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Research article

Physical, morphometric, and physiological quality of *Dasylirion cedrosanum* Trel. seeds in *Viesca*, state of *Coahuila de Zaragoza*

Calidad física, morfométrica y fisiológica de semillas de *Dasylirion cedrosanum* Trel. en Viesca, Coahuila de Zaragoza

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Abstract

The quality of propagative material is a key factor in the regeneration and management of plant species. There is limited information on variations in quality between *Dasylirion cedrosanum* seeds from different natural localities or provenances. Within this context, the objective of this study was to evaluate the morphometric, physical, and physiological quality of *D. cedrosanum* seeds collected in four locations within *Viesca* municipality, state of *Coahuila de Zaragoza*, Mexico. Morphometric variables (length and width) and physical (pure seeds, empty seeds, inert matter, bulk density, and moisture content) and physiological quality parameters (viability, germination, abnormal seedlings, and ungerminated seeds) were analyzed. The results showed significant differences in seed size and physiological quality ($p \leq 0.05$) between localities, while some physical variables showed no variation. Viability ranged between 60 and 96 %, and germination, from 55 to 94 percent, with the highest values recorded at *Rancho Grande*. The linear regression between viability and germination was significant ($p < 0.001$) and explained 56.8 % of the variation; therefore, the viability may indicate germination behavior. However, the presence of abnormal seedlings suggests that viability does not fully explain the physiological quality of the evaluated lots. Overall, the results show that the quality of propagation material varies across localities, highlighting the importance of selecting *D. cedrosanum* seed sources with high physiological performance for use in propagation and management programs in arid ecosystems.

Keywords: Embryo, germination, provenance, *sotol*, intraspecific variation, viability.

Resumen

La calidad del material propagativo es un componente clave para la regeneración y manejo de especies vegetales. Respecto a *Dasylirion cedrosanum*, existe información limitada sobre la variación de la calidad entre semillas de diferentes localidades naturales o procedencias. En este contexto, el objetivo del presente estudio fue evaluar la calidad morfométrica, física y fisiológica de semillas de *D. cedrosanum* recolectadas en cuatro localidades del municipio Viesca, Coahuila de Zaragoza. Se analizaron variables morfométricas (largo y ancho); parámetros de calidad física (semillas puras, vanas, materia inerte, peso volumétrico y contenido de humedad), así como fisiológicas (viabilidad, germinación, plántulas anormales y semillas no germinadas). Los resultados mostraron diferencias significativas entre localidades para las dimensiones de las semillas y la calidad fisiológica ($p \leq 0.05$), mientras que algunas variables físicas no presentaron variación. La viabilidad osciló entre 60 y 96 %, y la germinación de 55 a 94 %, con los valores más altos en Rancho Grande. La regresión lineal entre viabilidad y germinación fue significativa ($p<0.001$) y explicó 56.8 % de la variación, por lo que la viabilidad puede indicar el comportamiento germinativo. Sin embargo, la presencia de plántulas anormales sugiere que la viabilidad no explica completamente la calidad fisiológica de los lotes evaluados. En conjunto, los resultados evidencian que la calidad del material propagativo varía entre localidades, lo que resalta la importancia de seleccionar fuentes semilleras de *D. cedrosanum* con alto desempeño fisiológico para utilizarlas en programas de propagación y manejo en ecosistemas áridos.

Palabras clave: Embrión, germinación, procedencia, sotol, variación intraespecífica, viabilidad.

Introduction

In Mexico, arid and semiarid regions are home to a wide variety of plant species adapted to conditions of low water availability, high temperature variability, and shallow or stony soils (Granados-Sánchez et al., 2011; Villarreal-Quintanilla et al., 2017). Notable among these species are those of the *Dasylirion* genus, which is endemic to North America and closely associated with the xerophytic scrub of the Chihuahuan Desert (Ruiz-Flores & Castro-Castro, 2024). In recent years, interest in this genus has grown due to increased exploitation and the need to establish a scientific foundation for its sustainable management and conservation (Becerra-López et al., 2020).

