DOI: 10.29298/rmcf.v14i75.1288

Review article

Los ambientes áridos y semiáridos: su relación con la dispersión y germinación de especies

Arid and semi-arid environments: their relationship with the dispersion and germination of species

Jaime Sánchez[1], Eduardo Estrada Castillón[2], Mario A. García Aranda[1,3], Mario F. Duarte Hérnandez[1], Fabián García González[4], Luis M. Valenzuela Nuñez[1], Gisela Muro Pérez[1]*

Fecha de recepción/Reception date: 16 de agosto de 2022
Fecha de aceptación/Acceptance date: 15 de noviembre del 2022

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[1]Universidad Juárez del Estado de Durango, Facultad de Ciencias Biológicas. México.
[2]Universidad Autónoma de Nuevo León, Facultad de Ciencias Forestales. México.
[3]Especies, Sociedad y Hábitat, A. C. México.
[4]Universidad Autónoma Chapingo, Unidad Regional Universitaria de Zonas Áridas. México.

*Autor para correspondencia; correo-e: giselamuro@ujed.mx
*Corresponding author; e-mail: giselamuro@ujed.mx

Resumen

Los ambientes semiáridos son dominados por condiciones extremas que influyen de manera directa en la dispersión y germinación de semillas, así como el establecimiento, desarrollo y mantenimiento de la cubierta vegetal. Este ciclo depende directamente de la disponibilidad del recurso hídrico. Sin embargo, en las zonas semiáridas el agua es limitada, por lo que las especies que ahí habitan presentan adaptaciones para su dispersión como el desarrollo de estructuras y estrategias de movilidad para asegurar su supervivencia. Las etapas de la dispersión hasta el establecimiento de las semillas se manifiestan mediante distintas estrategias o mecanismos para pasar de una fase a otra. Lo anterior aunado a la humedad, la disponibilidad de agua y los sustratos favorecen la dispersión. La interacción de los bancos de semillas y sus estructuras constituyen un factor decisivo para que las especies se adapten a las zonas áridas y semiáridas. Adicionalmente, las microestructuras seminales juegan un papel particular en cada especie al proporcionar ventajas ante las inclemencias que deben sortear, como sucede con el hilo prominente y los tegumentos delgados de las semillas, así como las formas singulares que facilitan no sólo la absorción de agua, sino la dispersión hacia sitios seguros que hagan posible iniciar el proceso de establecimiento.

Palabras clave: Adaptaciones, establecimiento, estructuras seminales, morfometría, semidesierto, semillas.

Abstract

Semi-arid environments are dominated by extreme environmental conditions that directly influence seed dispersal and germination, as well as the establishment, development and maintenance of plant cover. This cycle depends directly on the availability of the water resource. However, in semi-arid areas water is limited. Therefore, the species that grow there develop adaptations for their dispersal, such as structures and mobility strategies to ensure their survival. The stages of dispersal until the seeds establishment follow different strategies or mechanisms to pass from one phase to another. This strategy in addition to humidity, water availability and substrates ensure dispersion. The interaction of seed banks and seed structures are a determining factor for species to adapt to arid and semi-arid zones. Additionally, the seminal microstructures play a particular role in each species by providing advantages in the face of inclement weather that they must overcome, as is the case with the prominent thread and the thin integuments of seeds, as well as the singular forms that facilitate not only water absorption but also dispersal towards safe places that accomplish the beginning of the establishment process.

Keywords: Adaptations, establishment, seminal structures, morphometry, semi-desert, seeds.

Introduction

Dispersal and germination models in arid and semi-arid environments

Arid and semi-arid condition. To speak of aridity is to emphasize a scarcity of water, in which precipitation and atmospheric humidity behave below the annual averages defined worldwide by 840 mm (González, 2012). In Mexico, the average annual rainfall is 777 mm (INEGI, 1994; INEGI, 2014). Therefore, an arid zone has an evaporation greater than its annual rainfall (Tarango, 2005). If the rainfall values range between 300 to 700 mm per year, it can be considered a semi-arid zone (Paz and Díaz, 2018), but if the catchment is 100 mm or less, then it can be properly called a desert, which generates a particular degree of aridity for each area depending on the season of the year (Granados-Sánchez *et al.*, 2011).

