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Research article

Variación física y parámetros germinativos de semillas de árboles superiores de *Cedrela odorata* L.

Physical variation and germinative parameters of seeds from *Cedrela odorata* L. high quality trees

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Abstract
Cedrela odorata is a species of economic importance due to the quality of its wood and is currently planted through reforestation programs and commercial forestry plantations. Propagation in forest nurseries is carried out by seed that is harvested regardless of its physical quality and origin. The objective of the present research was to assess the physical quality and germination parameters of seeds from *Cedrela odorata* plus trees. Seeds were collected from 10 trees distributed within an altitudinal gradient of 10 to 700 m in the *Soconusco* region of the state of *Chiapas*, Mexico. 20 days after collection, the purity, 100-seed weight, moisture content, and viability of the seeds were determined, as were their germination capacity, average daily germination, peak value, and germination value. The seeds' physical quality and viability differed ($p \leq 0.0001$) between trees. The average germination capacity of the seeds was 65.8 %. Viability, germination capacity, mean daily germination, peak value, and germination value were positively associated with the altitude; seeds from trees located at altitudes above 400 m recorded higher values. Seeds from higher trees differ in physical quality, viability, and germination parameters, a fact which establishes the importance of the altitudinal origin in seed collection.
Key words: Seed analysis, germination capacity, red cedar, Tetrazolium test, seed collection, *Soconusco* region.

Resumen
Cedrela odorata es una especie de importancia económica por la calidad de su madera; en la actualidad se planta mediante programas de reforestación y plantaciones forestales comerciales. Su propagación en los viveros forestales se realiza por semilla que se recolecta sin considerar su calidad física y procedencia. El objetivo de la presente investigación fue evaluar la calidad física y parámetros germinativos de semillas de árboles superiores de *C. odorata*. Las semillas se recolectaron en 10 árboles superiores distribuidos en un gradiente altitudinal de 10 a 700 m en la región Soconusco, Chiapas, México. Después de 20 días de la recolecta se determinó la pureza, peso de 100 semillas, contenido de humedad y viabilidad de semillas, así como la capacidad germinativa, germinación media diaria, valor pico y valor germinativo. La calidad física y

la viabilidad fue diferente (p≤0.0001) entre los árboles. La capacidad germinativa promedio de las semillas fue de 65.8 %. La viabilidad, capacidad germinativa, germinación media diaria, valor pico y valor germinativo presentaron asociación positiva con la altitud; las semillas de los árboles ubicados en altitudes superiores a los 400 m presentaron mayores valores. Las semillas de los árboles superiores difieren en calidad física, viabilidad y parámetros germinativos, por lo que se establece la importancia del origen altitudinal en la recoleta de semillas.
Palabras clave: Análisis de semillas, capacidad germinativa, cedro rojo, prueba de Tetrazolio, recolecta de semillas, región Soconusco.

Introduction

Red cedar (*Cedrela odorata* L.) originates from Tropical America (Pennington and Sarukhán, 2005) and is distributed from Mexico, Central America, the Antilles and northern South America to Peru and Brazil (Patiño, 1997). In Mexico, it grows in diverse environments with warm to sub-humid climates in the humid and sub-humid tropics (Hernández-Ramos *et al.*, 2018; Sampayo-Maldonado *et al.*, 2019).

Its timber is of high commercial and economic value (Romo-Lozano *et al.*, 2017), due to its quality, beauty (Cruz-Jiménez *et al.*, 2017), durability, color, and aroma (Mader *et al.*, 2018). It is used in the manufacture of luxury furniture, musical instruments, and interior decoration (Ruiz-Jiménez *et al.*, 2018); in addition, it provides environmental services (Romo-Lozano *et al.*, 2017). These characteristics lead to illegal harvesting and, as a result, their natural populations have been fragmented and reduced (Hernández-Ramos *et al.*, 2018). The value of its timber contributes 0.2 % of the Gross National Domestic Product of the forestry sector (Conafor, 2020). In 2016, the estimated price of timber from standing trees amounted to USD $288 328 788 (Romo-Lozano *et al.*, 2017).