The *Dasylirion* taxa are rosette-forming plants that produce panicle-like inflorescences and monospermous capsule fruits (Benavides-Mendoza et al., 2023). These morphological and reproductive traits represent evolutionary adaptations to arid ecosystems, where seed protection, dormancy and efficient dispersal are critical for their establishment (Orozco-

Sifuentes et al., 2019; Ortiz-López et al., 2024). The high germination rate documented under controlled conditions confirms the importance of *Dasylirion cedrosanum* Trel. seeds for the species' natural regeneration and the persistence of its populations (Benavides-Mendoza et al., 2023; Ruiz-Flores & Castro-Castro, 2024).

Sotol is a distilled alcoholic beverage made from the flower heads of species in the *Dasylirion* genus, including *D. cedrosanum*. From an economic standpoint, it has expanded its presence in regional and international markets. Within this context, the use of *D. cedrosanum* provides a source of income for rural communities (Madrid-Solórzano et al., 2021; Toribio-Ferrer et al., 2025).

However, the increase in demand has raised concerns about the exploitation of natural populations of *D. cedrosanum*, as the removal of plants of reproductive age can reduce seed availability and affect their natural regeneration. In this regard, knowledge of reproductive biology and seed quality is essential for the management and conservation of the species (Finch-Savage & Leubner-Metzger, 2006; Penfield, 2017; Rajjou et al., 2012).

Seeds are the primary unit of plant propagation and a critical stage in their life cycle; therefore, their physical and physiological quality is crucial to the successful establishment of plants in natural populations (Rajjou et al., 2012). A viable seed contains a functional embryo and reserve tissues that support early development (Finkelstein et al., 2008). In arid environments, seeds exhibit various adaptations, such as hard seed coats, physical dormancy, and dispersal strategies that help them survive until favorable conditions for germination arise (Finch-Savage & Leubner-Metzger, 2006; Penfield, 2017). The analysis of such attributes as size, weight, viability, and vigor is essential for understanding how a species' adaptations to arid ecosystems influence natural regeneration (Moles & Westoby, 2006; Morales-Santos et al., 2017).

D. cedrosanum is a taxon of ecological and economic interest in the state of *Coahuila de Zaragoza*, due to its presence in rosette desert scrubs and its use as a non-timber forest resource associated to *sotol* production. This situation has increased the need to generate biological data to support its propagation, conservation and regulated use. However, information regarding the physical, morphometric and physiological qualities of its seeds in natural populations in the Southeastern Chihuahuan Desert remains limited. Therefore, the objective of this study was to evaluate these attributes in seeds from four locations in *Viesca* municipality, *Coahuila de Zaragoza*, in order to provide basic information for the selection of seed sources, production of plants, and the strengthening of strategies for their conservation and management.

Materials and Methods

Study area

The research was conducted using seeds collected from natural populations of *D. cedrosanum* located in four *ejidos* in *Viesca* municipality, *Coahuila de Zaragoza*, Mexico (Figure 1). The area is characterized by a semi-warm arid climate (BWhw), with a temperature range of 16 to 38 °C and an average annual precipitation of 120 to 350 mm (Instituto Nacional de Estadística, Geografía e Informática [INEGI], 2006, 2008). The soil type is Litosol (I), while the vegetation cover consists of rosette desert scrub (Instituto Nacional de Estadística y Geografía [Inegi], 2018).

