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Influence of some site factors on germinative parameters of *Quercus* seeds

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***Abstract*— *The genus Quercus has a high economic and ecological potential in Mexico. Nonetheless, its populations are reducing yearly, which demands the implementation of efficient management strategies to preserve them. To determine germinating capacity of seeds, and to learn about their relationship with some conditions of collecting sites (latitude N, accumulated degree-days >5 C in the frozen-free period (AD), precipitation of growing season (PGS)) we used information of seeds and collecting sites for natural populations of Quercus crassifolia, Q. jonesii, Q. polymorpha and Q. potosina. We determined that Q. potosina, the northernmost population; showed higher values of seeds mean weight, percentage of germinated seeds (PGS), average germination time (AGT), peak value (PV), and germination energy (GE), than other species. Q. polymorpha also showed high mean values of seeds weight, PGS, PV, and GE and it was collected at northern latitudes near those of Q. crassifolia and Q. jonesii. Q. jonesii was the southernmost population and showed lower values in these parameters. On the other hand, the analysis also determined that Q. jonesii, Q. plymorpha, and Q. potosina had quicker germination than Q. crassifolia. We inferred that for the species in the analyzed sites, increasing PGS improves sites conditions, which promotes better germination of germplasm.*

Keywords*— *Germination energy, latitude, weight seed, growing season precipitation, mean germination time.

I. INTRODUCTION

Holm oaks (*Quercus* spp.) are one of the *genus* with the greatest diversity of species in Mexico, and they form a model system for the study of evolutionary, biogeographic, and ecological aspects (Rodríguez-Acosta and Coombes, 2020). However, many of their populations are reduced by the effect of anthropogenic activities (expansion of agricultural land, deforestation), and stressed by current environmental change (droughts, frosts).

Due to their great ecological importance in Mexico, they have been subject of several researches, *i.e.* on fruit and seed size (Rubio-Licona *et al*., 2011), germination (García *et al*., 2016), seed predation (Díaz-Guzmán and Bonfil, 2020), seed viability (González-Salvatierra *et al*., 2013), restoration (Rodríguez-Trejo and Myers, 2016), and intraspecific variation (Uribe-Salas *et al*., 2008). However, knowledge is still scarce for most of the species of this *genus* due to its high diversity and wide national geographic distribution.

The phenotypic and genotypic variation between species, populations, trees, and within individuals is fundamental for their conservation and genetic improvement (Morgenstern, 1996). Faced with climate change scenarios, this variation is important, since it allows maintaining a broad genetic base (variation and structure) of forest resources that is key in the implementation of management, conservation, restoration, and reforestation programs (Gorgonio-Ramírez *et al*., 2017). For example, restoration/reforestation actions must privilege the use of appropriated seed sources, which impacts on immediate success and long-term viability of plantings (Boshier *et al*., 2015). These two aspects prevail as important issues in Mexico's reforestation programs since nurseries produce a limited number of species, typically from unknown seed sources (Burney *et al*., 2015). The relevance of seed sources or provenances regarding seedling performance under different ecological conditions, particularly in harsh environments, is widely recognized (Boshier *et al*., 2015; Carevic *et al*., 2017). Despite the great diversity of oak species in Mexico, they are rarely included in reforestation programs. Nonetheless, successful restoration efforts involving oaks seedlings require knowledge on reproductive limitations of target species to formulate effective strategies (Bargali *et al*., 2018). In this sense, the characterization of germinative parameters of the germplasm based on its geographical origin is an important step in the production of plants for any purpose (Gorgonio-Ramírez *et al*., 2017; Oyama *et al*., 2018).

Therefore, the objective of this work was to analyze the germination capacity of oak seeds at the interspecific level and to know its relationship with some characteristics of the collecting site for *Q. crassifolia* Humb. & Bonpl., *Q. jonesii* Trel., *Q. polymorpha* Schltdl. & Cham. and *Q. potosina* Trel. The following questions were raised: 1) do the germination parameters vary with the weight of the seed in the analyzed species?; 2) Is there any relationship between seed size and germination parameters with latitude (North), degree-days above 5 °C accumulating within the frost-free period, and growing season precipitation of the germplasm places of origin? The answers to these questions will be of help for decision-making during the selection of germplasm for restoration/reforestation purposes, based mainly on phenotypic aspects. In this regard, to be able to choose populations with greater establishment capacity in sites that present adverse conditions (*e.g.* low availability of soil moisture) it is necessary to include the genotypic part in the phenotypic selection.