Red cedar is listed as vulnerable by the Convention on International Trade in Endangered Species of Wild Fauna and Flora (Cites, 2023) and is on the red list of the International Union for Conservation of Nature (Mark and Rivers, 2017). In Mexico, it is subject to special protection according to the norm NOM-059-SEMARNAT-2010 (Semarnat, 2010) and, as of 2011, the Ministry of the Environment and Natural Resources established procedures for its regulated use (Ruiz-Jiménez *et al.*, 2018). Likewise, in order to establish plantations with this species, a Wildlife Conservation Management Unit (UMA) subject to intensive management must be registered (Secretaría de Gobernación, 2000).

In view of this situation, reforestation programs are being carried out and the establishment of commercial forestry plantations is being encouraged in the state of *Chiapas* (Conafor, 2020). This requires large quantities of quality seeds, however, in the *Soconusco* region there are no certified Forest Germplasm Producing Units of *C. odorata*. In addition, reforestation programs and commercial forestry plantations do not comply with technological considerations to identify the provenance of harvesting sites, which leads to low survival and slow growth of plantations.

Quality seeds ensure rapid and homogeneous germination (Márquez *et al.*, 2020), and for this purpose, it is necessary to select seed trees of superior quality for seed collection. Environmental variations such as soil, temperature, and precipitation in combination with latitude and altitude influence the germination capacity of seeds (Viveros-Viveros *et al.*, 2017; Arce-Cordova *et al.*, 2018, Sampayo-Maldonado *et al.*, 2019). In *C. odorata*, Márquez *et al.* (2020) indicate that sites and progenies influence the productive potential of seeds in the state of *Veracruz*, Mexico; and Arce-Cordova *et al.* (2018) determined that environmental variation has an effect on the quality of *C. odorata* seeds in two regions of the state of *Chiapas*. Likewise, the altitude of the provenances has an impact on the germination parameters of *Enterolobium cyclocarpum* (Jacq.) Griseb. on the coast of *Oaxaca*, Mexico (Viveros-Viveros *et al.*, 2017).

Therefore, the objective of this work was to evaluate the physical quality, viability, and germination parameters of seeds of *C. odorata* plus trees in the *Soconusco* region, *Chiapas*, Mexico. The physical quality and germination parameters of tree seeds are expected to be different because the trees are located at different altitudes, which may have a bearing on the quality of the seeds.

Materials and Methods

Selection of plus trees and collection of seeds

Ten *C. odorata* trees with the following desirable phenotypic characteristics were selected: straight stem without bifurcations, free of pests and diseases, and distributed within an altitudinal gradient of 12 to 693 m in the *Soconusco* region, *Chiapas*, Mexico (Figure 1). The selection method was by comparison of its superiority in height and diameter in relation to neighboring trees within an immediate radius of 10 to 15 m (Vallejos *et al.*, 2010).