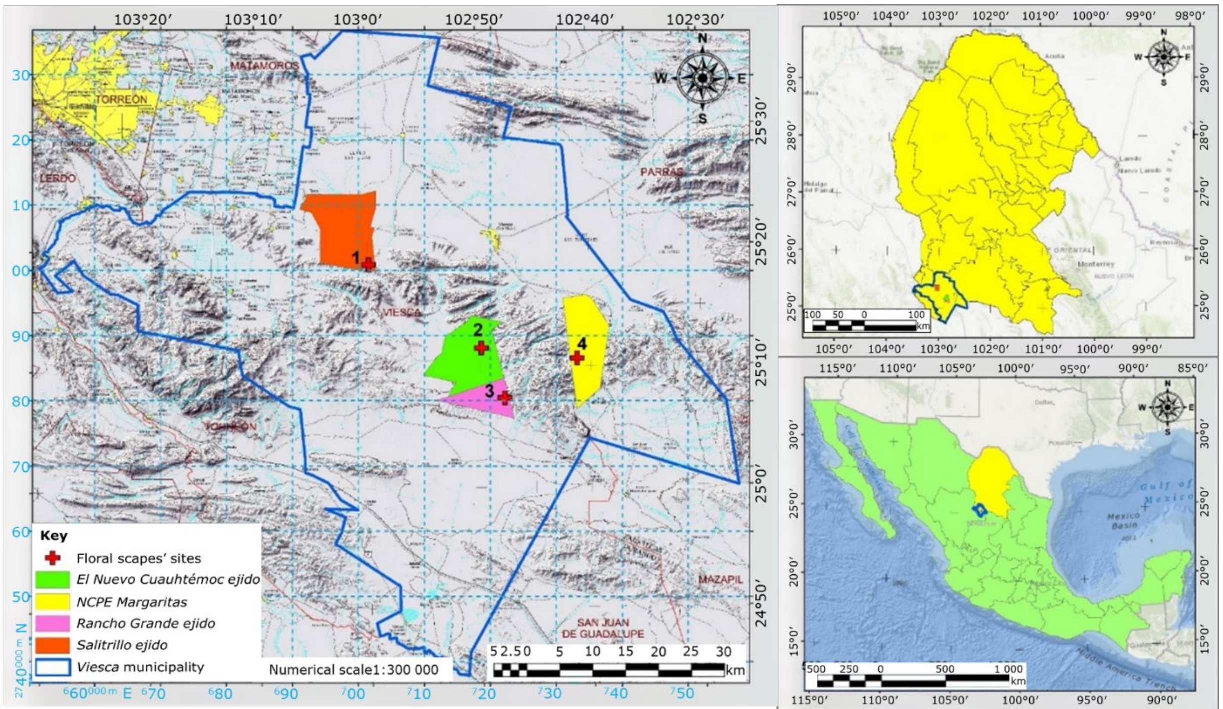


Figure 1. Collection sites for floral scapes of *Dasylirion cedrosanum* Trel. in *Viesca* municipality, *Coahuila de Zaragoza*, Mexico.

Collection of plant material

Five plants were selected per site, and the floral scape was collected from each pistillate plant of *D. cedrosanum* (Table 1) during August 2025. The collection was carried out using targeted sampling, selecting five individuals per location that had mature flowering scapes, were in good phytosanitary condition, and had sufficient seeds available for quality analysis. The geographic coordinates of each plant were recorded (model eTrex 20x Garmin® GPS), and its morphological variables were measured using a model 12696 Truper® tape: total plant height excluding the scape (*H*, cm), average crown diameter (*ACD*, cm), and length of the floral scape (LFS, cm) from the base of the head. In addition, the physiographic variables of the site, such as elevation and aspect, were recorded using a model eTrex 20x Garmin® GPS device.

Table 1. Morphological variables and geographic distribution of the pistillate plants of *Dasylirion cedrosanum* Trel. selected for the collection of floral scapes in *Viesca*, *Coahuila de Zaragoza*, Mexico.

Plant	Total height without scape (cm)	Average crown diameter (cm)	Scape length (cm)	Locality	Latitude	Longitude	Altitude (m)
1	200	250	345	*Salitrillo ejido*	25°18'37.36"	102°59'52.89"	1 227
2	187	210	365				
3	170	145	276				
4	135	145	387				
5	187	190	336				
6	155	215	320	*El Nuevo Cuauhtémoc ejido*	25°11'35.96"	102°49'49.47"	1 562
7	190	187	398				
8	220	164	330				
9	120	156	280				
10	171	204	365				
11	141	135	390	*Rancho Grande ejido*	25°07'24.51"	102°47'44.85"	1 729
12	211	178	376				
13	234	217	387				
14	243	222	408				
15	235	206	398				
16	120	140	259	*NCPE Margaritas*	25°11'36.52"	102°41'22.63"	1 422
17	106	165	265				
18	167	154	300				
19	132	132	323				
20	110	141	354				

