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## Short communication

# Native dispersers induce germination asynchrony in a macaronesian endemic plant (*Rubia fruticosa*, Rubiaceae) in xeric environments of the Canary Islands

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## Abstract

A comparison of the germination rate of a Macaronesian endemic plant (*Rubia fruticosa*) between two xeric badland areas of the easternmost islands of the Canaries (Lanzarote and Fuerteventura) is presented. A similar germination rate was observed between both seed control plants from the populations of Lanzarote and Fuerteventura in the two years. However, some germination asynchronies were observed when the native frugivores participated in this seed dispersal system; seeds from Lanzarote germinated earlier than in Fuerteventura when they were consumed by lizards and birds. Although this pattern did not present a between-year consistency, seeds germinated earlier in the more stressed badland even when climatic differences are not so great. This asynchrony, caused by frugivorous dispersers (lizards and birds), is important in geographical zones where rain is unpredictable and where it increases the probability that seedlings can recruit successfully and for a longer period.

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**Keywords:** *Rubia fruticosa*; Speed of germination; Frugivorous effects; Arid habitats

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## 1. Introduction

Seed germination performance involves two distinct ecological factors that clearly lead to different ecological consequences: (1) the germination success of seeds from control plants and after ingestion by different frugivorous species; and (2) the germination rate which expresses the timing of germination (or speed of germination) (see review of Traveset, 1998). In this regard, a large number of studies carried out on the ecology of seed dispersal systems in fleshy-fruited plant species have focused on the afore-mentioned factor (see reviews of Traveset, 1998; Traveset and Verdú, 2002). In general, these contributions have evaluated the role of frugivores as seed enhancers, inhibitors or non-affecters in the germination of some plant species. Although this factor has often been examined in these fleshy-fruited plants, patterns in germination rate have not frequently been studied and still less interpreted in an ecological and evolutionary context (Verdú and Traveset, in press). However, Geber and Griffen (2003) have demonstrated that early germination of seeds is a heritable trait subject to strong selection pressure mediated by competitive interactions.

Temporal pattern variation of germination of uningested control seeds has often been described among individuals or populations within a species (Zimmerman and Weis, 1984; Khatri et al., 1991; Miller et al., 1994), indicating that the mother plant effect is one of the main ecological factors related to this phenomenon. Natural selection, modulated mainly by seed disperser agents, could have played an important part in the phenology of seed germination, because it can modify the duration of seed dormancy (Izhaki and Safriel, 1990; Traveset et al., 2001). Furthermore, it is interesting to note that in xeric zones, other factors such as rain patterns are also a basic and limiting climatic factor that directly conditions the germination processes (Guterman, 1993; Baskin and Baskin, 2001).

In summary, in xeric environments, maternal effects, seed dispersers gut treatment and rain patterns are three of the main ecological factors related to germination rate. The study of the evaluation of these factors is especially interesting in some oceanic islands where plant species can be present in different environments, mainly structured as a function of altitude and orientation. This is the case of *Rubia fruticosa* (Rubiaceae), an endemic plant of the archipelagos of Madeira, Desertas, Salvages and Canaries, that is present in practically all the xeric habitats of the islands and islets in this last archipelago (Nogales et al., 2001).

In this study we evaluate how the afore-mentioned ecological factors affect the two populations of *R. fruticosa* (Rubiaceae). Both populations are located on the easternmost islands of the Canaries (Lanzarote and Fuerteventura) in two semi-arid badlands, where slight variability in climatic conditions might differentially affect selection in the phenology of seed germination (Symonides, 1977). Theoretically, seedlings from the most stressed environment have to emerge earlier to become promptly vigorous and robust so as to resist the arrival of the dry seasons (spring and summer) (see Verdú and Traveset, in press). Lastly, we also assess whether the intervention of lizards and birds in this xeric seed dispersal system could produce asynchronous germination, which provides better possibilities of seedling success.