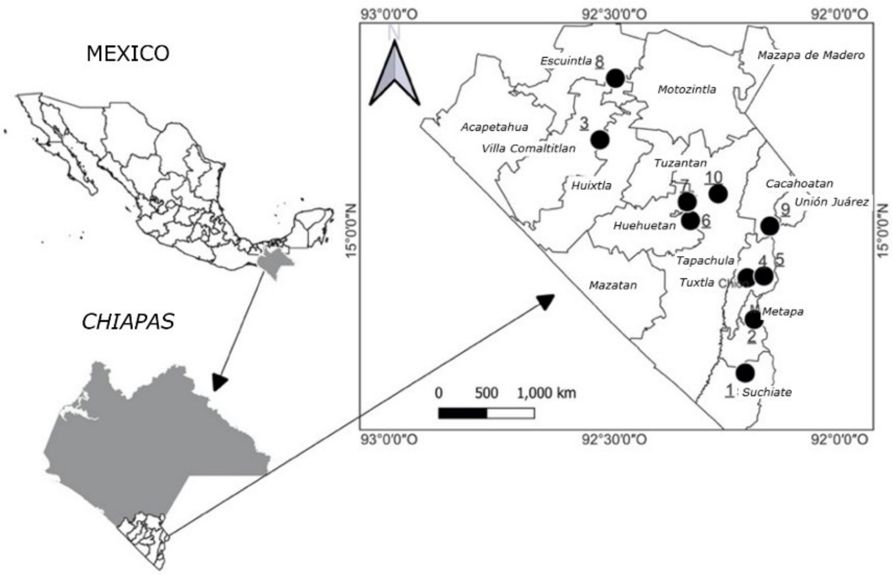


Figure 1. Location of *Cedrela odorata* L. plus trees.

Seed-bearing fruit was collected from December 2021 to January 2022, by scaling the trees with the method described by Jara (1996). Table 1 shows the morphological characteristics of the trees.

Table 1. Morphological description of trees and environmental characteristics for seed collection.

Tree	Normal diameter (cm)	Height (m)	Crown diameter (m)	Locality	Municipality	Altitude (m)	Mean annual precipitation (mm)[1]	Mean annual temperature (°C)[2]	Soil group[3]
1	63	22	9	*Ejido Dorado Nuevo*	*Suchiate*	12	1 500	28	Cambisol
2	50	21	12	*Poblado El Arenal*	*Metapa de Domínguez*	88	2 100	28	Cambisol
3	60	18	11	*Ejido Nuevo Brasil*	*Villa Comaltitlán*	119	2 500	28	Cambisol
4	48	20	8	*Primera Sección de Medio Monte*	*Tuxtla Chico*	190	2 700	27	Luvisol
5	52	21	12	*Ejido Sur de Guillén*	*Tuxtla Chico*	216	2 800	28	Luvisol
6	75	20	14	*Ejido Belisario Domínguez*	*Huehuetán*	295	2 700	28	Luvisol
7	65	16	9	*Ejido Tepehuitz*	*Huehuetán*	418	2 800	27	Acrisol

8	62	23	16	*Comunidad Las Vegas*	*Escuintla*	485	3 100	26	Luvisol
9	52	21	15	*Ejido Rosario Ixtal*	*Cacahoatán*	592	3 300	24	Cambisol
10	60	23	13	*Fracción Santa Elena*	*Tapachula*	693	3 500	21	Acrisol

Source: [1,2]SMN (2023); [3]INEGI (2007a, 2007b).

Seed management

After collection, the fruits with seeds were put into sacks with tree data and date of collection for transport to the Forest Seeds Laboratory of the Graduate School of Agricultural Sciences of the Autonomous University of *Chiapas* (*Universidad Autónoma de Chiapas*), where they were spread out on sacks to dry under the sun and induce the opening of the drupes, which were then stored in a cold room at 22±3 °C in paper bags. Seed analysis was performed 20 days after harvesting, according to the International Seed Testing Association (ISTA, 2016; Hurtado *et al.*, 2020).

Physical analysis of the seeds

Purity. For each tree, 100 seeds (g) were weighed with five replications in a completely randomized design; then, with the help of tweezers, they were separated and weighed individually. The percentage of purity was quantified using the following Equation (ISTA, 2016):

$$Purity\ (\%) = \frac{Weight\ of\ pure\ seeds}{Sample\ weight} \times 100 \qquad (1)$$

Weight of 100 seeds. To estimate the weight of 100 seeds, eight replications per tree were weighed, and the number of seeds contained in one kilogram was subsequently calculated (ISTA, 2016). A completely randomized design was used.

$$Weight\ of\ 1\ 000\ seeds\ = \sum of\ the\ weights\ of\ eight\ replications \times 1.25 \qquad (2)$$

Moisture content. 100 fresh seeds (g) per tree were weighed with five replicates in a completely randomized design. The seeds were then placed on stratified paper and placed in a drying oven (model 1390FM, VWR International® Sheldon Manufacturing USA) at 75 °C until a constant weight was reached in order to estimate the dry weight (g), which was determined by the difference of weights with the following Equation (ISTA, 2016):

$$\%\ of\ Moisture\ content\ (MC) = \frac{(Moisture\ weight - Dry\ weight)}{Moisture\ weight} \times 100 \qquad (3)$$

A M310 Denver Instruments® USA analytical balance was used to estimate the weights for purity analysis, the 100-seed weight, and the moisture content, with an accuracy of 1.0 mg.