II. MATERIALS AND METHODS

We considered the information on seed weight (g) and germination days of four *Quercus* species recorded by Sánchez-Montes de Oca *et al*. (2018), which is summarized in Table 1 and available at the following Zenodo address: https://doi.org/10.5281/zenodo.1100945. The study area is located in the Sierra Madre Occidental, in a region known as Sierra de Álvarez, about 25 km east of the San Luis Potosí city, Mexico. Specific geographic location for *Q. crassifolia* were at 22º 03' 56.19” N, 100º 38' 58.99" W, altitude 1 980 m; *Q. jonesii* at 21° 58' 39.86" N, 100° 34' 17.18" W, altitude 1 896 m; *Q. polymorpha* at 22° 04' 00.89" N, 100° 13' 10.24" W, altitude 1 896 m; and *Q. potosina* at 22° 58' 53.36" N, 100° 38' 28.08" W, altitude 1 980 m.

Table 1: Information of the characteristics of four Quercus species Sánchez-Montes de Oca et al. (2018).

Species	Seed weight		Total number of seed geminated
	Mean	Standard error	
Quercus potosina Trel.	2.3	0.9	58
Q. polymorpha Schltdl. & Cham.	1.8	0.5	56
Q. crassifolia Humb. & Bonpl.	1.1	0.3	49
Q. jonesii Trel.	0.4	0.1	37

From these data (seed weight and germination days), the average weight (g), percentage of germinated seeds (PGS, %), average germination time (AGT, days), peak value (PV, seeds), germination energy (GE, %) and germination speed to reach a germination percentage ≥50 ($T_{\geq 50}$, days) were calculated. Likewise, the species that presented rapid and slow germination were determined using only viable seeds (those that presented germination). The AGT is the sum of the product of the number of germinated seeds by the number of days after sowing divided by the number of days after sowing. The PV is the maximum value of the sum of the germination percentage divided by the number of days (Kolotelo *et al*., 2001), and GE is the sum of the number of germinated seeds divided by the energy period (30 days) (Czabator, 1962; Côme, 1970; FAO, 2017).

On the other hand, we obtained from Sánchez-Montes de Oca *et al*. (2018) the geographical data of each population, to determine their degree-days above 5 °C accumulating within the frost-free period (GSDD5) and growing season precipitation (GSP, mm). We selected these two variables since they are associated with the entry of energy and water into the plants (Llanderal-Mendoza *et al*., 2017). These values were calculated using the ANUSPLIN® program (Crookston, 2017), which has shown its usefulness to adjust spatial climate models for Mexico (Sáenz-Romero *et al*., 2010). We used correlation analysis, for latitude and these climatic variables to determine if they were related to the weight of *Quercus* seeds and their germination parameters at the interspecific level.

III. RESULTS AND DISCUSSION

The interspecific analysis (Table 1) showed that the mean weight of seeds varied from 0.4 g for *Q. jonesii* to 2.3 g for *Q. potosina*. Likewise, the germination parameters were different: PGS ranged between 37 for *Q. jonesii* and 58 for *Q. potosina*, AGT were from 12.0 for *Q. jonesii* to 17.0 for *Q. crassifolia*, PV had values from 1.7 for *Q. crassifolia* up to 2.9 for *Q. polymorpha*, while GE was lowest (37) for *Q. jonesii* and highest (58) for *Q. potosina* (Table 2).

Table 2: Germination parameters of four Quercus species.

Species	Parameter†				
	PGS	AGT	PV	GE	$T_{\geq 50}$
Quercus potosina	58	13.1	2.7	58	13
Q. polymorpha	56	12.2	2.9	56	13
Q. crassifolia	50	17.0	1.7	46	17
Q. jonesii	37	12.0	1.9	37	10

†PGS: percentage of germinated seed, AGT: average germination time, PV: peak value, GE: germination energy, $T_{\geq 50}$: germination speed to reach ≥50 germination percentage (value is only for viable seeds germinated).

Based on the viable seeds, *Q. polymorpha* and *Q. potosina* achieved full germination on day 18 and *Q. jonesii* on day 23. They had rapid germination with PGS values of 56, 58, and 37, and $T_{\geq 50}$ of 13, 13, and 10 respectively; while *Q. crassifolia* germinated slowly (31 days) with a PGS of 50, and $T_{\geq 50}$ of 17 (Figure 1, Table 2).

