and appropriate silviculture toward this important species of the Algerian forest. As reported elsewhere (Gentilesca et al. 2017, Kim et al. 2017, Ritsche et al.2021, Mechergui et al. 2023), Algerian cork oak landscapes are experiencing continuous degradation in the form of decreasing tree cover (stand density) in formations such as open woodlands and shrublands with an acute lack of natural regeneration.

To overcome the deficiency of natural regeneration that has long been reported in Algerian cork oak forests (e.g. Djinit 1977, Zeraia 1981, Yessad 1999), several reforestation projects have been carried out either by direct seeding or planting but without much success (Benamirouche 2005, Bouhraoua et al. 2014). Among several causes, the use of poor-quality plants is one of the main factors involved in the recorded failures. In fact, successful forest restoration requires the planting of high-quality seedlings with optimal successful establishment and growth potential (Grossnickle and MacDonald 2017). Genetic quality and nursery conditions have a direct influence on plant quality and field performance (Landis et al. 1990, Branco et al. 2002, Villar-Salvador et al. 2004). Taghvaei (2010) reported significant differences among seed sources in terms of the seed germination and seedling attributes of *Quercus brantii* Lindl. Varela et al. (2015) reported significant differences in seedling growth and survival among *Quercus suber* provenances. Thus, proper selection of seed trees to collect quality seed, may have a major influence on the success of forest tree planting programs (Nirsatmanto and Sunarti 2020). The choice of the best seed source for a desired plant species is crucial for successful plantation programs (Yisau et al. 2023). Seed sources should represent the best available genetic material for planting, as exhibited by the plus trees or parental material (Mbora and Mnadass 2009). Seed biometrics are a pertinent tool for detecting genetic variability within populations of a given plant species and the relationships between this variability and environmental factors, as well as for breeding programs and seedling performance (Gonçalves et al. 2013). In this context, seed source testing is one method for screening the naturally available genetic variation to select the best planting material for increased productivity and future breeding work (Bhat and Chauhan 2002, Alex et al. 2020).

Hence, to produce seedlings for out-planting purpose, seeds should be collected from phenotypically superior trees (vigorous, healthy and well-formed trees) selected in superior forest stands. Within this context, 61 superior cork oak stands have been identified across the

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Algerian area of the species, but to date, no studies have investigated the variability of seeds and seedlings in relation to the identified seed stands. Thus, the main objective of this study was to assess the effect of seeds collected from thirty phenotypically superior trees selected in six provenances of *Quercus sube*r distributed in the state of Jijel in northeastern Algeria on seed biometry, seed storage, seed germination, and early seedling growth. The results should provide useful guidelines for cork oak seed collection, processing, storage and seedling cultivation.

Materials and methods

Seed sampling and collection

The seeds used in this study were hand collected from trees grown wild in six cork oak natural stands (provenances) located at different elevations in the state of Jijel in northeastern Algeria (Fig. 1).

The general characteristics of the sites of the sampled provenances are presented in Table 1.

The sampled provenances reflect a variety of ecological conditions, including the following:

- a littoral provenance represented by the Kissir stand located at 20 m elevation;
- two low-altitude provenances Draden and Krina Boulbalout, are located at elevations of 350 and 400 m, respectively;
- two middle-altitude provenaces represented by the stands of Harma and Tassouda located at elevations of 620 and 630 m, respectively;
- a high-altitude provenance represented by the T'Saroubia stand located at 800 m elevation.

From each provenance, five trees without apparent phenotypic and/or pathogenic damage and sufficiently distant apart to avoid sampling related individuals (Harfouche 2005, Nayak and Sahoo 2020, Olaniyi et al. 2023), were selected for seed collection.

Figure 1 - Location of the studied provenances.