Viability and germination parameters

Seed viability. The viability test was performed with a Tetrazolium (2, 3, 5 triphenyl tetrazolium chloride; Sigma-Aldrich® T8877, USA) topographic assay (Ortiz-Bibian *et al.*, 2019). Five replications of 50 seeds per tree (total of 250 seeds per tree) were placed in water for 24 h in a completely randomized design. A small cut was made at the end of each seed that was opposite to the micropyle in order to facilitate the absorption of the reagent. Subsequently, the 50 seeds were placed in Petri dishes (4.5 cm in diameter and 1.5 cm deep), to which 10 drops of diluted 1 % Tetrazolium were added. After the seeds were treated, they were incubated for 24 h. Red staining indicated that the tissue was alive (ISTA, 2016; Ortiz-Bibian *et al.*, 2019). The viability (%) for each replication was calculated with the following Equation:

$$Viability\ (\%) = \frac{Number\ of\ stained\ seeds}{Total\ number\ of\ seeds} \times 100 \qquad (4)$$

Germination parameters. Five replicates of 100 seeds were obtained per tree (total of 500 seeds per individual) and germinated on wet paper with purified water using the paper germination method or cue test (ISTA, 2016) in 15×12×4.6 cm aluminum trays at room temperature (28±2 °C) with a completely randomized design. Germination was considered when the radicle emerged and reached at least 2 mm (Trindade-Lessa *et al.*, 2015).

The germination parameters evaluated were: germination capacity, average daily germination, germination value and peak value. The germination capacity was considered as the percentage of seeds that germinated by the end of the test period [(Number of germinated seeds/Total number of seeds)×100]. The average daily germination resulted from dividing the accumulated germination percentages per day by the number of days required for germination of the total number of seeds (ISTA, 2016), and the peak value was the cumulative maximum germination (Viveros *et al*., 2015). While the germination value (*GV*) was estimated with two equations: *GV1* (Czabator, 1962) and *GV2* (Djavanshir and Pourbeik, 1976):

$$GV1 = Average\ daily\ germination \times peak\ value \quad (5)$$

$$GV2 = \left(\frac{\sum DGS}{N}\right)(GP)(10) \quad (6)$$

Where:

DGS = Daily germination speed

N = Frequency of the number of *DGS* that were calculated during the test

GP = Percentage of germination at the end of the test

10 = Constant

Statistical analysis. The assumption of normality of the data was verified using the Shapiro-Wilk test (Rahman y Govindarajulu, 1997) and the homogeneity of variances with Levene (Bisquerra, 1987). All variables did not meet both statistical assumptions ($p \leq 0.0175$), except the 100-seed weight ($p > 0.0690$) and peak value ($p > 0.2847$), which only had homogeneous variances but did not meet the assumption of normality. Nonparametric tests and RT1 multiple comparisons of ranks were performed to determine differences among trees in physical quality, viability and seed germination parameters (Conover, 2012). The following statistical model was applied:

$$Y_{ij} = \mu + T_i + \varepsilon_{ij} \qquad (7)$$

Where:

Y_{ij} = Observed value of the ij^{th} variable

μ = Overall average

T_i = Effect of i^{th} tree

ε_{ij} = Experimental error

In order to determine the association between physical quality, viability and germination parameters with altitude, Spearman correlation coefficients were obtained (suitable for variables that do not comply with statistical assumptions) using the CORR procedure in SAS® software version 9.3 (SAS Institute Inc., 2011).