Seed dispersal models. Seed dispersal is the central point in the process of regeneration and establishment of vegetation (Traveset *et al.*, 2014), which reach new areas, densities and extensions of future adult plants (Bullock *et al.*, 2003). Dispersal is the distance of the seed from the mother plant (Howe and Smallwood, 1982). This event is extremely complex since elements of secondary dispersal (Wang and Smith, 2002) or dispersal syndromes (Simpson and Todzia, 1990) are directly and indirectly involved.

According to Grime (1974), three types of dispersal are considered in dry environments. The first is closely related to the predisposition of seeds to a high level of disturbance under stress, the second, to a tolerant strategy that results from a high level of stress and low disturbance and, finally, to a competitive strategy that implies adaptations to stress and disturbance conditions. These types of dispersal could be responsible for the adaptive responses of the seeds to initiate germination under different conditions of humidity, cold and heat (Went and Westergaard, 1949; Odion and Davis, 2000). In a similar way, germination strategies are affected by the number of reproductive events they present, depending on whether they are seeds of semelperous, iteroparous or annual species (Sánchez *et al.*, 2015).

Dispersal strategies

Seed dispersal or dispersal syndrome. There are several strategies for seed dispersal, including wind, water and animals (Eriksson and Kiviniemi, 2001).

Dispersal will depend on the characteristics of the seeds, the site and the dispersing agents (Colombo and de Viana, 2000). Studies in this context allow to understand the evolutionary processes of current plants, their distribution and, to a certain extent, model the future of plant populations (Sádlo *et al.*, 2018).

From an ecological perspective, primary dispersal is the most addressed phenomenon, and is defined as the initial dispersal; secondary dispersal is any significant movement of viable seeds after primary dispersal, which often involves different agents. For example, in the first instance, a seed can be dispersed by bird defecation and, secondly, water runoff can intervene and re-distribute them spatially (Vander and Longland, 2004). There are studies that are based on hypotheses and experimental models to explain the process of seed dispersal, as well as their viability and vigor and the subsequent survival of seedlings (Maldonado-Peralta *et al.*, 2016).

It is considered that the most used term to refer to seeds is the one proposed by Sernander (1927) as diaspora, which refers to plant elements or particles from plants. The seed is known as diaspore, propagule, grain, embryo (Garnier *et al.,* 2017), *germule*, *migrule* or *chore* (van der Pijl, 1982). However, seed is the most used and correct term, since more than 3 million works call it that way, compared to grain, embryo and diaspora, which are the most related synonyms.

Something similar happens when it comes to seed dispersal. At present, this phenomenon has been classified into five types of dispersal, which, depending on the form of transport (phoresis), receive a specific classification. According to Alcaraz *et al.* (1999), the best known types of mobility and/or transport are autochory (the plant itself spreads the diaspore), anemochory (wind), barochory (gravity), hydrochory (water) and zoochory (animals).

The dispersal mechanism depends on the characteristics of the ecosystem, since it provides a general overview of the dominant dispersal mechanisms in the species distribution environment (Hughes *et al.*, 1994) and even with the macro or microstructural characteristics of the species seeds (Sánchez-Salas *et al.*, 2015). However, the process that dominates seed dispersal is of a secondary type; for this reason it can be considered an essential process, since most plants need terrestrial dispersers, considered to be the most effective agents (Jansen *et al.*, 2004), and the plant's own strategies (Gutterman, 1994).

The basic dispersal strategy in plants is to produce and offer a large quantity of seeds with nutritional qualities that attract ants, rodents, birds and reptiles, which are the essential dispersers in semi-arid environments (Wunderle, 1997).

Seeds from semi-arid environments have odoriferous protein storage structures called "elaiosomes" (pulp, arils, ariloid) that are offered as a reward to different dispersers to increase the distance of dissemination (Camacho-Velázquez *et al.*, 2018). Another form of distribution is by means of the wind, for which the plants have developed "wings" that favor wind dispersion (Abraham de Noir *et al.*, 2002). Species from semi-arid environments such as *Tecoma stans* (L.) Juss. ex Kunth they have doubly winged seeds, which increases the probability of dispersal to greater distances towards safe sites (Young and Kelly, 2018) where they will germinate and later establish themselves (Sánchez-Salas *et al.*, 2017).