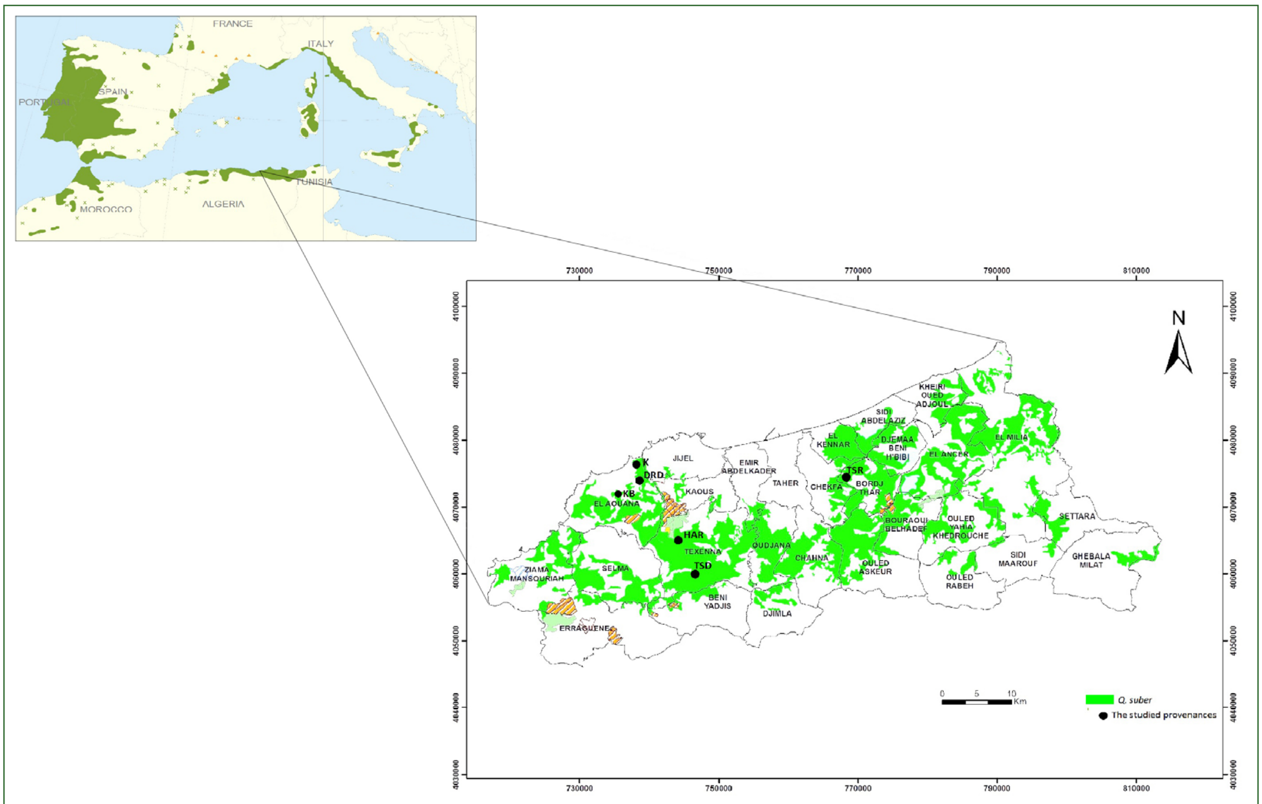


Table 1 - Location and characteristics of the provenances selected for acorn collection.

Stand	Bioclimate	Substratum	Georgraphical cordinates (UTM WGS 84)		
			Latitude	Longitude	Elevation (m)
Kissir (K)	Humid	Numidian sandstone	36°47'28.81"N	5°39'58.09"E	20
Krina Boulbalout (KRN)	Humid	Numidian sandstone	36°44'55.16"N	5°38'06.14"E	400
Draden (DRD)	Humid	Numidian sandstone	36°45'34.20"N	5°40'30.72"E	350
Harma (HAR)	Sub-humid	Numidian sandstone	36°39'06.26"N	5°47'18.36"E	620
Tassouda (TSD)	Cool Sub-humid	Numidian sandstone	36°38'56.86"N	5°46'14.95"E	630
T'Saroubia (TSR)	Cool Sub-humid	Numidian sandstone	36°44'48.12"N	6°1'57.36"E	800

UTM: Universal Transverse Mercator; WGS84: World Geodesic System 1984; m: meter.

Seed handling and storage

After collection in December 2018, the seeds from different mother trees in each provenance were placed separately in perforated plastic boxes and transported to the laboratory of the regional forest research station in Jijel (36°47'29.79"N; 5°39'59.65"E; 20 m elevation), where they were hand cleaned of impurities and damaged acorns, including infested, germinated, and dried acorns. The apparently healthy and intact acorns from different mother trees were measured for their morphological variation as described in the biometric section below and then kept separate in a cold room maintained at 0 to 2°C, according to Benamirouche et al. (2018) until the nursery experiment.

Biometric study of acorns

To evaluate the morphological variability of acorns representing the different mother trees, subsamples of 15 acorns (5 acorns × 3) from each sample tree were biometrically characterized through the measurement of the parameters length from base to apex (L, mm), median diameter (MD, mm) expressing seed thickness measured at the seed midline, and seed weight (W, g). Length and diameter were measured with a 0.01 digital calliper, whereas weight was measured with the aid of a 0.001 precision analytical balance. The quotient length/median diameter (%) was also measured.