## 2. Study area and methods

### 2.1. Study sites

The badland areas are located in the north of the driest easternmost islands of the Canarian Archipelago (Lanzarote and Fuerteventura). The badlands of Lanzarote (Malpaís de La Corona) are located near to the coastal zone (1.5 km from the coast; 100 m a.s.l.), while the Fuerteventura badlands (Malpaís de La Arena) are situated inland (9 km from the coast; 220 m a.s.l.).

Due to the proximity to the northwest coast of Africa ( $\approx 100$  km at the closest point), the climate is strongly influenced by the dry Sahara Desert winds. The climate is semi-arid, rainfall being scarce in both systems. According to data provided by the Centro Meteorológico Territorial en Canarias Oriental (Instituto Nacional de Meteorología, Ministerio de Medio Ambiente), precipitation and temperature is rather similar in the two sites studied. The Lanzarote study area has a slightly higher annual rainfall ( $157.8 \pm 80.6$  mm/year;  $n = 19$  years) than that of Fuerteventura ( $145.3 \pm 96.92$ ;  $n = 19$  years) (periods: 1973–1977, 1986–1987, 1989–1993, 1995–1996, 1998–2000, 2002, respectively, for both islands). However, the annual mean temperature is also moderately higher in the Lanzarote site than in the Fuerteventura study area ( $21^\circ\text{C} \pm 0.60$  and  $20.5 \pm 0.24$ , respectively;  $n = 9$  years) (period: 1989–1997). Therefore, evapotranspiration is very similar in the two badlands (Thornthwaite Index, potential evapotranspiration; Lanzarote: 7.08 vs. Fuerteventura: 7.14). Unfortunately, most of the Canarian climate stations do not measure the effects provided by dew fall and atmospheric humidity. These factors have an important influence on plants in arid and semi-arid environments (Gutierrez, 1993; Whitford, 2002). Despite the lack of data available on the effect of these climatic factors, both of them are clearly higher in the Fuerteventura study area (more than 150 m higher in altitude) than that of the one in Lanzarote (pers. obs.). Lastly, taking all these climatic factors into account, and considering the general similarity between the climates of the two study areas, all seem to indicate that climatic stress could be moderately higher in the Lanzarote coastal area than that of the inland one in Fuerteventura. Another factor that supports this idea is the fact that fruit phenology of the plant population in Fuerteventura occurs later (a difference of two or three weeks) than in the Lanzarote one (pers. obs., data from the last three years: 2002–2004).

Vegetation composition is similar in both areas, consisting of a sparse xeric shrub composed mainly of *Euphorbia regis-jubae*, *E. balsamifera*, *Launaea arborescens*, *Kleinia neriifolia*, *Lycium intricatum*, *R. fruticosa* and *Asparagus* spp. Both seed dispersal systems show the same native seed dispersal species: lizards (the endemic *Gallotia atlantica*) and birds (*Sylvia conspicillata* and *S. melanocephala*).

### 2.2. Procedures

Fieldwork was simultaneously carried out in both badland areas in order to compare the potential differences between the two zones. A germination experiment

was then performed, controlling the same environmental conditions, in a greenhouse, for six months (1st October 2002–31st March 2003 and during the same period in 2004–2005), when rainfall is most likely in the xeric areas of the eastern Canary Islands (García et al., 2001). Therefore, we collected seeds in two different spring seasons (2002 and 2004) in order to evaluate the robustness of the obtained outputs in two different years. We randomly took 200 fruits (not more than seven per plant) directly from the mother plants ( $n \approx 70$  plants in each island population) and approximately the same amount of droppings from the two main native dispersers, lizards and birds. The participation of these native frugivorous are really important in the seed dispersal system of this species since no vegetative reproductive abilities have been observed. We only collected fresh droppings for the main vertebrate dispersers (see Nogales et al., in press) and we randomly extracted a total of two or three seeds per dropping, from both birds and reptiles, so as to perform the germination experiments. Seeds from the mother plants were collected in the period when most of fruits were ripen and taking into account the differential phenology of both previously mentioned plant populations. Droppings were stored and analysed independently, and seeds were manually extracted and counted. A total of 200 seeds were planted for most of each treatment (seeds from control, lizards and birds, respectively). Each seed was independently planted in a  $4\text{ cm}^2$  pot, using a standard substrate (25% turf, 25% volcanic sand and 50% culture soil). Each seed was buried about 5 mm deep and watered every two days. Germination was considered to be the emergence of any seedling part from the soil, and was recorded. Data were taken every five days and Kolmogorov-Smirnov tests were employed to evaluate differences in germination speed between treatments. To avoid possible bias in calculating speed of germination, caused by the differential percentage of seed germination between treatments, only those data that comprise the period since the first seedling emerged ( $\approx 15$  days) until the germination curve was established were considered.