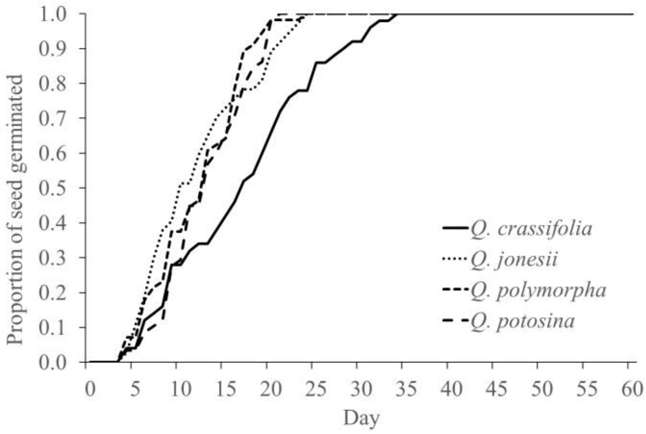

Fig. 1: Germination curves of four Quercus species.

For average weight, the correlations (r) of the seed weight and their germination parameters with the latitude of the collection sites ranged from 0.0138 for $T_{\geq 50}$ to 0.7708 with an upward trend (Figure 2). With respect to GSDD5, they were between -0.4931 for AGT to 0.2572 for PV (Figure not included), and with GSP they were -0.0494 for $T_{\geq 50}$ to 0.7725 for PV (Figure not included). The lack of significance in the correlations of seed weight and most germination parameters with latitude is probably due to the short latitudinal range accounted for by our sample. In spite of this, there is a noticeable northward trend in increasing average seed weight and some germination parameters in these oak species. This fact suggests important local habitat differences within the Sierra de Alvarez, which determine differential performances of analyzed parameters at the interspecific level in oaks. As stated by Alonso-Conrrado *et al*., (2014) differences in germination are due to life history and ecological characteristics (type of reproduction, fruit production, associations, abundance, habitat preferences of oak species).

Q. potosina, the northernmost population in the study area, had higher values of mean weight, PGS, AGT, PV, and GE (Figure 2) than the rest of the species. However, *Q. polymorpha* also presented high values of mean weight, PGS, PV, and GE, and it is located at latitudes similar to *Q. crassifolia* and *Q. jonesii* (Figure 2). *Q. jonesii* was the species collected further south and consistently presented the lowest values in the variables evaluated (Figure 2).