Assessment of acorn viability after storage

The viability of the acorns was monitored after 3 months of storage through the measurement of moisture content and germination on a working sample of 100 acorns (25 acorns × 4) for each sample tree as follows:

The moisture content (WC, %) was determined for a subsample of 15 acorns (5 acorns × 3) among the 100 acorns representing each sample tree. The fresh weight (FW, g) of the acorns from each replicate was measured using a precision balance, and the samples divided lengthwise into two parts using a scalpel, and then oven dried at 103°C for 17 hours for dry weight (DW, g) measurements (ISTA 2009). The moisture content was calculated on a fresh weight basis using the formula: MC% = [(FW-DW)/FW] × 100.

Germination was measured on a subsample of 30 (10 × 3) apparently intact acorns among the 100 extracted for evaluation for each sample tree. The acorns were sown in early April 2019 in boxes filled with sawdust. The boxes were moistened with distilled water whenever necessary and placed under laboratory conditions for a period of 30 days. Germination, defined by radicle protrusion, was assessed for the first time after 7 days, and then every two days until the end of the experiment. Germination data were subsequently used to calculate the germination percentage as the total number of germinated acorns on the 30th day, and the germination speed was calculated as the mean germination time (MGT):

$$MGT = \frac{\sum GN}{\sum n} \qquad \text{(eq.1)}$$

GN represents the number of acorns germinated on day N, and n represents the number of days calculated from the start of the germination experiment.

Effect of the provenance on seedlings growth

The experiment was carried out at the nursery of the regional forest research station in Jijel to assess the potential inter- and intra-provenance effects on seedling growth.

Seed sowing and seedling cultivation

Eighty apparently intact acorns of each tree were individually sown in early April 2019 in open-bottomed WM containers (400 cm^3) of Reidacker filled with the same mixture of *Acacia cyanophylla* Lindl. compost, topsoil, and cork granules (1/1/1, v/v/v). The experiment was laid out in a completely randomized design with four replications; each sample tree was considered a treatment within each provenance and represented by 80 seeds (20 seeds × 4). Thus, the experiment consisted of 2,400 seeds (80 acorns/tree × 5 trees/stand × 6 provenances). The containers consisted of 40 units in perforated plastic boxes, which were randomly placed on benches elevated 30 cm from the surface of the ground to allow root air-pruning. Irrigation and weed control were uniformly applied as necessary throughout the experiment period. No fertilization was applied.

Seedling sampling and measurements

For seedling growth and quality assessment, 20 seedlings per sample tree were randomly selected and labelled for morphological attribute measurements, including height, collar diameter, root and shoot dry weight, number of leaves and leaf area. Seedling height (H, cm) was measured using a gradual ruler, and root collar diameter (D, mm) was measured using a digital calliper at 90, 120, 150, and 180 days after sowing. 180 days after sowing, the shoot dry weight (SDW, g) and root dry weight (RDW, g) of the sampled seedlings were measured using an analytical balance with an error of 0.01 g after oven drying the stems and roots at 80°C for 24 hours. Leaf attributes, including the number of leaves (NL), leaf area (LA, cm^2) and mean leaf area (MLA) area/plant (cm^2.plant^{-1}) were also measured on the last sampling date.

Statistical analysis

The biometric data were analyzed by univariate statistics to obtain position measurements (mean, maximum, and minimum values) and dispersion (coefficient of variation and standard deviation). The data on seedling growth were subjected to ANOVA at the p = 0.05 significance level. When significant differences were found in the ANOVA, means were compared using the Newman-Keuls post-hoc multiple range test. In addition, principal component analysis (PCA) was performed to explore the interactions between different quantitative variables (site variables, seed and seedling parameters). All the statistical analyses were performed using the XL-STAT software package.

Results

Biometric study of seeds

The aspects of acorns of the studied provenances are illustrated in Figure 2. The average seed weight, seed length, and seed median diameter are shown in Figures 3, 4, and 5.

Figure 2 - Acorns of the thirty mother trees after 3 months of storage.

Photo by Samir Benamirouche (Regional station of forest research of Jijiel, Algeria). DRD: Draden; H: Harma; K: Kissir; KB: Krina; TSD: Tassauda; TSR: T'Saroubia.

Figure 3 - Average weight of cork oak acorns from different provenances. Bars with no common letters are significantly different at p = 0.05.