Dispersal types. Knowing seed dispersal strategies is crucial to conserving native species that generally inhabit fragmented sites, a situation mainly caused by uncontrolled population growth (Sádlo *et al.*, 2018) or to generate management plans that control invasive species.

When seeds fall, they can experience different types of dispersal:

a) Autochory, which is particularly related to anthropogenic or disturbance flora as in the taxa Asteraceae, such as *Tagetes moorei* H. Rob. var. *breviligulata* Villareal (*cempasuchil*) through the dispersion of the achenes (Serrato and Cervantes, 2012). It is considered a type of shot, because the fruit bursts at the time of dehiscence due to maturation, as in *Bidens pilosa* L., which violently projects the seeds at a considerable distance from the mother plant (Calderón *et al.*, 2000).

b) Anemochory, seeds with this type of dispersal are regularly small, light, dry, and become dispersed by the wind and have accessory structures such as wings, hairs or feathers that help their dispersion and increase the thrust area within the seeds air currents (van der Pijl, 1972; Howe and Smallwood, 1982).

Mostly, this type of dispersal is related to grasses (Sádlo *et al.*, 2018) such as the Mexican crowfoot (*Chloris submutica* Kunth) and *Muhlenbergia rigida* (Kunth) Kunth (Sánchez-Ken, 2019), vines (Vázquez and Givnish, 1998) and herbaceous plants such as dandelion (*Taraxacum officinale* F. H. Wigg.) (Sádlo *et al.*, 2018), but if it is combined with the autocora dispersal it can occur in some shrubby species such as *Larrea* sp. (Abraham de Noir *et al.*, 2002).

c) Barocoria is the name given to seed dispersal by gravity, a basic dispersal mechanism of climatophilous communities (when development depends on rainfall and general ecological conditions of the territory) (Giménez and González, 2011). It occurs in most plants with dehiscent fruits that, when the diaspore matures, fall freely to the ground due to its own weight or gravity, as in shrubby species (Vázquez and Givnish, 1998), especially Fabaceae such as *huizache* (*Acacia farnesiana* (L.) Will.), the guava leaf (*Senna ripleyana* (H. S. Irwin & Barneby) H. S. Irwin & Barneby), *garabatillo* or *gatuño* (*Mimosa aculeaticarpa* var. *biuncifera* (Benth.) Barneby) (Aguilar *et al.*, 2021).

d) Hydrochory, which is the seed dispersal by means of water flow, which is related to species from aquatic ecosystems such as *Eichhornia crassipes* (Mart.) Solms and from riparian zones such as *Typha angustifolia* L. However, as paradoxical as it may seem, in dry regions (arid and semi-arid) there are species that have seeds adapted for hydrodispersion, with certain morphology such as the clam shape in the *mezquite* (*Prosopis laevigata* (Humb. & Bonpl. ex Willd.) M. C. Johnst.) and boat shape as in the bishop's cap cactus (*Astrophytum coahuilense* (H. Moeller) Kaufer) and asparagaceae the noa (*Agave victoriae-reginae* T. Moore) (Sánchez-Salas *et al.*, 2012; Sánchez *et al.*, 2017).

e) Zoochory occurs in seeds of trees, shrubs and some cacti with hard seeds, such as endozoochory in seeds of *nopal* (*Opuntia rastrera* F. A. C. Weber) (by ingestion), epizoochory such as the fruit of the devil's horn (*Ibicella lutea* (Lindl.) Van Eselt.) (externally attached to the body), and sinzoocoria such as the old man (*Echinocereus longisetus* (Engelm) Lem.) (dispersal by birds) according to Howe and Smallwood (1982).

Types of seed banks. The first study involving a seed bank was done by Darwin, who observed germination with soil samples from the bottom of a lake. The first work published in this regard was in 1882 by Putersen, in which the effect of burial depth on germination was assessed (Roberts, 1981). Currently, herbaceous plant seed banks are have been mostly addressed from their importance for agricultural matters.

