SEED GERMINATION STUDIES OF SELECTED GALAPAGOS ISLANDS ANGIOSPERMS

by

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Many problems in the evolution of flowering plants are posed by immigration to oceanic islands. Obstacles that must be overcome by a plant when colonizing such islands include seed transport, germination, establishment, and reproduction. The first of these, seed transport, has been dealt with extensively in the literature, both for oceanic islands in general, and for the Galapagos Islands specifically (Ridley, 1930; Carlquist, 1974). The most recent figures for the Galapagos would indicate that birds have been the most important dispersal agents of flowering plants representing 48.6% of the dispersal events, followed by man (38.8%), oceanic drift (7.0%), and wind (5.6%) (Porter, 1983).

This paper reports on viability and germination tests that were performed on seeds of several species of flowering plants of Isla Santa Cruz. The species chosen for these experiments were among those comprising a larger study dealing with the reproductive biology of Galapagos Islands angiosperms. The objectives of these tests were to determine: 1) seed germination ability; 2) the presence or absence of seed dormancy; and 3) what correlations exist between seed dormancy and plant resident status, habitat and dispersal mechanism.

The seeds used for the viability tests were obtained from plants located in five of the seven major vegetation zones on the southern slope of Santa Cruz (Wiggins and Porter, 1971; van der Werff, 1979). The locations of the study quadrats by vegetation zone were as follows: 1) Arid Zone — near Darwin Station; 2) Transition Zone — 3.5 km N Puerto Ayora near road; 3) *Zanthoxylum* Zone — near Santa Rosa; 4) *Scalesia* Zone — near Los Gemelos and 5) Pampa Zone — 3 km N Media Luna. The seeds were tested for viability using a 0.1% solution of 2, 3, 5 Triphenyl Tetrazolium Chloride (TTC) which acts as an indicator or respiration in the embryo. All of the species included in this study showed positive TTC results indicating that the seeds were viable and possessed the potential for germination.

For the germination tests seeds of each species were divided into two groups. The first group was subjected to five minutes exposure in a 2.6% solution of sodium hypochlorite. This treatment was performed to sterilize the seed coat and in so doing destroy any fungi that might be present. This treatment was found necessary after preliminary tests involving the seeds of several other species had to be terminated due to fungal damage. The second group of seeds was subjected to the same solution, but for one hour duration. This second treatment was mentioned by Rick and Bowman (1961) as being quite effective in breaking dormancy in *Lycopersicon cheesmanii* var. *minor.* The type of dormancy that would be affected by this kind of treatment is one in which there is a structural barrier to germination which might be broken by removal of part of the seed coat by the solution. The seeds were then rinsed very thoroughly in water and placed on moist filter paper in petri dishes and observed for a period of 21 days. The paper was kept moist and the seeds were counted and removed as they germinated. As a precaution against contamination the dishes and water were sterilised by autoclaving. For *Croton scouleri* var. *scouleri* and *Scutia spicata* var. *pauciflora* only enough seeds were available for the control treatment.

The results of the germination tests are shown in Table 1. The percentage of seeds germinated for each exposure period as well as the number of seeds tested (in parentheses) is given. It was arbitrarily decided that seed dormancy would be indicated for those plants in which there was less than 25% germination under the five minute (control) exposure. Using this measure 51.9% of the species tested showed seed dormancy. None of these species showed a significant increase in seed germination after the one hour exposure period. This would seem to indicate either that the dormancy type is not one of a simple mechanical barrier brought about by the seed coat, but perhaps a dormancy requiring some other treatment, for example the removal of a certain chemical from within the seed-coat; or that the seed coats required an even longer exposure to the sodium hypochlorite solution. This latter possibility is supported by the observation that several of the species showing dormancy seemed to have seeds with thick, tough seed coats. Examples of this are seen especially well in *Tournefortia rufo-sericea, Croton scouleri* var. *scouleri, Cassia occidentialis,* and *Clerodendrum molle* var. *molle.* This contrasts with several of those plants not showing seed dormancy, such as *Justicia galapagana, Adenostemma platyphyllum,* and *Jaegeria gracilis,* which have seed coats that are not as thick and that showed a significant drop in germination after exposure for an hour to the solution indicating that some of the embryos may have been destroyed.