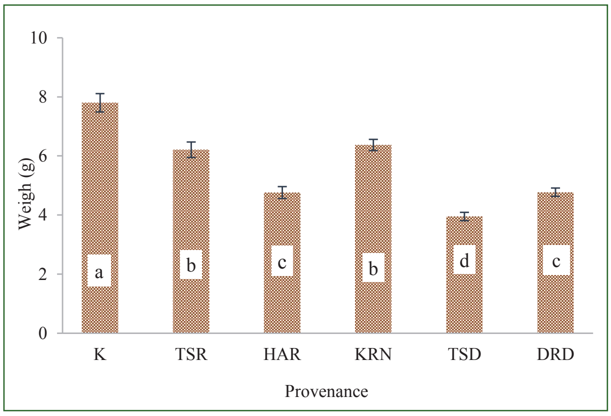


Figure 4 - Average lenght of cork oak acorns from different provenances. Bars with no common letter are significantly different at p = 0.05.

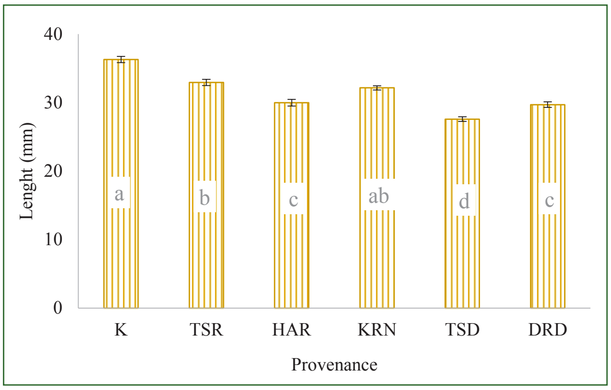
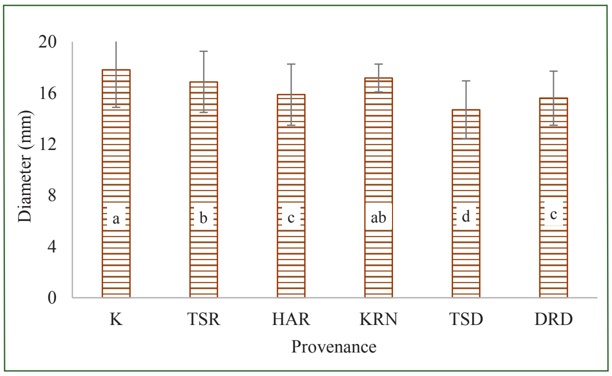


Figure 5 - Average median diameter of cork oak acorns from different provenances. Bars with no common letter are significantly different at p = 0.05.



Data analysis revealed the accuracy of sampling through the low standard error in all seed variables, indicating that the sampling size provided consistent data, with little variation in relation to the average found for the trees of each provenance. The morphometric analysis of the seeds revealed significant differences ($P<0.05$) between the six provenances for all the measured parameters, with considerable amplitudes of variation, such as for acorn weight, which showed the highest coefficient of variation value of 36.39%. The acorns had an average weight of 5.72 g, a length of 31.61 mm, and a diameter of 16.39 mm. The acorns harvested from Kissir were the longest (36.29 ± 0.46 mm) and heaviest (7.80 ± 0.31 g), whereas the acorns from Tassouda were the smallest (27.58 ± 0.35 mm) and lightest (3.95 ± 0.14 g). At the intra-provenance level, considering the high standard deviation values, great mean variations were shown between trees of the same provenance for all the studied parameters. For instance, tree 4 of the Kissir provenance produces heavy acorns with an average weight of 10.09±0.19 g, while tree 1 of the same provenance produces light acorns with an average weight of 3.84±0.16 g.

Moisture content and germination

Data on moisture content, seed germination percentage and mean germination time are presented in figures 6,7, and 8 respectively.

Figure 6 - Average moisture content of cork oak acorns from different provenances. Init: moisture content at hervest; 3Mths: moisture content after 3 months of stoarge. Bars with no common letter are significantly different at p = 0.05.