In dry or desert environments, seed banks consist of seed aggregations of ephemeral, annual (Simpson *et al.*, 1989) and persistent perennial plants that survive successfully because they spread the risk of germination in batches over several years; thus, this is the main pathway for plant recovery of species that can sometimes hardly reproduce asexually (Montenegro *et al.*, 2006). These seed banks can be of the transitory type with seeds able to germinatie in less than a year, with a single reproductive event and deposited on the surface or among organic remains of vegetation (Thompson *et al.*, 1997), or of the persistent type, characterized by having seeds with viability recorded for up to centuries, with several germinative events (Walck *et al.*, 1996), as well as buried seeds (Milberg *et al.*, 2000), which, in general, keep the vegetal cover even when they are subject to disturbances, fires and hydric fluctuations (Harper, 1977; Fenner, 1995; Odion and Davis, 2000; Sánchez *et al*., 2015).

Two factors directly influence seeds in order to be preserved without germinating in the seed bank: the intrinsic or typical of the diaspora, such as the types of dormancy and chemical inhibitors, and the extrinsic ones such as the scarcity of water, light, mechanical scarification or amount of oxygen, especially in buried terrestrial seed banks (Granados and López, 2001). These factors may be acting in the modification of the structure of the seed banks, since sites have been observed where the dominant species are ruderal (Sánchez *et al.*, 2010).

Ecological importance of the seed bank as a strategy for the conservation of species. Knowing the seed banks in the soil is an alternative for the management and recovery of deforested sites, specifically with native taxa in order to reduce the risk of invasive species modifying the plant cover (Sánchez-Salas *et al.*, 2015). It is extremely relevant to assess the "gene pool" (genetic reserve) of deforested or abandoned sites (Garza *et al.*, 2010) to implement and evaluate restoration programs with species native to the areas. In the Cactaceae family, in genera such as *Ariocarpus*, *Coryphantha*, *Echinocactus*, *Mammillaria* and *Obregonia*, the fruits remain at the apex and/or between the thorns, which prevents their dispersal (Zavala-Hurtado y Valverde, 2003; Rodríguez-Ortega *et al.*, 2006; Peters *et al.*, 2009), and they behave, to a certain extent, like an aerial seed bank (De Souza *et al.*, 2006).

Germination process. The diaspore is the wrapping or covering where the embryo is sheltered and protected, which will lead to a new plant called spermatophyte (Dimitri and Orfila, 1985; Carrión and Cabezudo, 2003). Water is the limiting factor by nature in dry environments for the diaspora to activate the germination process (Evenari, 1985; Hernández *et al.*, 2015), so its response is adaptation to pluvio-environmental variations (Rees, 1994). Thus, this phenomenon is risky, the seeds have a limited time to respond to the rainfall pulses that are short (Escudero *et al.*, 1997), so the seeds react quickly to ensure their survival (Gutterman, 1993).

The germination process is influenced by external agents such as the time to germinate, the absence or presence of light, the mineral structure of the soil and the content of reserves (Valverde *et al.*, 2004), which also favors or inhibits it (Uruç and Demirezen, 2008). The first step in this direction is imbibition (Taylor *et al.*, 1992) and it occurs in three phases:

I) Hydration: It consists of the movement of water inside the seed through a potential gradient from high to low energy (Black *et al.*, 2006) that regulates the internal moisture level in the diaspore and the enzymatic function of the cell membranes (Brocklehurst and Dearman, 1983; Martínez-Balbuena *et al.*, 2010), which will allow the regulation of the imbibition level required for an optimal hydration process that triggers the germination process. Thus, the hydration or hydration-dehydration-rehydration processes are the pre-germinative treatments that, par excellence, increase the germinative capacity in most seeds (Henckel, 1982; Dubrovsky, 1996; Sánchez-Salas *et al*., 2012; Sánchez *et al.*, 2017) and call it "hydration memory" in the seeds of desert species.

II) Imbibition/Absorption: This phase reactivates the metabolic activity of the diaspore, which initiates the germination process. The absorption event is directly related to the permeability of the testa (Méndez *et al.*, 2008) and can be affected by accessory structures such as envelopes or funicular envelopes as in *Opuntia* spp. (Monroy-Vázquez *et al.*, 2017) that present an "aril or third integument" (Flores and Engleman, 1976; Porras-Flórez *et al.*, 2017) that covers the seeds and protects them, in particular, in Phases I and II, in case of an interrupted environmental hydration process that causes dehydration in the diaspore (Taylor *et al.*, 1992). The rate of imbibition is generally intermediate until the process is complete (Moreno *et al.*, 2006), but this can vary depending on the size and diaspora of each species, inducing the start of the last phase of the process.

