Colegio de Postgraduados

Seed germination of four amaranth species (*Amaranthus* spp.)

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ABSTRACT

Amaranthus (*Amaranthus* spp.) is a species of great importance that benefits human and animal nutrition; therefore, its reproduction must be based on useful information obtained from rigorous experiments. Consequently, the aim of this work was to determine the germination of 20 accessions from four *Amaranthus* spp. The work was carried out at the Instituto Tecnológico de Chiná, Campeche, Mexico, using seeds from Africa, Asia, Greece, South America, the US, and Mexico, donated by The North Central Regional Plant Introduction Station (NCRPIS), Iowa State University. After they were weighed and measured, the seeds were placed in Petri dishes and kept in the dark inside a germination chamber, at 27 °C and with a 54% relative humidity. Germinated seeds were counted and removed every 24 hours. The analyses were carried out using the ANOVA test in order to identify weight, length, and germination differences between accessions. The results showed no statistical differences in seed length, neither between species nor accessions; however, there were statistical differences in the weight, both between species and between accessions. A. hypochondriacus from India recorded the highest weight (0.00093±0.000075 g). Regarding germination, there were statistical differences between the various evaluation periods (24 and 48 hours): the highest germination was recorded by *A. hypochondriacus* and *A cruentus*. Therefore, the following conclusion was reached: seed germination is different between species and accessions.

Keywords: *Amaranthus* spp., germination, amaranth, adaptation, accessions.

INTRODUCTION

Amaranthus (*Amaranthus*) is a dicotyledon pseudocereal (Amaranthacea), known for its nutritional value. Its structure does not contain gluten and therefore can be used to develop

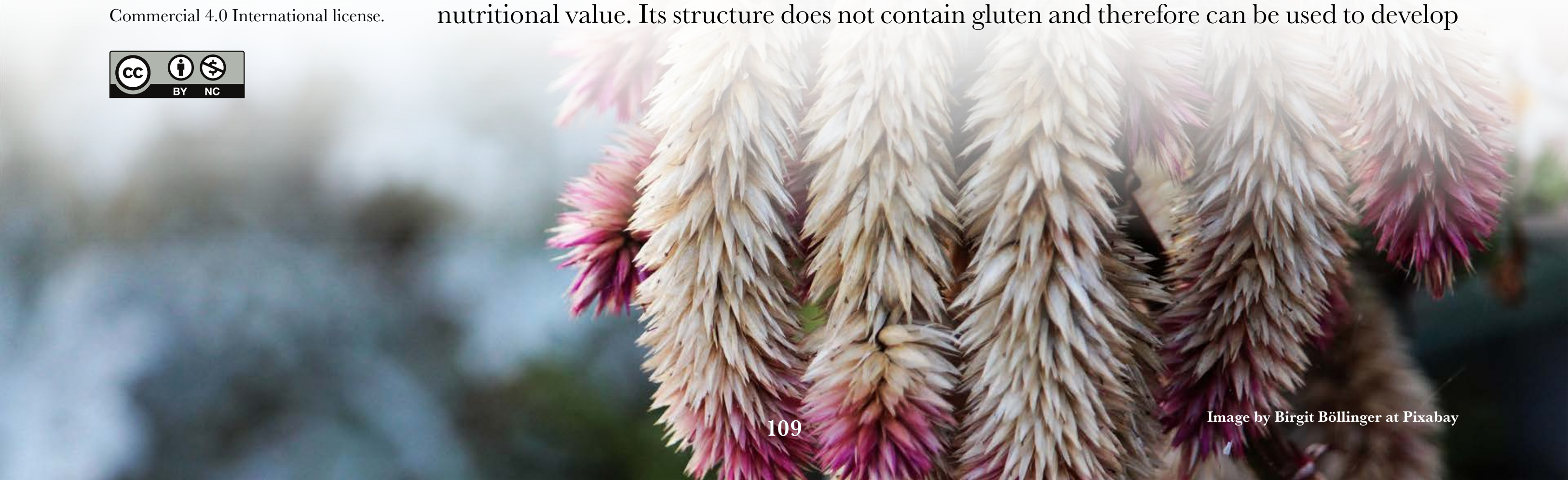

Image by Birgit Böllinger at Pixabay

food formulas for coeliac patients (Pagamunici *et al.*, 2014). Plants from this genus can be easily grown under water scarcity and high temperature environmental conditions (Silva *et al.*, 2019; Zhang *et al.*, 2019).