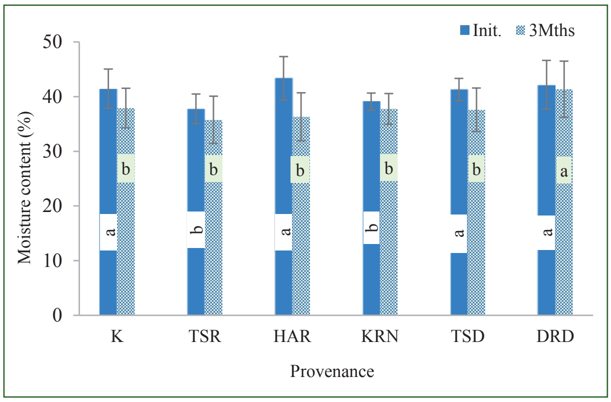


Figure 7 - Average germination percentage of cork oak acrons from different provenances after three months of storage. Bars with no common letter are significantly different at p = 0.05.

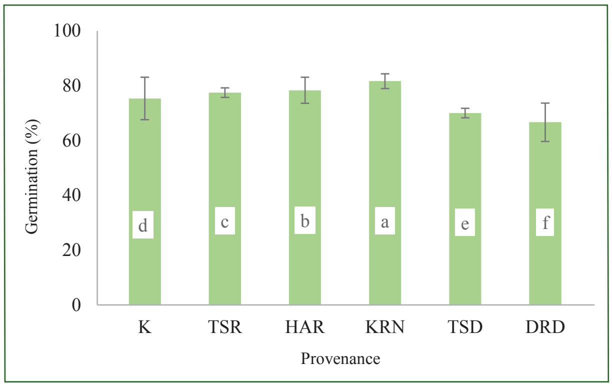
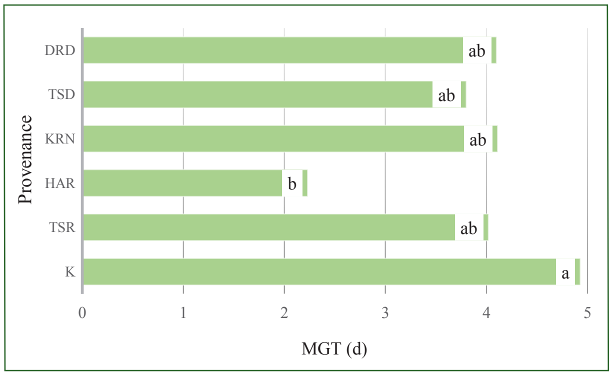


Figure 8 - Average mean germination time of cork oak acorns from different provenances. Bars with no common letter are significantly different at p = 0.05.



At harvest, the average moisture content ranged from 41 to 43% for the Kissir, Draden, Harma, and Tassouda provenances, which formed a homogenous group, followed by the acorns from T'Saroubia and Krina, which had average moisture contents of 37.80% and 39.11%, respectively. After 3 months of storage, the moisture content of the acorns in all the provenances fluctuated. Water losses ranged from 2.05% for acorns from T'Saroubia to 7.03% for acorns from Harma. In terms of germination capacity, there were significant differences in percentage of germination among the six provenances after 3 months of storage ($P< 0.0001$). Newman-Keuls's test revealed germination was significantly the lowest (66.67%) in Draden provenance as compared to other provenances exhibiting values ranging from 70 for Tassouda to 81.66 % for Krina. The germination speed, expressed as the mean germination time, was faster for the seeds from Harma (2.23) than for those from other provenances, which exhibited values ranging from 3.80 for Tassouda to 4.93 for Kissir.

Seedling growth parameters

The results in Figure 9 shows that emergence was satisfactory with an average percentage of 74.25%. Sowing from Harma, Tassouda and Kissir belonging to the same statistical group, exhibited highest emergences with respective percentages of 81, 83.75 and 84% whereas lowest emergence was observed in Draden (56.5%). Furthermore, significant differences in the growth parameters, including height (Fig.10), collar diameter (Fig.11), and root and shoot dry weights (Tab.2), were observed after emergence. Seedlings supplied by acorns from Kissir reached the highest values of all the studied parameters from the first measurement carried out at 90 days after sowing (H1) until the end of the experiment at 180 days after sowing (H4), whereas lowest values were observed in seedlings from Tassouda. In the same way, results on Table 2 displayed that leave parameters were highest in Kissir (LA = 188.66 cm^2, MLA = 4.76 $cm^2.plant^{-1}$) and lowest in Tassouda (LA=97.31 cm^2, MLA=2.71 $cm^2.plant^{-1}$). Seedlings from the other provenances (Harma, T'Saroubia, Krina and Draden), belonging to the same statistical group according to the Newman-Keuls ranking test, showed intermediate leaf areas with values ranging from 136.43 to 157.96 cm^2. Moreover, the analyze of the growth increase in height between the different measurement dates shows more increase in height during the second measurement date (H2) with values ranging from 7.05 to 11.23 cm than that of the other dates (H3 and H4) in all provenances. In contrast, the growth increase in diameter was more sustained during the last two measurement dates (D3 and D4) in all provenances.