Results and Discussion

Physical analysis of seeds

The percentage of seed purity of *C. odorata* showed statistical differences between trees (p<0.0001) with values above 99.00 % (Table 2). Trees 8, 9, and 10 located above 480 m had the best purity values. The lowest percentage of purity was obtained in the seeds collected from trees 4, 5, and 6, which are located within an altitudinal area of 150 to 300 m. The impurities were remnants of seed wings and empty seeds, which are considered to have a low impact on the collection. Similar purity results cite Arce-Cordova *et al.* (2018) with values between 80 and 90 % purity in 90 % of 60 *C. odorata* trees from different environments in *Chiapas*. Hurtado *et al.* (2020) point out that the purity of a seed lot shows the presence of mechanical damage or pathogenic infestation.

Table 2. Average values (±standard error) of multiple comparisons of ranges of physical analysis of *Cedrela odorata* L. seeds.

Tree	Purity (%)	Weight of 100 seeds (g)	Number of seeds kg^{-1}	Moisture content (%)
1	99.37±0.00 c	1.95±0.01 c	49 302.6±590.94 d	6.52±0.12 b
2	99.37±0.00 c	1.93±0.00 cd	50 842.9±462.13 c	7.87±0.61 a
3	99.28±0.00 d	1.71±0.01 e	56 376.7±1 003.82 b	6.97±0.29 ab
4	99.18±0.00 ef	1.48±0.01 f	66 489.7±754.42 a	7.73±0.26 a
5	99.19±0.00 e	1.51±0.01 f	65 572.8±893.07 a	8.07±0.83 a
6	99.16±0.00 f	1.45±0.01 g	66 551.1±613.22 a	6.58±0.19 b
7	99.36±0.01 c	1.91±0.03 d	51 170.7±781.22 c	5.66±0.13 c
8	99.48±0.00 a	2.35±0.01 a	41 952.0±391.31 f	6.46±0.24 b
9	99.47±0.00 b	2.31±0.01 b	42 855.9±357.95 e	6.63±0.50 b
10	99.47±0.00 ab	2.33±0.00 b	42 465.8±256.85 ef	5.75±1.07 b

Different letters in each column indicate differences with regard to $p \leq 0.05$.

The weight of 100 seeds showed significant differences ($p<0.0001$) between the plus trees. Seeds from trees 8, 9, and 10 located at altitudes above 450 m were heavier and ranged between 2.31 and 2.35 g. On the other hand, the seeds with the lowest weight were collected from trees 4, 5 and 6, which are located at altitudes between 150 and 300 m. This represented a 36.4 % greater weight of seeds collected from trees 8, 9, and 10 than from trees 4, 5 and 6, and 20.1 % in relation to trees 1, 2, and 3, which are located within an altitudinal zone of 10 to 130 m (Table 2). In this regard, Arce-Cordova *et al.* (2018) cite slightly higher values (1.6 to 2.5 g) in collections of *C. odorata* in different environments in *Chiapas*; however, Espitia-Camacho *et al.* (2017) report lower seed weight values (1.10 g) for the same species in *Cordoba*, *Colombia*. In this study, seeds collected from trees above 400 m (Table 1) grew in Cambisols and Luvisols of volcanic origin that are rich in organic matter (Conabio, 2015), which may have influenced the weight of the seeds. Lauder *et al.* (2019) document that nutrient-rich sites benefit seed production.

Seed weight is a primary morphological attribute in any species, due to the ability to produce plants with greater vigor to establish in diverse biotic and abiotic conditions (Rodríguez, 2008).

Trees 1 and 2, located in sites with low mean annual rainfall (Table 1), exhibited high seed weight values. This is attributed to their association with annual crops, which are irrigated during the dry season. In this regard, Viveros-Viveros *et al.* (2017) indicate that, for tropical species, temperature is no longer relevant, while precipitation acquires importance.