The Amaranthacea family has a cosmopolitan distribution: its 183 genera and 2,050 to 2,500 species can be found in arid, saline, and disturbed environments (Stevens, 2001). Although it is native to Mesoamerica and is adapted to regions located from 0 to 2,600 m.a.s.l., in recent times it has been introduced in milieux beyond its original adaptation range (Espitia *et al.*, 2021).

To understand the reproduction processes of seed species, their germplasm must be studied first. During the seed formation process, most species undergo changes first in the dessication state and later in the latency, until the point of germination (Legaria-Solano *et al.*, 2000). This germination process involves rehydration, the use of reserves, and the development of synthetical structures that will enable the seedling to take on an autothropic existence mode (King, 1991).

Water absorption is one of the processes that enable the start of germination. Amaranthus seeds absorb the maximum rate of water between 0 and 12 h, when water contains no salts; during this period, seeds absorb 50% of the water, increasing their weight in the same ratio. At 48 h, their weight increases by 60%, with just a 10% water absorption. Meanwhile, between 48 and 60 h, the increase reaches 93%, equivalent to an $\leq$30% absorption. Finally, seeds that were hydrated with water containing a -1.6 MPa concentration of NaCl were able to absorb 35% of water by 60 h (Legaria-Solano *et al.*, 2000).

Consequently, further studies must be carried out to understand every factor involved in germination. Although studies have been carried out on this subject, additional research is still required to determine and understand this process for each species and consequently to increase the efficiency of their reproduction. The environmental adaptation and survival characteristics are highly likely to change from one population to the next, particularly if the environmental conditions are significantly different between the places in which the populations live (Silvertown and Charlesworth, 2001).

The germination process is influenced both by the physiological characteristics of the seed itself and its environmental conditions, promoting a sequence of metabolic activities which result in the development of the embryonic axis (Bewley *et al.*, 2012).

This characteristic grows in importance when it is considered as a major adaptation trait that shows the high intraspecific phenotypic variability resulting from seed latency (Christal *et al.*, 1998). In most cases, the differences between the latency levels of the populations have been attributed to their production or germination conditions (Allen and Meyer 2002; Lacerda *et al.*, 2004). However, several studies have proven that different populations from several species can have similar latency levels and seedling emergence patterns, regardless of the diverse environments in which they are originated (Grundy *et al.*, 2003). Therefore, the objective of this work was to determine the morphological characteristics and the germination behaviour under lab conditions of seeds from 20 accessions from four *Amaranthus* spp. with different origin.

MATERIALS AND METHODS

Study area

The work was carried out in 2019, at the facilities of the Tecnológico Nacional de México, Campus Chiná, Campeche, Mexico. Campus Chiná is located at 18° 50' 11" N and 90° 24' 12" W and an altitude of 20 m.a.s.l. The weather is Aw1, with a 1,138 mm of annual rainfall and a mean annual temperature of 26.8 °C.

Morphological characterization of the seeds

The seeds used in this study belonged to four species, from which 20 accessions were taken (Table 1). They were donated by The North Central Regional Plant Introduction Station, Iowa State University (NCRPIS). A total of n=20 seeds was randomly selected to determine seed morphology. Their weight and length were measured with a CY 304® analytical balance (ACZET) and a graduated scale microscope, respectively.

Germination test

For the germination test, n=20 seeds from each of the 20 Amaranthus accessions were used. The seeds were placed on blue blotting paper and moistened with water in 5"×5¼" plastic boxes. Subsequently, they were established in a germination chamber, in total darkness. at 27 °C, and with a 54% relative humidity ((http://www.ars.usda.gov/mwa/ames/

Table 1. Accessions, species, and origin of the *Amaranthus* spp. seeds evaluated.