Figure 9 - Average emergence percentage of cork oak seedlings from difference provenances. Bars with no common letter are significantly different at p = 0.05.

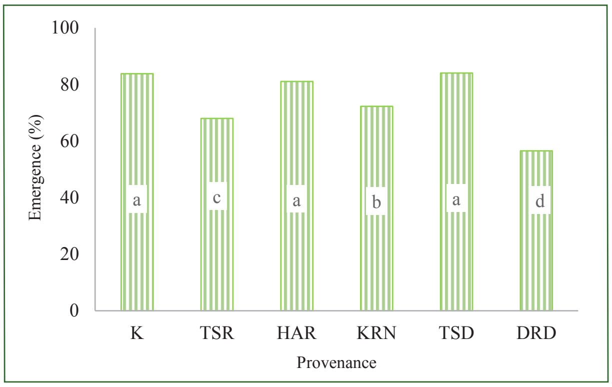


Figure 10 - Growhth trend in hight of cork oak seedlings from different provenances.

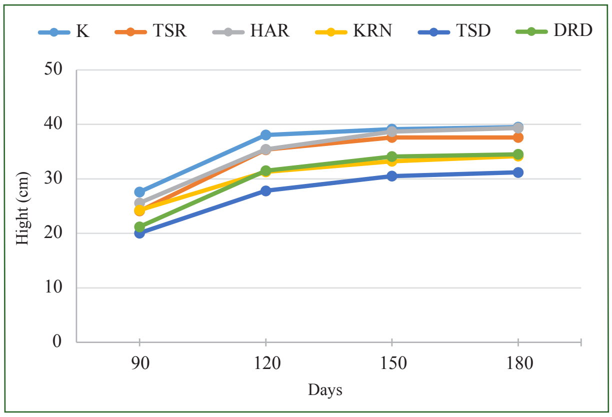


Figure 11 - Growhth trend in collar diameter of cork oak seedlings from different provenances.

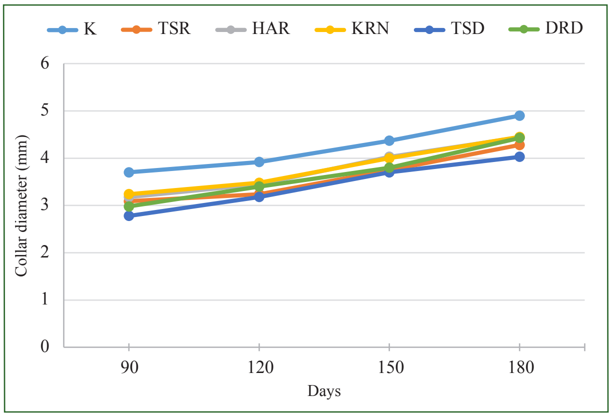


Table 2 - Mean root and shoot dry weights and leaf parameters of cork oak seedlings from different provenances (mean ± sd).

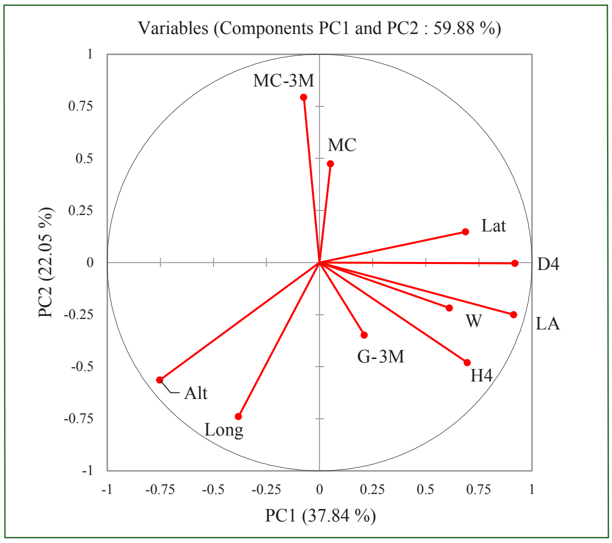
Paramètre	P	Kissir	T'Saroubia	Tassouda	Harma	Draden	Krina
RDW (g)	0.000	4,32±0,68a	3,28±0,61b	3,61±0,92b	3,15±0,86b	3,45±0,86b	3,38±0,51b
SDW (g)	0.0001	3,16±0,55a	2,42±0,81b	1,92±0,50c	2,51±0,51b	2,41±0,46b	2,18±0,43bc
NL	0.002	40,01±5,25ab	37,48±6,17abc	35,86±5,82bc	41,74±4,79a	38,40±6,50abc	34,61±4,60c
LW (g)	0.0001	3,73±0,67a	2,86±0,88b	1,94±0,52c	3,15±0,62b	2,72±0,54b	2,82±0,50b
LA (cm²)	0.0001	188,66±33,33a	143,20±44,19b	97,31±25,80c	157,96±30,76b	136,43±27,07b	141,13±15,12b
MLA (cm².plant⁻¹)	0.0001	4,76±0,77a	3,77±0,74b	2,71±0,58c	3,76±0,47b	3,60±0,75b	4,09±0,59b