The number of seeds per kg ranged between 41 952 and 65 572 seeds. The highest number occurred in trees 4, 5, and 6, indicating smaller seed size. The difference between the number of seeds per kg of trees 4, 5, and 6 with trees 1, 2, and 3 was 14 030 seeds, and in relation to the seeds of trees 8, 9, and 10, it was 23 779. Arce-Cordova *et al.* (2018) point out contrasting results for 30 sites, of which 25 presented an average of 43 946 seeds kg^{-1}, and five, 78 846 seeds kg^{-1}, at altitudes of 500 to 1 000 m. In contrast, the number of seeds differs from those recorded by Espitia-Camacho *et al.* (2017), who consigned 94 965 seeds kg^{-1} in commercial plots at an altitude of 13 to 50 m. The variation in the number of seeds may be influenced by the genetic constitution of the trees and the availability of nutrients

(Pramono *et al.*, 2019). Ortiz-Bibian *et al.* (2019) report the importance of the germination capacity of populations in each altitudinal zone, as compared to the number of seeds per kg.

Seed moisture content showed significant differences ($p<0.0001$) among plus trees (Table 3). Values ranged between 5.66 and 8.07 %. Seeds showed higher moisture content in trees 5 (8.07 %), 2 (7.87 %), and 4 (7.73 %). Tree 7 presented the lowest seed moisture content (5.66 %). The results were higher than those recorded by Arce-Cordova *et al.* (2018), who indicate values of 6.5 and 7.6 % seed moisture content of *C. odorata* in two regions of the state of *Chiapas*.

Table 3. Average values (±standard error) of multiple comparisons of ranges of germination parameters of *Cedrela odorata* L. seeds

Tree	Viability with Tetrazolium (%)	% of germination	Average daily germination rate (%)	Peak value	Germination value[1]	Germination value[2]
1	61.40±0.00 d	51.60±0.02 de	10.32±0.43 de	28.00±2.78 e	291.36±36.91 e	10.71±0.88 de
2	67.80±0.03 b	46.60±0.01 ef	9.32±0.29 ef	41.60±1.60 d	388.84±24.73 d	8.71±0.54 df
3	61.60±0.00 cd	40.00±0.01 g	8.00±0.20 g	23.00±1.83 e	184.96±18.36 fg	6.41±0.32 g
4	69.60±0.00 b	36.40±0.03 g	7.28±0.63 g	19.20±1.51 f	141.76±20.43 g	5.42±0.94 g
5	66.60±0.02 bc	44.80±0.02 f	8.96±0.50 ef	25.20±1.63 e	228.28±26.68 ef	8.11±0.87 f
6	70.00±0.01 b	57.40±0.03 d	11.48±0.75 d	33.80±1.91 d	392.56±45.16 d	13.36±1.63 d
7	94.00±0.01 a	90.60±0.01 c	18.12±0.37 c	52.40±2.70 c	952.08±65.34 c	32.88±1.36 c
8	92.40±0.00 a	98.00±0.00 a	19.60±0.12 a	60.40±0.90 a	1 183.88±20.02 a	38.42±0.47 a
9	93.60±0.00 a	97.40±0.00 ab	19.48±0.13 ab	59.20±2.24 ab	1 153.48±46.71 ab	37.95±0.52 ab
10	91.60±0.00 a	95.20±0.00 bc	19.04±0.17 bc	56.20±1.51 bc	1 069.92±28.80 bc	36.26±0.68 bc