No	Accesión	Especie	Planta	Procedencia
1	PI 667162	*Cruentus*	RRC 638	México
2	PI 604567	*Hybridus*	Mapes 830	Puebla, Mex.
3	PI 482048	*Hybridus*	TGR 540	Zimbawe
4	PI 490347	*Hybridus*	J&T 137	Burkina Faso
5	PI 500249	*Hybridus*	ZM 1845	Zambia
6	PI 526228	*Hybridus*	AMM 384	Zimbawe
7	PI 605351	*Hybridus*	RRC 847	Grecia
8	PI 511721	*Hypochondriacus*	HH 93	México
9	PI 604577	*Hypochondriacus*	Mapes 847	Puebla, Mex.
1	PI 6652860	*Cruentus*	RRC 1266	Venezuela
1	PI 490607	*Caudatus*	HH 54	Bolivia
1	PI 482051	*Cruentus*	TGR 603	Zimbawe
1	PI 494777	*Cruentus*	ZFA 3653	Zambia
1	PI 527570	*Cruentus*	IZ 166	Rwanda
1	PI 566897	*Cruentus*	Kerala Red	kerala, India
1	PI 628784	*Cruentus*	RRC 1139	Puebla, Mex.
1	PI 500267	*Cruentus*	ZM 2309	Zambia
1	PI 647848	*Cruentus*	RRC 548	California, USA
	PI 658729	*Cruentus*	RRC 844	Rep. Cen. Africana
2	PI 615696	*Hypochondriacus*	Annapurna	India

ncrpis). They were counted every 24 h and germinated seeds with >0.5-mm long radicles were removed.

Data analysis

The germination percentage was calculated based on the number of seeds placed in the Petri dishes and the number of germinated seeds. On the one hand, an analysis of variance (ANOVA) was carried out to identify differences between seed weight; on the other hand, a regression analysis was used to develop an equation that estimated the number of seeds per kilogram (Di Rienzo, 2020).

RESULTS AND DISCUSSION

The statistical analysis showed no difference regarding the length variable. However, the average length value was 25.77±20.55 μm, while the shortest seed length was recorded by *A. caudatus* (17.00±7.0 μm), followed by *A. hybridus* (20.67±13 μm) and *A. cruentus* (25.73±19 μm). Meanwhile *A. hypochondriacus* had the longest seeds (41.22±32 μm). Regarding their origin, the longest seeds belonged to *A. hypochondriacus* from the state of Puebla, Mexico (62.00±11 μm) (Figures 1 and 2).

Statistical differences were recorded between species ($P=0.0046$), as well as between origins ($P<0.0001$), regarding the seed weight variable, which fluctuated between 0.00015 and 0.00093 g. *A. hypochondriacus* from India had the heaviest seeds (0.00093±0.000075 g), while the seeds of *A. cruentus* from Mexico City recorded the lowest weight (0.00015±0.000092) (Figures 3 and 4). The abovementioned results are different from the values reported by Nieto (1990), who recorded seeds that weighed between 0.0001 and 0.0003 g and were 1 to 1.5 mm long.

The results do not differ from the findings of several studies in which seed weight were compared. For example, Ramírez-Sánchez (2006) recorded a seed weight of 0.00076 g and 0.0006-0.0008 g for *A. caudatus* and *A. hypochondriacus*, respectively. For his part, Spehar (2003) recorded a seed weight of 0.0007 g and 0.0003-0.0004 g for *A. cruentus* and *A. hybridus*, respectively. The individual seed weight of *A. cruentus* recorded