III) Germination: It is the stage in which the radicle is finally elongated due to the structures that surround the embryo, which generates an increase in the water absorption process that causes the expansion of the embryonic cells (Contreras *et al.*, 2015). At the same time, intrinsic proteins called PIPs (Nonogaki *et al.*, 2010) are activated, such as aquaporins that are responsible for transporting water through the membranes (Chávez *et al*., 2014) during the entire germination process, as well as the activation of intrinsic tonoplastic proteins called TIPs that regulate the passage of water through the membranes themselves (Nonogaki *et al.*, 2010). This ends with cell growth and division and the emergence of the root system and the plumule begins (Vázquez *et al.,* 1997).

Morphostructural adaptations in seeds from dry environments

The intra and inter specific heteromorphism of the seeds is considered a response to favorable environmental events to perpetuate the multiple reproductive strategies of the plants, which favors their permanence in the site (Venable, 1985). In this sense, plants with heteromorphism are of particular interest to understand not only reproductive or evolutionary strategies, but, above all, the mechanism of dispersion and germination (Rocha, 1996); such is the case of the *Agave victoriae-reginae* seeds, which are medium to large, with a porous cover surrounded by air chambers that facilitate hydrodispersion and capture of water in short flooding periods (Sánchez-Salas *et al*., 2017).

When a specific diaspore morphology is associated with specific diaspore functions, an analysis of seed structures is possible (Venable and Brown, 1988). For example, species from dry environments such as *Astrophytum coahuilense* and *A. myriostigma* Lem. and the *moriche* palm (*Mauritia flexuosa* L. f.) produce seeds of different size that favor germination (Sánchez-Salas *et al.*, 2012; Sánchez-Salas *et al*., 2015), since it has been determined that small seeds have dizzying or higher germination capacities, effectiveness in viability, emergence, survival and increased competitive ability among seedlings (Sánchez *et al.*, 2010). In a similar way, the size of the seeds is also a strategy to reduce the loss of the seed bank, as it occurs with *A. myriostigma* (Sánchez-Salas *et al.*, 2015) or the size of seeds can increase or decrease displacement in irregular topographies (Chambers *et al.*, 1991), such as xerophytic desert scrub species such as *Larrea tridentata* (DC.) Coville, *Agave lecheguilla* Torr. and *Atriplex canescens* (Pursh) Nutt. (Granados-Sánchez and Sánchez-González, 2003).

It has been determined that even the weight of 1 mg of difference between groups of seeds (sizes) produce different results in germination (Sánchez-Salas *et al.*, 2006), as in *Abutilon theophrasti* Medik. seeds. In which the group of large seeds (8.0-8.9 mg and 7.0-7.9 mg) achieved a higher germination percentage, since they may have greater nutrient storage capacity (Baloch *et al.*, 2001). However, an inverse effect can also be generated, since the larger the size, the longer the germination time is, because the seed takes longer to hydrate and soak (Harper *et al.*, 1970; Hernández-Valencia *et al.*, 2017). Alternatively, as in the case of *Stenocereus beneckei* (Ehrenb.) A. Berger & Buxb., the seeds vary in weight and size, which influences the dispersal and subsequent establishment of seedlings (Ayala-Cordero *et al.*, 2004).

Not only the size of the diaspore favors the dispersal process, but also the shape. For example, *Astrophytum* has a specialized diaspore shape for its dispersal specifically by water (hydrodispersion). It is characterized by the fact that five of its six species have navicular-shaped diaspores (*Astrophytum asterias* (Zucc.) Lem., *A. capricorne* (A. Dietr.) Britton & Rose, *A. coahuilense*, *A. myriostigma* y *A. ornatum* (DC.) Britton & Rose) (Bravo-Hollis and Sánchez-Mejorada, 1991), ball (Henrickson and Johnston, 1997) or hat (Barthlott and Hunt, 2000). The studies most related to morphometry with species from dry environments evaluated the shape, size, color and integumentary arrangements (Elizondo *et al.*, 1994), since all are closely related to the germinative capacity of the diaspora (Maiti *et al*., 1994).