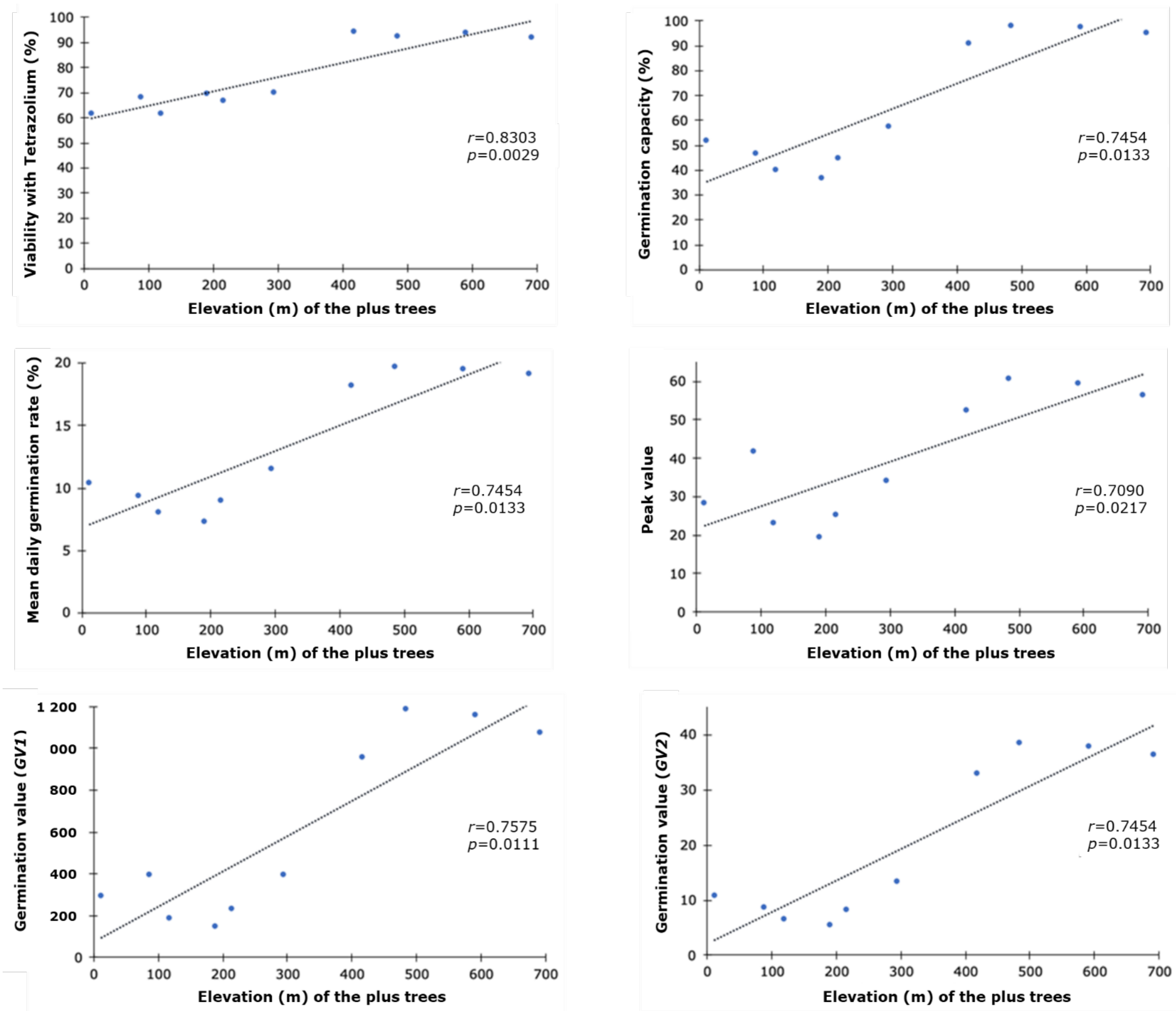
Different letters in each column indicate differences with regard to $p\leq0.05$. Source: [1]Czabator (1962); [2]Djavanshir y Pourbeik (1976).

Viability and germination parameters

The percentage of seed germination showed differences (p<0.0001) among the plus trees (Table 3). Individuals 7, 8, 9 and 10, located above 400 m, exhibited values of 90.6 to 98.0 %, and in the viability test with Tetrazolium had a variation from 91.6 to 93.6 %. In both tests, seeds with higher weights registered higher germination values. In this regard, Arce-Cordova *et al.* (2018) observed that 50 % of their total seeds accounted for the reddish coloration. The results of the present study exceed those of Andrés *et al.* (2011) who, in the dry tropical region of *Nicaragua*, obtained values of 55 to 66 % germination in *C. odorata* seeds stored under room (25-30 °C) and cold (5 °C) conditions. Conabio (2010) indicates that the seeds of *C. odorata* have, on average, a germination rate of 50 to 85 %. The variation documented here could be of genetic origin, in addition to its altitudinal origin, soil group, and precipitation of the location of the trees where the collection was carried out (Viveros-Viveros *et al.*, 2017; Márquez *et al.*, 2020).