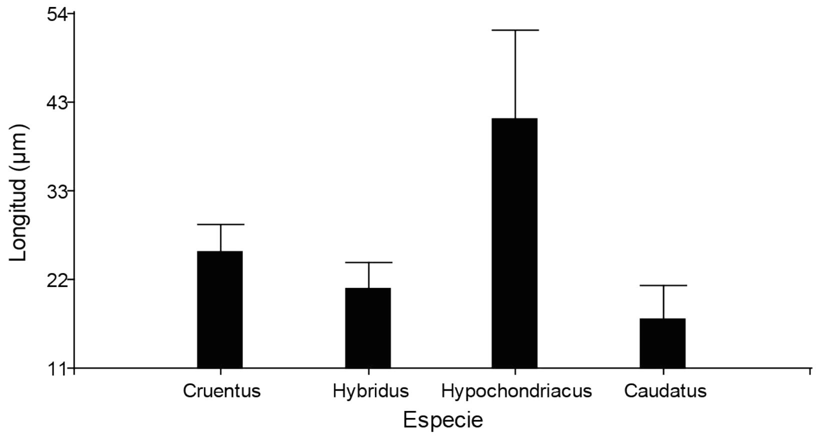

Figure 1. Seed length from several *Amaranthus* spp.

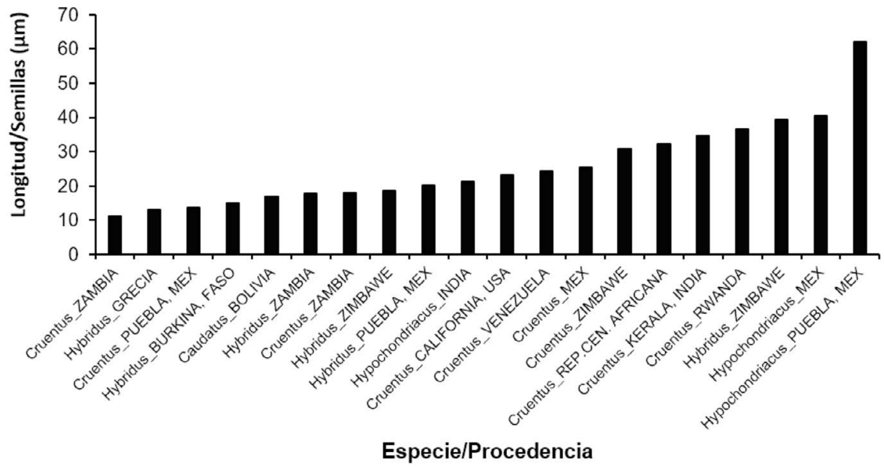

Figure 2. Seed length of several *Amaranthus* spp. from several origins.

the highest variation. Variations are mainly the result of weather, photoperiod, and sowing method.

An equation based on the seed weight data was applied to estimate the amount of seeds that can be obtained per kilogram, through a potential regression analysis (Figure 5) (Equation 1).

$$Seeds/kg = 10297619.34e^{-3270.17\,(X)} \quad R^2=0.90 \qquad \text{(Equation 1)}$$

No statistical differences were found between species and origin regarding seed germination; however, when speed germination was compared throughout time, statistical differences were recorded between each of the species studied. *A. cruentus* ($P>0.00001$) and *A. hypochondriacus* ($P=0.0394$) recorded the highest germination at 24 and 48 h. For its part, *A. hybridus* ($P=0.0012$) had the highest germination at 48 h. Finally, *A. caudatus* was the only species that did not record statistical differences regarding germination throughout time.

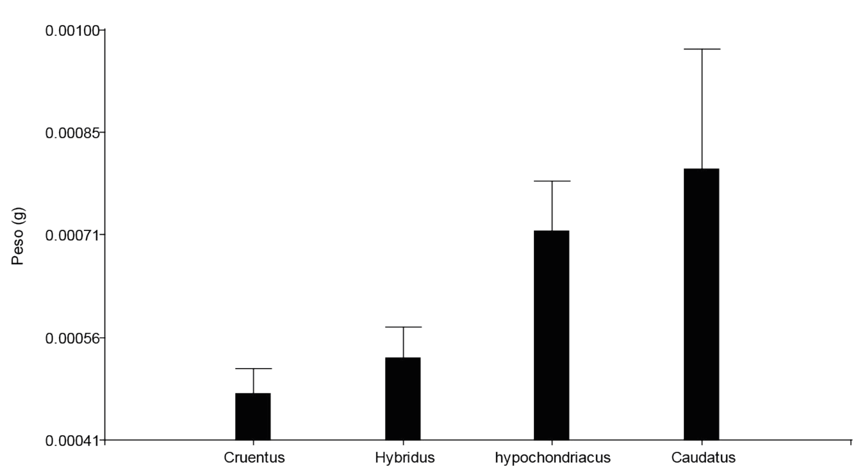

Figure 3. Average seed weight of four *Amaranthus* spp.