RDW: root dry weight; SDW: shoot dry weight; NL: number of leaves; LW: leaf weight; LA: leaf area; MLA: mean leaf area. Values in the same line with no common letter are significantly different at p=0.05 probability level according to the Newman- Keuls ranking test.

Interactions between variables and observations (PCA)

From the results of the PCA (Fig.12), the two first components with an inertia rate of 59.88% were selected. The biplot shows that the component PC1 groups the parameters of seed (weight and germination) and those of seedlings (height, collar diameter and leaf area) with altitude and longitude pointing to negatively correlations, whereas the second component PC2 groups the moisture contents MC and MC-3 measured at harvest and after three months of storage respectively. Among the three geographical variables, the results of the PCA revealed a positive correlation between latitude and most of seed and seedling parameters.

Figure 12 - Principal component analysis characterizing the interaction between different variables and observations. Alt: Altitude; Lat: Latitude; Long: Longitude; MC: Moisture content of seeds at harvest; MC-3M: Moisture content of seeds after three months of storage; G: Percentage of germination of seeds after three months of storage; W: Seed weight; H4: Seedling height at the 4th measurement date; D4: Seedling diameter at the 4th measurement date; LA: Leaf area.



Discussion

This study aimed to assess the potential effects of cork oak provenance on seed biometry and seedling growth parameters. The biometric study of acorns revealed significant variability (P<0.05) both at the inter and intra-provenance levels in all the studied parameters (length, thickness, and weight). Kissir showed the highest mean values with the largest variations in the data in all seed parameters while Tassouda showed the smallest mean values. Variability in seed traits observed in this study supports previous findings about various provenances across the area of the species (Merouani et al. 2001, Ramirez-Valiente et al. 2009, Xia et al. 2012, Zine El Abidine et al. 2016, Chouial et al. 2020). Except for the correlation observed between latitude and seed weight, there was no clear effect of the geographical location of the studied provenances on the biometry of acorns. However, this finding must be carefully interpreted given the small size of the sampled area, which does not allow for a clear geographical gradient. Hence, variation of seed traits among the provenances may be attributed to differences in the local conditions of the studied provenances (soil fertility, water availability and temperature) that could influence seed development and maturity (Negash 2010). Furthermore, the biometric variability observed at the intra- provenance level may be due to genetic factors resulting in maternal effect in the tree (Mercier and Rainville 1996, Alejano et al.2011). Also variation in seed traits within the same mother tree way be due to the position of seed on the plant. Regardless the reason, the variation in cork oak seeds could be the consequence of the range climatic conditions across the distribution area of the species, varying from humid to xeric, which suggests a high phenotypic plasticity and genetic variation.

Overall, moister contents ranging from 41 to 44% at harvest corroborate those obtained in other studies (Merouani et al. 2001, Benamirouche et al. 2018), supporting the recalcitrant behavior of cork oak seeds maintaining high water levels at maturity. The intra and inter provenance variability in moisture content observed in this study may be attributed to the environmental conditions prevailing during seed development that interact with the genotype (Chen et al. 2021). Compared to those registered before storage, the moisture contents registered after 3 months of storage fluctuated, showing that the acorns remained metabolically active during the storage process even at near freezing temperatures (0-2°C). Although there were more water losses than gains, the recorded dehydrations were not harmful to the viability of acorns as the moisture content remained close to the initial levels registered at maturity and above the minimum of 30% required for acorn germination suggested by Merouani et al. (2001). Therefore, after 3 months of storage, germination was satisfactory in all provenances, with an average germination percentage of 73.67%. Our results are in line with other studies that have demonstrated the high germination capacity of cork oak acorns (Benamirouche et al.2018, Mechergui et al. 2021, Chouial et al. 2022) and other oak species such as Portuguese oak (Aissi et al.2019) and Holm oak (Amimi et al. 2023). Moreover, germination in all provenances was synchronous with the absence of any dormancy delaying germination, whereby more than 50% of the acorns germinated during the first week of stratification in sawdust. Indeed, the adequate storage of acorns could enhance acorn germination by breaking dormancy and making germination rapid and uniform regardless the origin of the stored acorns, thus easing nursery sowing for cork oak seedling production.