Mendizábal-Hernández *et al.* (2016) mention that comparison between the germination of seeds from different parents will always produce differential values related to the expression of parent variability. The low seed germination rate in trees 3 and 4 located at altitudes below 200 m is attributable to higher temperatures and lower rainfall during the dry season, which coincides with the flowering period, as well as to the disturbance of their habitat by anthropogenic activities and the increase of inbreeding due to the presence of fewer trees (Juárez-Agis *et al.*, 2006). Cambisols, Acrisols, and Nitosols predominate at low altitudes in the *Soconusco* region (Conabio, 2015), possibly affecting seed production. In this regard, Andrade-Gómez *et al.* (2021) point out that certain environmental variables —particularly precipitation— influence the reproductive processes that define seed formation and production.

In general, the viability test with Tetrazolium (*r*=0.8303, *p*=0.0029) and germination through the paper method (*r*=0.7454, *p*=0.0133) evidenced a pronounced altitude pattern (Figure 2). Trees 7, 8, 9, and 10, located above 400 m, produce seeds with a higher germination percentage compared to the rest of the trees from which the collection was made.



The dotted lines refer to the linear regression line.

Figure 2. Association of the viability, germination capacity, mean daily germination, peak value and germination value with the elevation of the *Cedrela odorata* L. plus trees.

In terms of germination parameters, there were statistical differences between the evaluated trees ($p<0.0001$), which coincides with previous studies in *C. odorata* (Andrés *et al.*, 2011; Mendizábal-Hernández *et al.*, 2016; Arce-Cordova *et al.*, 2018) and *Enterolobium cyclocarpum* (Viveros-Viveros *et al.*, 2017).

The average percentage of germination capacity of the seeds was 65.8 %. Trees 7, 8, 9 and 10, located at altitudes above 400 m, showed the highest germination capacity values (Figure 2); in contrast, individuals at altitudes below 300 m exhibited a lower value. This is attributed to the prevailing environmental conditions where the collection was made. The average daily germination rate followed the same trend: seeds from trees located at altitudes above 400 m had values of 18.02 to 19.60 %, which decreased in seeds collected at lower altitudes, their germination rate being 32.6 % lower than the overall average (Table 3, Figure 2).

Regarding the peak germination value, the seeds of trees 7, 8, 9, and 10 exhibited the highest average with 57.05, while tree 4 had the lowest value with 19.20 (Table 3). The peak value was positively associated ($r=0.7090$, $p=0.0217$) with the location of the trees.

According to Czabator's Equation (1962), the germination value of the seeds of trees 7, 8, 9, and 10, was 1 089.8 on average, while tree 4, located at an altitude of 190 m, exhibited the lowest value (Table 3). The germination value estimated with the Equation proposed by Djavanshir and Pourbeik (1976) followed the same trend among the trees, *i. e.*: higher values at higher altitudes and lower values at lower altitudes (Figure 2). The above indicated an association between germination values and tree location (*r*=0.7575, *p*=0.0111 and *r*=0.7454, *p*=0.0133) (Figure 2).

The two estimates of germination value indicated that seeds from trees located at altitudes above 400 m showed a better physiological quality, which is related to a higher germination capacity, compared to seeds from trees located at lower altitudes.

Conclusions

Seeds of *Cedrela odorata* plus trees in the *Soconusco* region differ in physical quality, viability, and germination parameters; the most contrasting variables are purity, 100-seed weight, number of seeds per kilogram and moisture content.

Germination, viability and germination parameters show a positive association with altitude, as seeds collected at altitudes above 400 m have better physiological quality with higher germination capacity.

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Conflict of interest

The authors declare that they have no conflict of interest.

Contributions by author

Jorge Reyes-Reyes: proposal, data recording and drafting of the manuscript; Juan Francisco Aguirre-Medina: data analysis, preparation of graphs, and editing of the manuscript; Agustín Merino-García: follow-up of the results, and revision and editing of the manuscript.

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