Macro and microstructural adaptations. Barthlott and Voit (1979) and Elizondo *et al.* (1994) considered that the micro-morphology in seeds of the Cactaceae family is highly variable in shape, size, color and even in integumentary arrangements, which produces effects on germination (Maiti *et al.,* 1994).

In regard to studies that refer to the integumentary covers, those of Glass and Fitz (1992) on *Aztekium hintonii* Glass & Fitz Maurice; Elizondo *et al.* (1994) in seeds of *Astrophytum capricorne*, *Echinocactus horizonthalonius* Lem. and *Epithelantha micromeris* (Engelm.) F. A. C. Weber ex Britton & Rose. The seeds of *A. myriostigma* show the most complex microstructures in the Cactaceae family (Barthlott, 1981), which, both internally and externally, could be an adaptation to the environment where they are distributed (Sánchez-Salas *et al.*, 2015). Macro characters, such as the shape of the diaspore, are important for the sudden hydrodispersion typical of dry environments (Sánchez-Salas *et al.*, 2015). Regularly, hydrochoric seed forms have advanced characters for buoyancy such as light and small embryos, prominent hilum and thin integument that facilitate permeability (Sánchez-Salas *et al.*, 2015). Sánchez *et al.* (2017) carried out a study with seeds of *Agave victoriae-reginae* where they supose that the seeds are permeable, because they do not have leathery integuments that hinder water absorption; contrary to that of García-Aguilera *et al.* (2000), who concluded that *mezquite* (*Prosopis glandulosa* Torr.) and *huizache* (*Acacia farnesiana*) seeds have a hard and impermeable cover.

The shape of the embryo can influence dispersion, assuming that some type of dispersing agent could eliminate the testa. If the embryo is of the ovoid or clam type (Sánchez *et al.*, 2015) it will increase the chances of germinating, since not only does the seed have a navicular shape, but the embryo will also facilitate the dispersion process, which gives it a double dispersive capacity.

Regarding the microstructures, the xerophytic seeds could present some type of porous space accompanied by a navicular, clam or semi-flat lacriform shape that completely surrounds the testa, since the main function is to provide immediate buoyancy when in contact with water (Barthlott *et al.*, 1997; Sánchez *et al.*, 2017). The air chambers are formed by protective hypodermic collenchyma tissue that protect the embryo (Maiti and Perdome, 2003) during hydrodispersion.

The funicle in some seeds of semi-arid species is persistent (*A. myriostigma*) and facilitates nutrient uptake during the embryonic process (Sánchez-Salas *et al.*, 2015). Other examples of hydrochoric seeds are bromeliads: *Pitcairnia aphelandriflora* Lem. and *Pepinia punicea* (Scheidw.) Brongn. & André (Rommel and Beutelspacher, 1999). Said structure acts as a hydrodispersive strategy, although when there is no water, by maintaining the funiculus they can have zoochoric mechanisms (Sánchez-Salas *et al.*, 2015). Seeds with hydrodispersion mechanisms that maintain the funiculus are dispersed by chameleons and/or ants, possibly because the funiculus has oil (odoriferous substances that attract them) (Escala y Xena de Enrech, 1991; Sánchez-Salas *et al.*, 2015). It seems that there is a resistance to drought, salinity and high temperatures of the seeds that live in extreme environments, obtained through the mother plant as in *Campanula americana* L. (Galloway, 2001), so it could be considered that temperature is a factor that does not affect imbibition through the seed coat, however, it does intervene in the germination process.

When a species presents combinations of various dispersal strategies, it is known as polychoric (Lindorf *et al.*, 1986), which is an active and common process in seeds of xerophytic species (Wunderle, 1997), an example is white *chilca* (*Baccharis spicata* Hieron.) and *tala* (*Celtis tala* Gillies ex Planch.) (González and Cadenazzi, 2015).

In the Cactaceae family, the micropyle in the seeds is the most complicated structure to observe, its function is to absorb water to start the germination process and it is where the root system emerges (Sánchez-Salas *et al.*, 2015).

Seed viability (longevity). It is estimated that seeds with a testa (seminal cover or seed shell) are more long-lived (Granados and López, 2001) compared to naked seeds. However, low temperatures and a low percentage of humidity favor a slow metabolism, which allows greater longevity (Doria, 2010); therefore, a negative aspect in arid and semi-arid regions are the high temperatures that could decrease this condition.