Regarding emergence, the results were satisfactory in all provenances, with an average percentage of 74.25%. However, significant differences at both the inter and intra provenance levels were observed for this parameter, which should confirm the previous results of the germination phase. No tree or provenance exhibited a maximum emergence of 100%, which can be attributed to several causes, such as acorn rot caused by excess water in the substrate or too deep sowing of acorns. In the same way, all the growth parameters measured after emergence were significantly affected by provenance. On average, the height pattern was marked by fairly rapid growth in the first two months (Mai and June), a rapid growth in the 4th month (July), and then a slow growth in August and September. At the end of the growth cycle, Kissir seedlings reached the maximum average height, whereas Tassouda seedlings reached the minimum average height. The change in collar diameter showed the same trend as that of height but it was relatively more sustained in the months of August and September where seedlings from Kissir reached the maximum average diameter compared with other provenances. Leaf parameters were also in line with the growth parameters, for which significant differences were shown in both leaf number and area. Leaf parameters of seedlings from Kissir were highest compared with other provenances.

The analysis of the growth increase in height and collar diameter calculated between the different measurement dates provide evidence that cork oak seedling growth is rhythmic and follows distinct phases, which support those of Alatou (1990) about *Q. suber* and other *Quercus* species. After seedlings emergence (approximately 4 to 6 weeks after sowing), rapid height growth occurs in June and July matching the first growth wave, followed by a latent phase characterized by a temporary slowdown in elongation during the hot period where seedlings invest rather in hardening, reflected by the increase in diameter during this period, as an adaptation mechanism to these particular conditions. In fact, among the anatomical and functional adaptations to modifications in surrounding environmental conditions that have already been demonstrated for the species (Chelli-Chaabouni 2014, Ghouil et al. 2020, San-Eufrasio et al. 2020), the slowdown in height growth may correspond to a temporary reduction in terminal bud activity (Meriaux et al. 1974). However, the elongation rates of cork oak are not only governed by climatic conditions but also by other factors such as substrate and container size (Benamirouche et al. 2019).

In addition, the relationship between seed weight and seedling growth was also demonstrated. Plants from large acorns (Kissir) were the tallest and largest, whereas those from small acorns (Tassouda) were significantly the smallest. Mechergui et al. (2021) also observed this growth pattern in *Quercus suber* and attributed it to the greater growth unit achieved by seedlings from large acorns compared to small acorns. Moreover, the superiority observed in all the measured parameters (height, collar diameter, and leaf parameters) for seedlings of Kissir may also be attributed to better adaptation to the environmental conditions of the nursery located close to the sampled trees. However, given the growth rates achieved for the whole seedling, it can be concluded that the environmental conditions of the breeding nursery along with the favorable breeding itinerary including seed handling, seed storage, growth media and cultivation treatments (irrigation and weed control), were also favorable for all seedlings, irrespective of the provenance. Further experiments under limited growth conditions such as restraining water supply could help to confirm the real performance of seedlings from different provenances.

Conclusion

The study of cork oak acorns collected from six provenances in northeastern Algeria highlighted significant variation in seed morphology (size and weight), seed germination and seedling growth parameters. The Kissir's provenance displayed highest values in all seed and seedling parameters as compared with the other provenances. Based on our results, it is difficult to draw conclusions about the potential effects of the site characteristics (geographical location and bioclimate) of the studied provenances on seed and seedling parameters given the small size of the sampled area which doesn't allow for a clear gradient. However, irrespective of the provenance, it can be expected that adequate seed handling, including seed procurement, storage and seedling cultivation, provided in nurseries could enhance seedling quality to achieve greater success in reforestation programs. Given the harsh site conditions of the Mediterranean region, further research under limited growth conditions and with a larger provenance sample could help to confirm the real performances of different provenances to climate changes, and, therefore, to choose better seed source and seedling production regimes that could improve seedling quality and increase the probability of success of future reforestation programs.

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