### 3. Results and discussion

A clear differential pattern on germination success can be appreciated between the two island plant populations and in all treatments (Likelihood ratio tests;  $p < 0.05$ ; Fig. 1), the Lanzarote site presenting higher values than that of Fuerteventura. These differences between populations have been appreciated in other plant species (Khatri et al., 1991) and even in the eastern Canaries (e.g. *L. intricatum*, Solanaceae; Nogales et al., in prep.).

With regard to the main ecological factor focused in this contribution (the speed of germination), a similar pattern was observed in both seed control plants from the populations of Lanzarote and Fuerteventura (Fig. 1). This pattern was recorded in both years when the experiments were performed, indicating an important robustness of these results. In this regard, important variations in germination timing among populations have been reported in some particular species (Zimmerman and Weis, 1984; Khatri et al., 1991; Miller et al., 1994), and may be related to

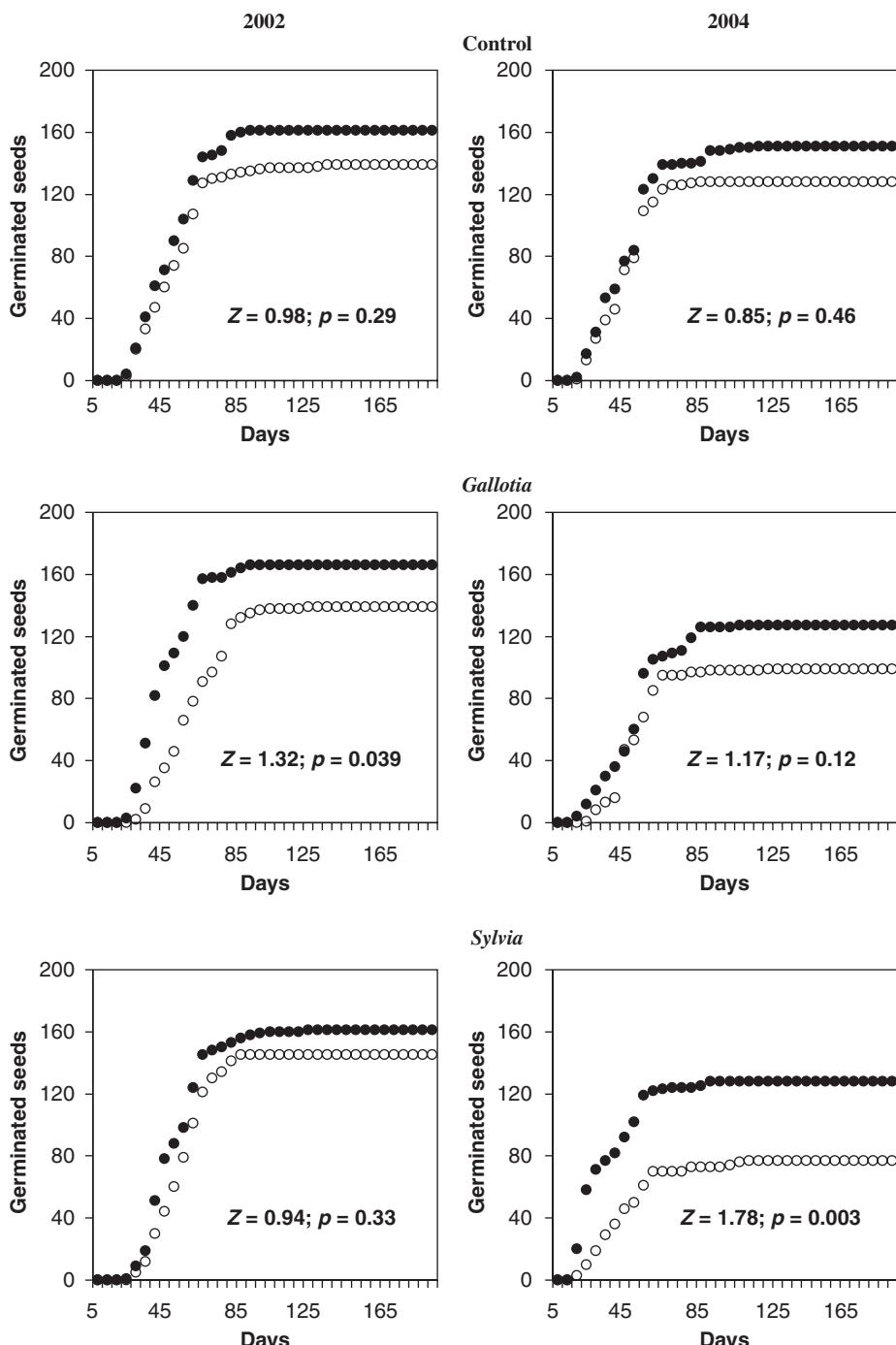


Fig. 1. Speed of seed germination of *Rubia fruticosa* obtained from the same treatments in both islands. Black dots: Lanzarote; white circles: Fuerteventura.

natural selection patterns conditioned by their respective evolution in different climatic conditions and ecological scenarios. These ideas are strongly supported by the fact that seed germination timing is a heritable trait modulated by different selective pressures (Geber and Griffen, 2003). However, in our case, the similar germination pattern recorded in the two control plant populations probably reflects the slight climatic differences existing between the two environments, despite the fact that the badland study area of Lanzarote is located in a coastal zone and that of Fuerteventura is situated inland and at twice the elevation (see location in Nogales et al., in press). These slight climatic differences existing between the two badlands are probably not strong enough to provoke a natural selection force that conditions differences in germination rate between these two control plant populations.