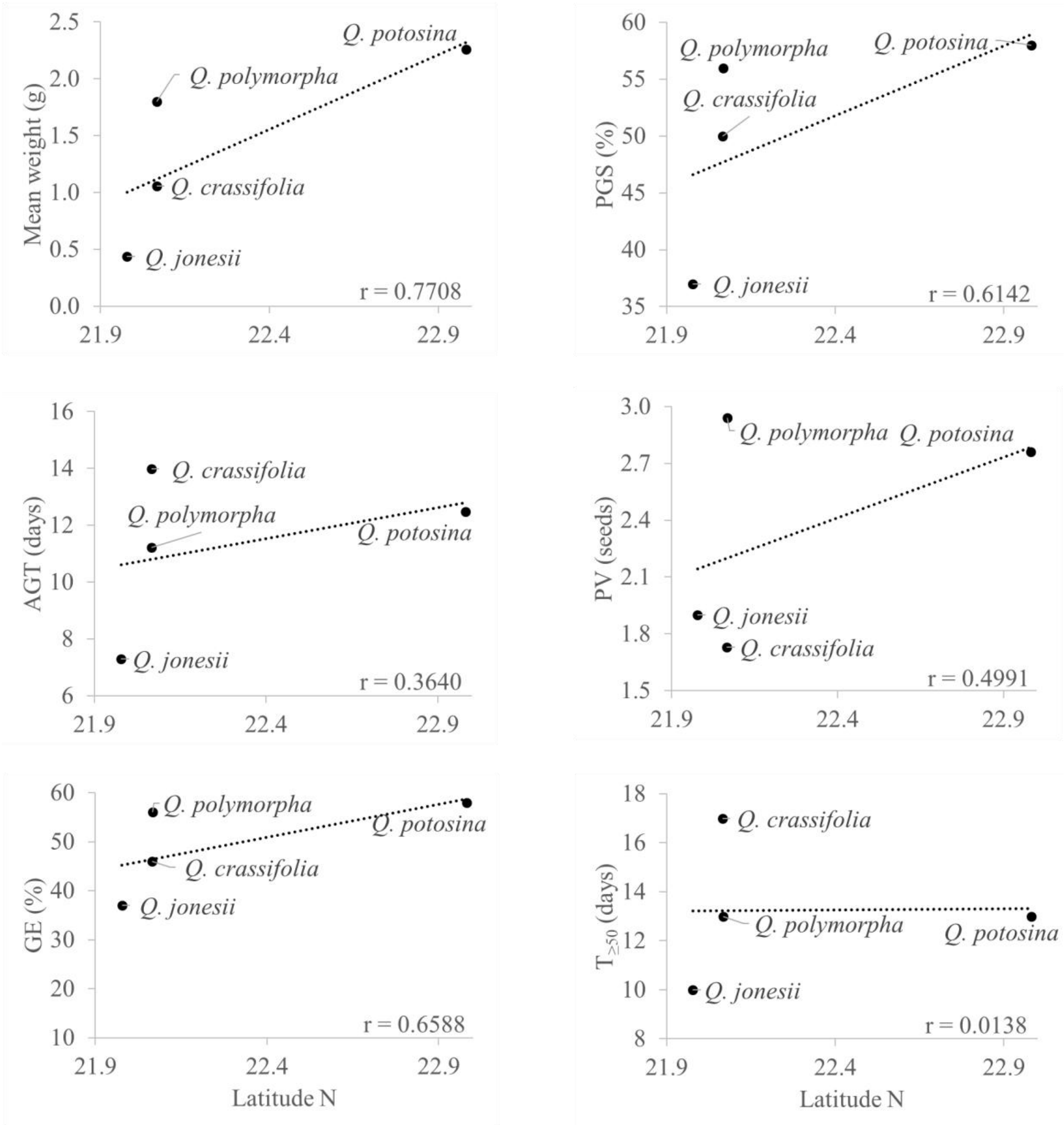

Fig. 2: Relationship between seed weight and its germination parameters with latitude (N) of the collection sites. None of the correlations had a significance level of $\rho \leq 0.05$. PGS: percentage of germinated seed, AGT: average germination time, PV: peak value, GE: germination energy, $T_{\geq 50}$: germination speed to reach ≥50 germination percentage.

Overall, considering the similar seed sizes of *Q. potosina* and *Q. polimorpha*, the performance of germination parameters seems more associated with seed weight than environmental conditions, which might have temporal variations. Therefore, it is likely that variations in weight and germination parameters of the analyzed oak species are due to genetic influences, and the interaction with environmental factors, as observed in other research works. In oak characterization studies, this behavior has been appreciated when comparing populations of the same species, *e.g. Q. oleoides* Schltdl. et Cham. had differences in seed weight (1.27, 1.61, and 3.10 g) in three locations (Márquez *et al*., 2005); where they found differences in both between and within populations.

With respect to latitude, there is a positive but moderate relationship with the variables evaluated. That is, there is a tendency that seed sizes increase as latitude increases in their geographical distribution as also found by the study of Alonso-Corrado *et al*. (2014). However, the opposite trend was observed with the germplasm of *Q. rugosa*, whose seeds from northern populations (Chihuahua) weighted less than those from southern populations (Chiapas), which authors attributed to the influence of climate on seed production (Llanderal-Mendoza *et al*., 2017). Clearly, the latitudinal effect on oak seed characteristics and related germination performance is notorious, but trends might differ at the intra- and interspecific levels.

In relation to GSP, increasing values suggest better site conditions, which promotes a greater development of the germplasm of the analyzed species, thus improving their reproductive parameters. It has been found that GSP affects seeds quality and quantity (Radić *et al*., 2009) when the microhabitat of each tree is affected by soil fertility and humidity during the growing season (Mrdja *et al*., 2012). In the germination parameters associated with latitude, the influence of the life history of the species seems to play an important role as observed with *Q. jonesii* that consistently showed the lowest values in most germination parameters in this study, suggesting a limited fit in the local conditions of our study area. Assessment of germination parameters of this species in its whole distribution range could help identify more suitable site conditions for its germination and growth.

IV. CONCLUSION

Differences in seed size between *Quercus* species showed a clear influence in their germination parameters as also found in other studies. Likewise, there is a relationship between these factors (weight and germination parameters) with latitude, explained by the degree-days above 5 °C accumulating within the frost-free period and the growing season precipitation.

As for restoration/reforestation implications, our results suggest that *Q. potosina* and *Q. polymorpha* can be used in areas with similar ecological conditions of the study area, while *Q. crassifolia* and particularly *Q. jonesii*, should be used in areas with better site conditions than those found in Sierra de Alvarez.

Although our results are relevant and can be useful in future reforestation efforts with the study species, we acknowledge that information on the proper adaptation of species to specific outplanting sites is still lacking. In this regard, studies on local adaptation, matching seed sources with reforestation site conditions, needs to be addressed at genetic levels. In particular, inter- and intraspecific genetic variations, are key elements to ensure oak populations permanence in the face of the current climate change scenarios.

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