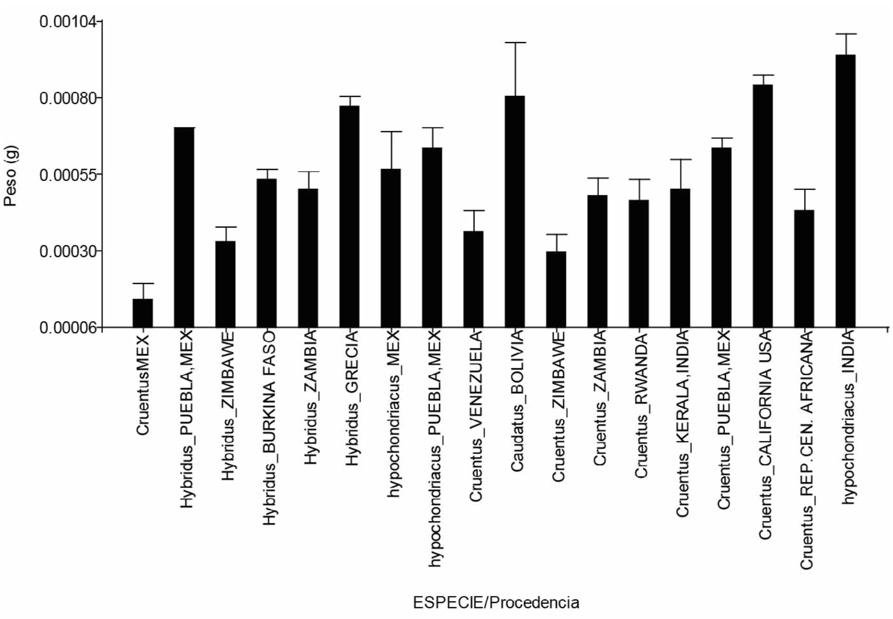

Figure 4. Seed weight of four *Amaranthus* spp. from several origins.

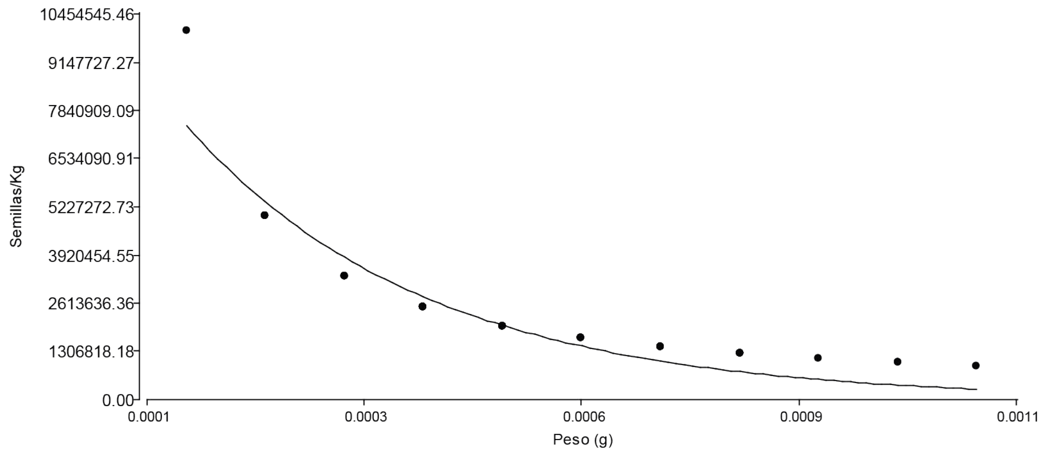

Figure 5. Estimation of the number of seeds per kilogram.