This similar germination pattern found between the seed control plants of both island populations change when the frugivores take part in this dispersal system. Thus, some germination asynchronies were observed when lizards and birds participated and seeds from Lanzarote germinate earlier than Fuerteventura when they are previously consumed (Fig. 1). Although this pattern did not present a between-year consistency, seeds germinated earlier in the more stressed badland even when climatic differences are not so great. Different frugivorous species can modify the duration of seed dormancy and earlier germination may represent an advantage for a particular species (Ross and Harper, 1972; Weaber and Cavers, 1979; Zimmerman and Weis, 1984; Verdú and Traveset, in press). However, germination selection timing does not always favour those seedlings whose seeds germinate earlier (Janzen, 1981; Traveset, 1990) and this probably depends on the ecological conditions of the ecosystem where the different plant species have evolved. This asynchrony produced by the intervention of different disperser types has been interpreted by some authors as an adaptation to geographical zones where rain is rather unpredictable, as occurs in some habitats of the Mediterranean Region (Izhaki and Safran, 1990; Traveset et al., 2001). Harper (1977) mentioned that asynchronous germination guarantees that seedling mortality is spread over a longer period, thus providing better possibilities of success for some of them.

As occurs with desert areas worldwide, the xeric areas of the Canaries are seasonal, and there is a predictable period of rainfall (October–March; see García et al., 2001), but the amount of yearly rainfall is not predictable (Whitford, 2002). Despite the fact that differences in germination recorded among *R. fruticosa* treatments may vary from several days to a week, small differences may lead to variations in seedling success (growth rate and death likelihood), later seedlings being at a disadvantage in some species (Symonides, 1977).

Finally, it would be interesting to contrast the results obtained in this contribution with other fleshy fruited-plant species that grow in xeric habitats of the Canaries. Furthermore, the ecological framework of this study could be extrapolated to other more humid ecological environments, where *R. fruticosa* is present, which include a differential stronger climatic gradient, caused by latitude, orientation or altitude, and whose seed dispersal systems are represented in the high altitude oceanic islands of the western Canaries.

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