

The Influence of Seed Size and the Dormancy on Germination Behaviour of *Prosopis juliflora*(Sw.) DC. growing in Qatar

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ABSTRACT. The leguminous tree *Prosopis juliflora* produces both small and large seeds the dormancy of which appears to be caused by the impermeability of the seed coat to water. Sulphuric acid was found to be the most effective breaker of dormancy. Seed size had no effect on the final germination percentage prior to breaking of dormancy. After dormancy breaking the small seeds were the faster to germinate during the first five days but the ultimate percentage germination of both categories of seeds was the same by the end of the experiment. As the dormancy was broken the percentage of seedlings emerging from both types of seeds was higher (and germination more rapid) from shallow sowing and decreased progressively with deeper sowing. Both types of seeds were found to germinate in a wide range of temperatures.

A great deal of attention has been given to the importance of different morphs associated with seed polymorphism in shape and size. These have ecological significance in dormancy, germination, emergence from deep sowing, dispersal mechanisms and hence repercussions on all processes associated with germination and establishment (Harper and Benton 1966, Harper and Obeid 1967, Harper *et al.* 1970, Thompson 1981, Saha and Takahashi 1981). *Prosopis juliflora* is a species dimorphic with respect to seed size as it produces both small and large seeds. The entry of water into seeds is determined primarily by the permeability of the seed coat, dormant and non-dormant seeds behaving differently with respect to water uptake. *Prosopis juliflora* is a member of the Leguminosae (Mimosaceae) in which selective permeability of seed coats to water is wide-spread (Harper *et al.* 1970, Mayer and Poljakoff-Mayber 1978,

Saha and Takahashi 1981). The seeds of *Prosopis juliflora* were found to exhibit dormancy. The experiments reported in the present paper were undertaken to determine the treatments necessary to break the dormancy of the seeds of this species in Qatar and the consequences of breaking the dormancy on the behaviour of seeds, particularly in relation to seed size.

The macromorphology of Prosopis juliflora (Sw.) DC.

This is a spiny tree up to 12 m high, with blackish bark. The leaves are compound bipinnate; each pinna has a sub-terete rachis and bears 14-16 pairs of pinnules. The pinnules (leaflets) are sessile, more or less elliptic and slightly mucronate. Stipules are lanceolate and at the leaf-base is a brownish pulvinus. The flowers are arranged in dense drooping axillary spikes. The drooping fruits (legumes) are glabrous, shiny and indehiscent. There are about 20 seeds per legume, embedded transversely in a dry yellowish spongy pulp. The fruit produces both large brown seeds (average weight 34 mg) and small brownish-black seeds (average weight 17 mg) with no consistent position and arrangement inside the pod (Al-Niwahi, Personal communication 1980). The species is indigenous to the West Indies and Mexico but is suited to the environmental conditions of Qatar being drought resistant. In Qatar the tree is of economic importance as it is cultivated in avenues, in gardens, in forests and as wind-breaks surrounding large agricultural farms.

Material and Methods

Seed used throughout these experiments was collected in December 1979 from the University of Qatar campus. The seeds were classified into two categories, small and large, on the basis of physical and morphological features. Seeds of each size group were allowed to germinate in Petri-dishes of 9-cm diameter containing Whatman No. 1 filter paper moistened with 6 ml distilled water. Twenty five seeds were placed in each Petri-dish and four replicates were used for each treatment. Seeds were examined daily and a seed was considered germinated when the tip of the radicle had emerged.

Five types of experimental investigations were made as follows:

1. Effect of Temperature and Alternating Light and Darkness

(a) Seeds of each size were germinated under constant temperatures of 10, 27.5, 30 and 40°C.

(b) As in (a) but the seeds were placed in complete darkness or in alternating light and darkness. The seeds were exposed to light for 11 hr/day.

2. The effect of Certain Chemical Treatments on Germination

The seeds of both categories were subjected to the following treatments and thereafter allowed to germinate as described before:

- a) immersion in concentrated sulphuric acid for 1 min followed by washing with distilled water
- b) immersion in 0.1M potassium nitrate for 24 hr
- c) immersion in 10% hydrogen peroxide for 10 hr
- d) immersion in boiling water for 20 min
- e) immersion in distilled water.

3. *The Time-Course of Germination of Both Categories of Seeds Before and After Dormancy-Breaking*

The same categories of seed size were allowed to germinate at 30°C under the following treatments:

- a) H₂SO₄.
- b) dormant seeds.

The daily march of germination percentage was compared.