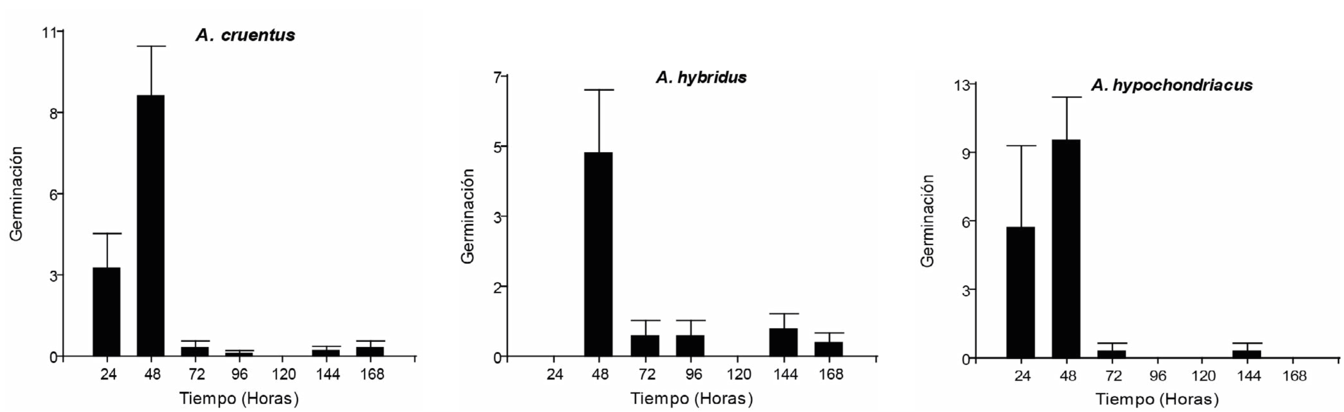

Figure 6. Germination behaviour of the seeds of various species of the *Amaranthus* genus throughout time (after sowing).

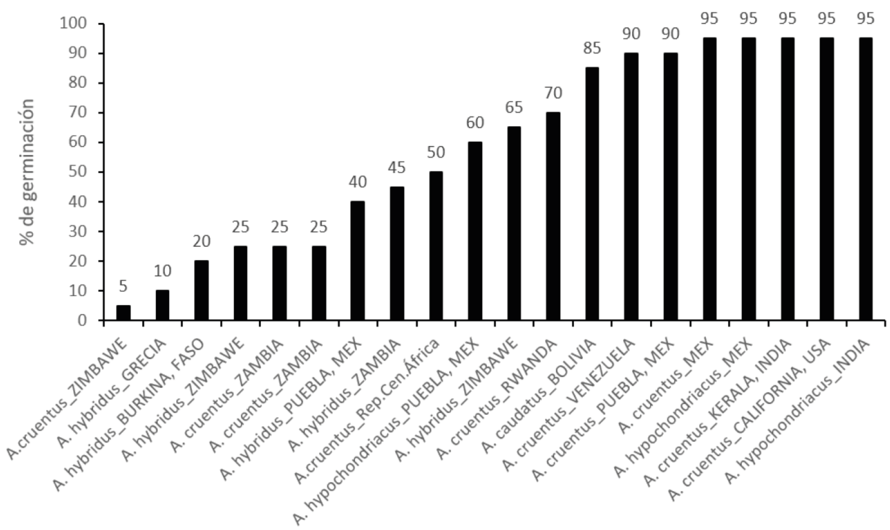

Figure 7. Germination percentage of *Amaranthus* spp. seeds from various origins.

Meanwhile, the highest germination percentages were obtained by A. hypochondriacus from Mexico and India (95%), as well as by A. cruentus from Mexico, California (USA), and Kerala (India) (95%) (Figure 7).

CONCLUSIONS

Regarding their morphology, *A. hypochondriacus* recorded the longest and heaviest seeds. The humidity and temperature conditions under which the seeds were established did not have any effect on the germination of the various species, only on the germination speed of each species. *A. cruentus*, *A. hybridus*, and *A. hypochondriacus* recorded the highest germination between 24 and 48 h. Meanwhile, *A. caudatus* had the same germination throughout the evaluated period.

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