The flower scapes were individually labeled for each plant and placed in brown paper bags for transport to the Plant Tissue Culture Laboratory (*LCTV*, for its acronym in Spanish) at the *Saltillo* Experimental Site, *CIRNE-INIFAP*, where they were processed for the corresponding analyses in accordance with the International rules for seed testing (International Seed Testing Association [ISTA], 2024).

For the comparison between locations, the unit of analysis was the individual plant, represented by the seed lot obtained from each floral scape. The replicates performed in the laboratory were considered subsamples of each batch and were used to calculate the average value per plant, which was then used in the statistical analyses.

Physical attributes

Purity (%). The collected sample (consisting of pure seeds, waste seeds, and inert material) was separated using a model CFY-II South Dakota® seed blower with a 2-cm opening and a constant airflow for 3 minutes. A seed was considered "pure" if it was whole, without fragmentation, and had a mature, well-developed ovule; "waste" seeds were those that were hollow, immature, or sterile, lacking an embryo, endosperm, or seed coat; and inert matter, all the fragmented material containing remnants of capsules, seed coats, or other components not considered seeds.

The percentage of each component was calculated using the following expressions:

$$Pure\ seed\ \% = \left[\frac{Pure\ seed\ (g)}{Collected\ sample\ (g)}\right] \times 100 \qquad (1)$$

$$Waste\ seed\ \% = \left[\frac{Waste\ seed\ (g)}{Collected\ sample\ (g)}\right] \times 100 \qquad (2)$$

$$Inert\ material\ \% = \left[\frac{Inert\ material\ (g)}{Collected\ sample\ (g)}\right] \times 100 \qquad (3)$$

Size (mm). A total of 100 whole seeds (four replicates of 25 seeds each) taken from the pure seeds were evaluated; their length and width (mm) were measured using a model BAKC250122 Losaitini® digital vernier caliper, with a measurement range of 0-150 mm.

Thousand-seed weight (g). From each plant, ten replicates of 100 seeds were randomly selected and weighed on a model EAB 314e Adam Equipment® analytical balance. Based on this value, the number of seeds per kilogram was calculated.

$$Thousand - seed\ weight\ (g) = \sum weight\ of\ ten\ sets\ of\ 100\ seeds \qquad (4)$$

Volumetric weight (kg hL^{-1}). It was obtained using the known-volume container method. The container was filled to the brim with seeds, taking care not to compact them; the contents were then weighed on a model EAB 314e Adam Equipment® analytical balance. Five replicates were conducted per plant, and the results were expressed as kg hL^{-1}.

Moisture content (%). The experiment was conducted using 25 seeds per experimental unit, with four replicates per plant. First, the seeds were weighed to determine their fresh weight (g); they were then placed in Petri dishes and placed in a model 1390FM VWR International Sheldon Manufacturing® drying oven at 40 °C until a constant weight was reached.

The moisture content was calculated using the following expression:

$$Moisture\ content\ (\%) = \left[\frac{Fresh\ weight\ (g) - Dry\ weight\ (g)}{Fresh\ weight\ (g)}\right] \times 100 \qquad (5)$$

Physiological characteristics

Viability with tetrazolium (%). It was evaluated using a 1 % solution of 2,3,5-triphenyl tetrazolium chloride. Four replications of 25 seeds each were used from each plant (100 seeds in total). The seeds were first soaked for 24 hours and then incubated in containers with 12.5 mL of the solution in a model ATTGPT-B Seedburo® incubator at 35 °C. Staining was assessed every 2 hours, and at 4 hours, a longitudinal section was made to expose the embryo. The seeds were considered viable when the cotyledons, axis, and embryonic structures stained cherry red, and unstained seeds were considered nonviable.