Table 1 also includes the locations by vegetation zones of the plants tested. The arid and transition zones are considered part of the basically arid ecological zone, while the *Zanthoxylum, Scalesia,* and pampa zones belong in the basically mesic ecological zone (Johnson and Raven, 1973). Also given is the resident status and supposed disseminule dispersal mechanism for each of the plants (Porter, 1983). This information was included to determine what correlations existing between these factors and seed dormancy.

Seed dormancy was found in 63.6% of the endemics, 60.0% of the natives, and only 36.4% of the non-indigenous (introduced weeds and cultivated escapes) species. If the species that were tested are divided into just two groups, indigenous and non-indigenous, 62.5% of the former show seed dormancy while only 36.4% of the latter show this characteristic. This would indicate that the non-indigenous plants are better able to immediately exploit any habitat that might open up, whereas the endemics and natives show a "strategy" of waiting for more favorable conditions before germinating. It is worth noting that the majority of introduced weeds showing greater than 50% germination have a high seed set potential which could compensate in part for a high mortality that might result from more immediate or almost total seed germination in a less than hospitable environment. Unfortunately, these factors also help to explain why some of the introduced weeds and cultivated escapes on the Islands are successful in advancing into areas that are temporarily exposed due to factors such as fires and pasture use. These plants are pre-adapted to making a quick start in these disturbed locations and in turn slowing or halting the return of the native vegetation.

When ecological zones are considered 66.7% of the species in the basically arid zone show seed dormancy while 33.3% of those in the basically mesic zone show dormancy. The explanation for this seems straightforward enough in that plants which would be favored to survive in the dry or xeric conditions represented in the transition zone and especially the arid zone are those with seeds that could remain dormant until the most favorable conditions were present. Whereas the basically mesic zone, being less harsh, might allow a more haphazard "strategy" of immediate germination. Within this mesic zone are found the highest number of non-indigenous species studied, in fact, 66.7% of the species from this area are either introduced weeds or cultivated escapes, and the relationship between lack of seed dormancy and non-indigenous resident status has been mentioned in the previous section.

Dormancy also appears correlated with dispersal mechanism. Of those species with seeds carried internally by birds, 88.9% show seed dormancy but only 16.6% of those carried externally by birds and 36.3% of those introduced by man show dormancy. The one species with wind dispersal also shows dormancy. From these results it would appear that those seeds carried in the digestive tracts of birds need a protective covering, which could also act as a dormancy mechanism. Also suggested is the need of passage through the digestive system to break this dormancy, although in some cases destruction of the seeds has been known to occur after passage through birds (Rick and Bowman, 1961). In addition, all of the plant species studied here which are dispersed internally by birds have a widespread distribution throughout the archipelago indicating that this might indeed not only be a method of promoting germination, but also dispersal among the islands. The dormancy observed in *Darwiniothamnus tenuifolius* var. *tenuifolius* might also be correlated to its dispersal type since it is well known that aerial transport can at times be very harsh due to the extended time and low temperatures which might be encountered. Those seeds transported by man show the least amount of dormancy. This, again, can be explained by the fact that some weedy plants may be better suited if little or no dormancy is present. It is explained for the cultivated escapes by the simple fact that these plants are normally bred, either intentionally or not, so that dormancy is lost (Harper, 1965). *Paspalum conjugatum* appears to contradict this with its low germination. Perhaps it is best considered a native as Black (1973) suggests, rather than a cultivated escape.

In summary, just over half, or 51.9% of the species tested show seed dormancy represented by less than 25% germination. It appears from these tests that factors associated with this degree of dormancy are an indigenous resident status, an arid habitat, and internal dispersal by birds (other animals might also be important). However, dormancy is not an all or none situation in most cases. These tests do not preclude the possibility of a lesser degree of dormancy in the other species. Indeed, this would seem very likely since two characteristics of known value to many weeds and colonizers of open habitats are their ability to germinate in a wide variety of environmental situations, and continuous germination over an extended period of time (Mulligan, 1965; Ehrendorfer, 1965). The weedy character of the Galapagos flora and its open pioneer habitat are well known (Porter, 1976, 1979; Hendrix, 1981), and many of these species may simply be demonstrating this "strategy" of staggered germination. This greatly increases the chances of sooner or later encountering suitable conditions for growth and perhaps establishment.