As time goes by, the embryo cells die and their germinative capacity is reduced, so the storage period is determined both genetically and environmentally, therefore, seeds for agricultural use are viable for less time compared to species from dry environments (Escobar-Álvarez *et al.*, 2021).

There are different techniques to define the viability time: 1) Visual: the quality of the diaspora is observed (*e.g.* fissures, malformations), 2) Germinative evaluation of a population sample of seeds to determine viability (Araiza *et al.*, 2011), and 3) Biochemical test (tetrazolium test): consists of evaluating the reduction process of living cells, by taking the hydrogen released by the dehydrogenase enzymes, which form a red hue, which indicates the viability potential in the seed (Victoria *et al.*, 2006).

Germination vigor. The loss of vigor is the decrease in the germinative capacity known as physiological aging. From a biochemical point of view, vigor involves the ability of an organism to biosynthesis energy and metabolic compounds, such as proteins, nucleic acids, carbohydrates and lipids, which is associated with cell activity, cell membrane integrity and the use of reserve substances (Navarro *et al.*, 2015). The final deterioration of the diaspora is death, when it no longer exhibits any activity. However, the seeds lose germination vigor before germination capacity, which is why it is common for seed lots to record similar germination values, but with different physiological age (degree of deterioration) and respond with different germination vigor (ISTA, 2022). The permeability to water and oxygen is a factor that can affect (positively or negatively) the germination of the seed, since with it, it is possible to start functioning (Chandra *et al.*, 2017).

Latency and types of latency. Latency is a phenomenon of ecophysiological adaptation, which ensures the survival of a future individual by restricting germination at unfavorable times (Varela and Arana, 2011) that directly interacts with the diaspora's hydration memory (Dubrovsky, 1996). There is a wide range of latency intensity that can go from absolute, in which the diaspora does not germinate under any circumstances, the intermediate one, when the germination is only of a certain amount of the total lot of seeds, and the absent one, when the seeds germinate under any condition (Varela and Arana, 2011). According to Baskin and Baskin (1989), several types of latency are known depending on the cause and its embryonic characteristics. According to ISTA (2022), different types of seed dormancy are known:

1) Dormancy due to seed cover or exogenous. Physical dormancy: Testa or hardened parts that are impermeable. Mechanical dormancy: Hardened seed coat that prevents the expansion of the embryo during germination. Chemical dormancy: Production and accumulation of substances that inhibit germination.

2) Morphological or endogenous dormancy: Present in seed embryos with incomplete development at the time of maturation. Rudimentary embryos: Seeds with embryos barely embedded in an endosperm. Undeveloped embryos: Underdeveloped seeds shaped like torpedoes, which can be up to half the size of the seed cavity.

3) Internal latency: In many species, latency is controlled internally in the tissues. Physiological: Germination is prevented by an inhibitory physiological mechanism. Intermediate internal: Dormancy is induced by the seminal coats and surrounding storage tissues. Of the embryo: To reach germination, a period of humid cooling is required and due to the inability of the embryo to germinate normally.

4) Combined morphophysiological latency: Consists of the combination of embryonic underdevelopment with inhibitory mechanisms.

5) Combined exogenous-endogenous dormancy: Various combinations of dormancy in the shell or pericarp.

Conclusions

Seed dispersal in arid and semi-arid environments is a complex system, in which intrinsic and extrinsic (environment) aspects of seeds interact. To understand the aspects related to dispersal, it is necessary to know the dispersal models used by the seeds, which determine the best strategy to reach safe sites. The complexity of mobility lies in the specific macro and microstructural characteristics that the seeds of xerophytic species have, both for their dispersal and for their germination and subsequent establishment, which ensures the maintenance of plant cover in these environments.

Acknowledgements

We thank the referees of this work, who undoubtedly contributed to improving the writing of the same for its publication.

Conflict of interest

It is declared that there is no conflict of interest between the authors of this document.

Contribution by author

Jaime Sánchez: coordinator of the review and author; Eduardo Estrada Castillón: writing, compilation and edition; Mario A. García Aranda: review, compilation and edition; Mario F. Duarte Hérnández: review, compilation and edition; Fabián García González: review, compilation and edition; Luis M. Valenzuela Núñez: writing, compilation and edition; Gisela Muro Pérez: writing, compilation, edition and author by correspondence

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