Standard Germination (%). The experiment was conducted using pure seeds from each plant, with four replicates of 25 seeds (100 seeds per plant). Each replicate was considered a subsample of the seed lot per plant. The seeds were spread evenly on Whatman® #1 filter paper that had been moistened with sterile distilled water. The paper was then rolled up, and each roll was placed in a plastic bag to retain moisture during the test. The rolls were incubated in a model UMF500 Hoffman® chamber at 28±1 °C with a photoperiod of 16 hours of darkness and 8 hours of light. The evaluation was conducted 7, 14, and 21 days after sowing; the number of normal seedlings, abnormal seedlings, and ungerminated seeds was recorded. Normal seedlings were those that had a well-developed primary root and hypocotyl, as well as complete cotyledons; abnormal seedlings were those with malformed or damaged structures; and ungerminated seeds were those that showed no visible changes in their structure.

Statistical analysis

The data were analyzed using descriptive statistics (mean±standard error). Subsequently, an analysis of variance (ANOVA) was performed to evaluate the effect of the locality on the physical and physiological attributes of the seeds. When significant differences were detected ($p \leq 0.05$), the means were compared using Tukey's test. To evaluate the relationship between viability and germination, a simple linear regression model was fitted in which germination was defined as the dependent variable, and viability, as the independent variable. The analyses were performed using R version 4.5.2 (R Core Team, 2025).

Results and Discussion

Physical and morphometric characteristics of the seeds

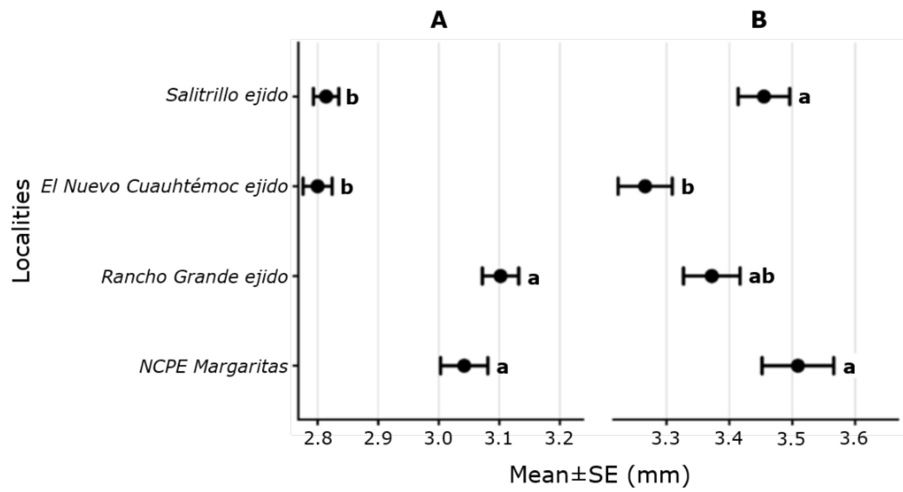
The physical and morphometric characteristics of *D. cedrosanum* seeds showed moderate variation between localities (Table 2). The weight of 1 000 seeds and the number of seeds per kg showed no significant differences between localities ($p>0.05$), suggesting a relatively uniform reproductive investment among populations. However, the values recorded in this study (9.73-13.33 g per 1 000 seeds and 83 290-106 058 seeds kg^{-1}) were higher in weight per kg and lower in number compared to those obtained for *Dasylirion* spp. in the *Mixteca* region of the state of *Oaxaca* (1.82-5.28 g and 189 393-549 450 seeds kg^{-1}) (Ortiz-López et al., 2024). A pattern consistent with observations in species of the Chihuahuan Desert, where intraspecific variation in seed weight is typically limited under similar environmental conditions (Pérez-Sánchez et al., 2011).

Table 2. Physical and morphometric characteristics of *Dasylirion cedrosanum* Trel. seeds collected in four localities of *Viesca* municipality, *Coahuila de Zaragoza*, Mexico.