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Table 1. Plant data and results of tests showing the percentage of seeds germinating after exposure to Sodium Hypochlorite solution. The number of seeds tested is shown in parentheses.

Plant Tested & Study Site	**Resident Status**	**Dispersal Mechanism**	**5 Minute Exposure**	**1 Hour Exposure**	**Seed Dormancy**
ACANTHACEAE					
Justicia galapagana (T)	endemic	birds (a)	67 (30)	0 (30)	No
ASTERACEAE					
Adenostemma platyphyllum (Z)	introduced weed	man	80 (40)	45 (40)	No
Ageratum conyzoides subsp. *conyzoides* (P)	introduced weed	man	61 (100)	65 (100)	No
Bidens pilosa (Z)	introduced weed	man	90 (50)	80 (50)	No
Darwiniothamnus tenuifolius subsp. *tenuifolius* (S)	endemic	wind	0 (100)	0 (100)	Yes
Jaegeria gracilis (P)	endemic	birds (a)	44 (50)	16 (50)	No
Scalesia pedunculata (S)	endemic	birds (a)	30 (50)	16 (50)	No
BORAGINACEAE					
Tournefortia pubescens (A)	endemic	birds (b)	33 (18)	44 (18)	No
Tournefortia rufo-sericea (T)	endemic	birds (b)	0 (50)	0 (50)	Yes
CACTACEAE					
Opuntia echios var. *gigantea* (A)	endemic	birds (b)	0 (50)	0 (50)	Yes
CYPERACEAE					
Cyperus elegans subsp. *rubiginosus* (A)	endemic	birds (b or a)	24 (100)	27 (100)	Yes
EUPHORBIACEAE					
Croton scouleri var. *scouleri* (A)	endemic	birds (b)	0 (9)		Yes
FABACEAE					
Cassia occidentalis (T)	native	birds (b)	10 (50)	2 (50)	Yes
LAMIACEAE					
Hyptis rhomboidea (P)	introduced weed	man	62 (100)	65 (100)	No
LYTHRACEAE					
Cuphea racemosa (P)	introduced weed	man	86 (50)	66 (50)	No
MALVACEAE					
Bastardia viscosa (A)	native	birds (a)	4 (50)	6 (50)	Yes
Sida rhombifolia (S)	introduced weed	man	14 (50)	14 (50)	Yes
PLUMBAGINACEAE					
Plumbago scandens (T)	native	birds (a)	73 (11)	100 (9)	No
POACEAE					
Paspalum conjugatum (S)	cultivated escape	man	24 (50)	24 (50)	Yes
POLYGONACEAE					
Polygonum opelousanum (P)	native	birds (a or b)	48 (30)	39 (30)	No
PORTULACACEAE					
Portulaca oleracea (A)	introduced weed	man	77 (100)	74 (100)	No
RHAMNACEAE					
Scutia spicata var. *pauciflora* (A)	endemic	birds (b)	0 (12)		Yes
SOLANACEAE					
Capsicum fruitescens (T)	cultivated escape	man	48 (25)	100 (25)	No
VERBENACEAE					
Clerodendrum molle var. *molle* (A)	native	birds (b)	0 (20)	0 (20)	Yes
Lantana peduncularis var. *peduncularis* (A)	endemic	birds (b)	0 (30)	0 (30)	Yes
Verbena litoralis (Z)	introduced weed	man	0 (100)	0 (100)	Yes
ZYGOPHYLLACEAE					
Tribulus cistoides (A)	introduced weed	man	0 (34)	0 (34)	Yes

(A) arid zone, (P) pampa zone, (S) *Scalesia* zone, (T) transition zone, (Z) *Zanthoxylum* zone, (a) external, (b) internal

Resident status and dispersal mechanism from Porter (1983)

When two types of bird dispersal are indicated the first is considered most probable.