Locality	Weight of 1 000 seeds (g)	Seeds kg^{-1}	Seed length (mm)	Seed width (mm)
Salitrillo ejido	9.73±0.81 a	106 058.51±9 779.68 a	3.455±0.04 a	2.814±0.02 b
El Nuevo Cuauhtémoc ejido	10.62±0.47 a	94 970.45±4 554.28 a	3.266±0.04 b	2.800±0.02 b
Rancho Grande ejido	12.47±1.24 a	83 290.24±7 757.98 a	3.372±0.04 ab	3.102±0.03 a
NCPE Margaritas	13.33±2.12 a	84 118.94±14 494.16 a	3.509±0.05 a	3.042±0.03 a

The values represent the mean±standard error. Different letters in the same column indicate significant differences between localities (ANOVA; Tukey's test, $p \leq 0.05$).

The morphometric dimensions of the seeds differed between localities (Table 2; Figure 2). The length of the seeds ranged from 3.266 to 3.509 mm, while the width ranged from 2.800 to 3.102 mm; these variables showed significant differences between localities ($p \leq 0.05$). Higher values have been reported for fruits of *Dasylirion* spp. collected in the *Mixteca* region of *Oaxaca*, with average lengths ranging from 5.1 to 6.8 mm and average widths ranging from 3.2 to 4.8 mm (Ortiz-López et al., 2023).



A = Seed width (mm); B = Seed length (mm). SE = Standard error.

Figure 2. Morphometric dimensions of *Dasylirion cedrosanum* Trel. seeds collected in four localities of *Viesca* municipality, *Coahuila de Zaragoza*, Mexico.

These differences can be attributed to the interaction between the environmental conditions at each site, the availability of resources during reproductive development, and the species' inherent genetic variability. Variation in seed size is a common trait among plant species and may reflect differences in resource allocation during fruit development and in the degree to which the embryo is filled, which influences the physiological quality and germination potential of the seeds (Morales-Santos et al., 2017; Rajjou et al., 2012). In species of the genus *Dasylirion*, sexual reproduction is the primary mechanism of population regeneration; therefore, seeds are the essential resource for natural propagation (Ortiz-López et al., 2024).

Physical quality of seeds

There were no significant differences between localities in the physical quality variables of the seeds, including seed purity, waste seeds, inert matter, and moisture content (p>0.05); however, the volumetric weight did differ between localities (p≤0.05). The batches had relatively low proportions of pure seed (29.19-39.15 %) and high proportions of waste seeds (49.65-62.00 %), indicating variation in the physical quality of the harvested material (Table 3). The purity and bulk density of a seed lot are key indicators of seed quality, which influence the handling, storage, and germination performance of the seeds (Rajjou et al., 2012). A high proportion of waste seeds is associated with failed fertilization or incomplete embryo development—processes that can be exacerbated during fruit development under such conditions as low water availability, extreme temperatures, limited nutrient availability, or reduced pollination efficiency (Finch-Savage & Leubner-Metzger, 2006; Huss & Gierlinger, 2021).

Table 3. Physical quality parameters, bulk density, and moisture content of *Dasylirion cedrosanum* Trel. seeds collected at four sites in *Viesca* municipality, *Coahuila de Zaragoza*, Mexico.

Locality	Pure seeds (%)	Waste seeds (%)	Inert material (%)	Volumetric weight kg hL^{-1}	Moisture (%)
Salitrillo ejido	39.15±10.15 a	49.65±10.73 a	11.20±1.36 a	37.03±0.20 b	9.08±2.13 a
El Nuevo Cuauhtémoc ejido	33.16±8.51 a	57.16±7.82 a	9.68±2.33 a	36.01±0.08 c	8.51±2.65 a
Rancho Grande ejido	35.46±7.55 a	54.47±6.63 a	10.08±1.76 a	36.20±0.25 bc	6.95±0.36 a
NCPE Margaritas	29.19±7.54 a	62.00±8.84 a	8.80±2.31 a	33.13±0.27 a	6.69±0.50 a

The values represent the mean±standard error. Different letters in the same column indicate significant differences between localities (ANOVA; Tukey's test, p≤0.05).

Moisture content ranged from 6.69 to 9.08 %, with no differences between localities. This suggests that the conditions under which they were collected and preserved were similar. These values are consistent with seeds that exhibit orthodox behavior, in which low water content helps preserve viability during storage (Probert et al., 2009). In contrast, differences in bulk weight between localities are attributed to variations in seed density and the degree to which the seeds are filled. From an ecological perspective, a high proportion of waste seeds may reflect limitations in pollination and fertilization, as well as subsequent failures in embryo development or seed filling during fruit formation; common phenomena in species found in arid environments, where the climate conditions influence reproductive success and the quality of propagative material (Huss & Gierlinger, 2021; Rubio-de Casas et al., 2017).

Physiological quality of the seeds

The physiological quality of *D. cedrosanum* seeds showed significant differences between localities in terms of viability and standard germination ($p \leq 0.05$), while the percentage of ungerminated seeds did not differ (Table 4). The viability ranged from 60 to 96 %; the highest values were recorded in the *Rancho Grande ejido*, and the lowest, in the *Salitrillo ejido*. Germination consistently showed a similar behavior, with values ranging from 55 to 94 %, confirming the direct correlation between the two parameters.

Table 4. Physiological quality of *Dasylirion cedrosanum* Trel. seeds in four localities of *Viesca* municipality, *Coahuila de Zaragoza*, Mexico.

Locality	Viability with tetrazolium (%)	Germination (%)	Abnormal seedlings (%)	Ungerminated seeds (%)
Salitrillo ejido	60±4.32 c	55±5.51 b	37±6.61 a	8±2.31 a
El Nuevo Cuauhtémoc ejido	79±1 b	86±5.03 a	4±2.83 b	10±2.58 a
Rancho Grande ejido	96±0 a	94±2.58 a	1±1 b	5±3 a
NCPE Margaritas	79±1.91 b	83±3.79 a	10±5.29 b	7±1.91 a

The values are expressed as mean±standard error. Different letters in the same column indicate significant differences between localities (ANOVA; Tukey's test, $p \leq 0.05$).

The percentage of abnormal seedlings varied by locality; it was highest in the *Salitrillo ejido* (37 %) and lowest in *Rancho Grande ejido* (1 %); this difference indicates a disparity in the physiological quality of the seeds depending on their location. In contrast, the ungerminated seeds showed low and consistent values (5-10 %), suggesting that a significant proportion of the seeds with poor physiological performance did germinate but produced abnormal seedlings—possibly due to low vigor, partial damage to the embryo, or incomplete development of essential structures.

A simple linear regression showed a positive and significant relationship between viability and germination ($p<0.001$), and the model had a Coefficient of determination of $R^2=0.568$, indicating that viability accounted for 56.8 % of the observed variation in germination (Figure 3). The positive slope ($\beta=0.93$) indicates that for every one percentage point increase in viability, germination increases by an average of 0.93 percentage points. These results show that the batches with a higher proportion of viable seeds tended to have greater germination capacity; therefore, the tetrazolium test is considered a useful indicator of the physiological quality of *D. cedrosanum* seeds.

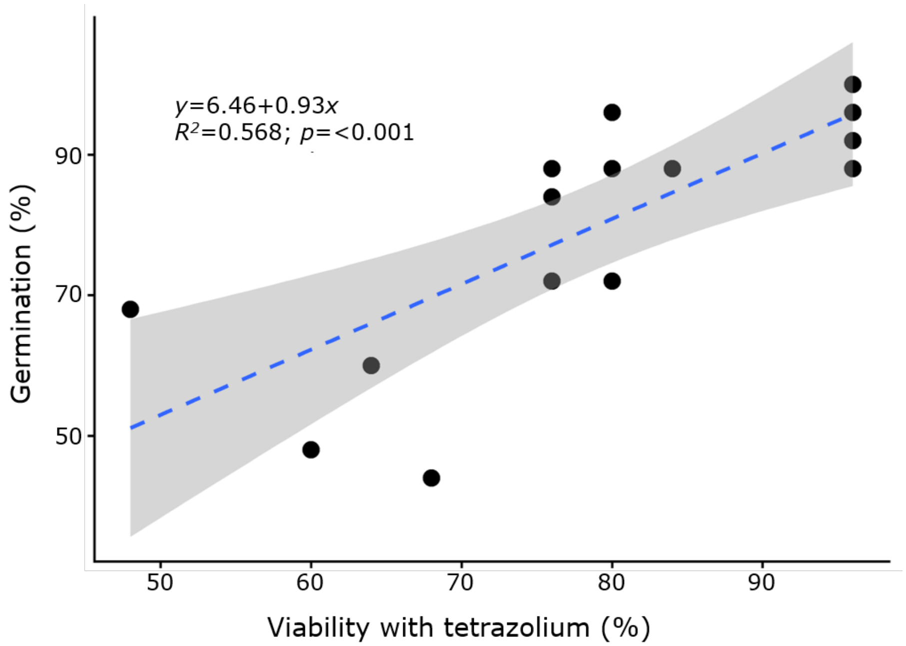


Figure 3. Simple linear regression between viability and germination of *Dasylirion cedrosanum* Trel. seeds.

From a physiological perspective, the positive correlation between viability and germination suggests that embryo integrity and seed metabolic activity were adequate in most of the lots evaluated, which is essential for the development of normal seedlings (Rajjou et al., 2012). However, the R^2 value indicates that viability does not fully explain the germination behavior; therefore, other factors—such as seed vigor, degree of embryo filling, damage to essential structures, or differences between localities—also influence the expression of the germination potential (Finch-Savage & Leubner-Metzger, 2006; Penfield, 2017).

Differences in viability, germination, and the formation of normal seedlings are related to environmental conditions and the physical quality of the lots at each locality. The study area is characterized by a semi-arid, warm climate, with temperatures ranging from 16 to 38 °C and an average annual rainfall of 120 to 350 mm—conditions that can cause water and heat stress during flowering, fertilization, and seed filling. Furthermore, the localities differed in altitude and in the proportion of empty seeds, suggesting variations in the degree of embryo filling and in the physiological quality of the batch. In this regard, the better performance of the material from *Rancho Grande ejido* and the higher proportion of abnormal seedlings obtained from seeds from *Salitrillo ejido* could be associated with local differences in moisture availability, exposure, pollination, and embryonic development.

The behavior described above is consistent with what has been observed in species of arid regions, where the environmental conditions during the reproductive stage influence seed viability, germination, and vigor (Morales-Santos et al., 2017).

Conclusions

The quality of *D. cedrosanum* seeds is closely linked to the locality, as the environmental conditions have a decisive influence on the reproductive potential of the populations. The variations observed in morphometry and volumetric weight suggest a differential allocation of resources during seed ontogeny, influenced by the conditions at the collection site.

The material collected from the *Rancho Grande ejido* exhibits the best physiological performance, with the highest viability and germination rates, as well as the lowest proportion of abnormal seedlings. In contrast, the sample from the *Salitrillo ejido* showed lower germination rates and a higher incidence of abnormal seedlings, indicating differences in the physiological quality of the evaluated plots.

Finally, identifying stands with superior physical and physiological attributes is essential for delimiting qualified seed sources. These findings make it possible to optimize plant production in nurseries and strengthen forest restoration programs and the sustainable use of genetic resources in arid ecosystems.

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Conflict of interest

The authors declare that they have no conflict of interest.

Contribution by author

Luis Miguel Toribio-Ferrer: methodological design, modeling and statistical analysis, drafting, and literature review; Eulalia Edith Villavicencio-Gutiérrez: research design and supervision, revision and editing of the manuscript; Oscar Alberto Aguirre-Calderón: results analysis, revision and editing of the document; Antonio Cano-Pineda: results analysis, revision and editing of the document; Javier Jiménez-Pérez: revision and editing of the document; José Abenamar Jiménez-Jiménez: results analysis and interpretation.

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