4. *The Effect of Depth of Sowing*

The two categories of seeds, after having their dormancy broken, were sown at depths of 0, 1, 3 and 5 cm in a sandy soil (88.9%, 6.1% and 5.0% of sand, clay and silt, respectively) in small plastic pots (6.5 cm diameter × 13 cm depth). Four replicates were included in a randomized block design. The experiment was conducted in a glasshouse where the temperature range was 15-30°C, *i.e.* conditions similar to those prevailing in the field. All of the pots were irrigated with water, so that the soil was maintained close to the field capacity. Five seeds were sown per pot and emergent seedlings were recorded daily and counted till no further emergence occurred during the last 2-3 days. The term emergence is used here to mean the appearance of parts of the seedling above the soil surface (Harper and Obeid 1967).

5. *The Pattern of Water Uptake*

In order to understand the rate and mode of water penetration into seeds, 40 large and 40 small seeds were treated with H₂SO₄ and another 40 large and 40 small seeds were left dormant. The initial weight of the seeds was recorded. Ten seeds were sown per Petri-dish (4 replicates of each treatment) and allowed to germinate at 30°C as previously mentioned till the emergence of the radicles (about 28 hr). After each time period of 4 hr, the seeds were removed individually, blotted dry on filter paper and rapidly weighed. Blotting dry and weighing took about 1 min.

Results

1. *Effect of Seed Size, Temperature and Light on Germination*

The seeds of both size categories germinated within a temperature range of 10-40°C (Table 1). There were no significant differences in response to temperature between large and small seeds, but in both there were significant differences ($P=0.01$) in

germination across the temperature range. There were no significant differences between the two seed types in relation to their light requirements and therefore only one result is presented (Table 2).

Table 1. The effect to temperature on the germination percentage of the two categories of seeds of *P. juliflora*.

Temperature (°C)	Germination (%)	
	Categories of seeds	
	Large brown with smooth surface (average weight of seed 34 ± 4.68 mg)	Small brownish-black with smooth surface (average weight of seed 17 ± 1.92 mg)
10.0	7	7
27.5	29	28
30.0	33	32
40.0	16	15

L.S.D. at $P = 0.05$ is 1.31

Table 2. The effect of alternating light and darkness on the germination percentage of seeds of *P. juliflora*.

Temperature (°C)	Germination (%)	
	Darkness	Alternating light and darkness
10.0	7	9
27.5	29	26
30.0	35	36
40.0	13	16

L.S.D. at $P = 0.05$ is 4.05

2. Effect of Chemical Treatments and Seed Size on Germination

There were no significant differences between large and small seeds in relation to the final percentage germination but there were significant differences between treatment with H_2SO_4 and the other treatments (Table 3).

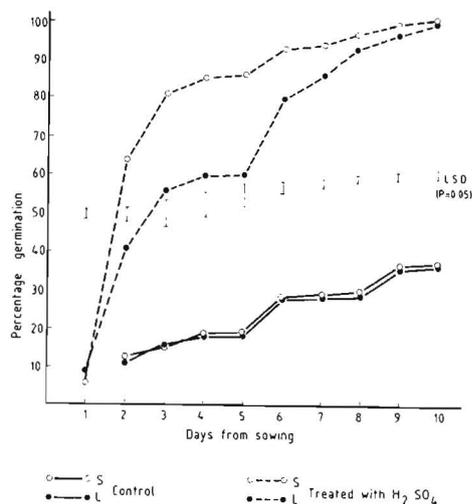
Table 3. The effect of different chemicals at 30°C on the germination capacity of both categories of seeds (for details of treatments see text).

Treatment	Germination (%)	
	Large seed	Small seed
1. H ₂ SO ₄	100	100
2. KNO ₃	37	37
3. Hydrogen peroxide	37	38
4. Boiling water	34	36
5. Control	40	41

L.S.D. at P = 0.05 is 6.05

3. The Influence of Seed Size and Dormancy Breaking on the Course of Germination

There were highly significant differences between the seeds treated with conc. H₂SO₄ (dormancy breaker) and the untreated seeds irrespective of size (P=0.01) in relation to germination. There was no effect of seed size of untreated seeds (control) on the time course of germination. In the treated seeds, large seeds were significantly slower to germinate than small seeds. This difference in speed of germination became significant on the second day of the experiment and continued with the small seed superior in germination capacity (Fig. 1) until the sixth day. By the end of the experi-

**Fig.1** The influence of seed size on germination and dormancy.

L = Large seed

S = Small seed

ment the final percentage germination of both categories of seeds was similar.

4. The Influence of Depth of Sowing on Emergence from Seeds of Different Size

Figure 2 shows the time course of emergence for both categories of seeds sown at four depths. It can be seen that the rate of emergence and the final percentage emergence were reduced by increasing the depth of sowing from 0 to 5 cm ($P=0.05$). Seed size did not affect the rate of emergence appreciably.

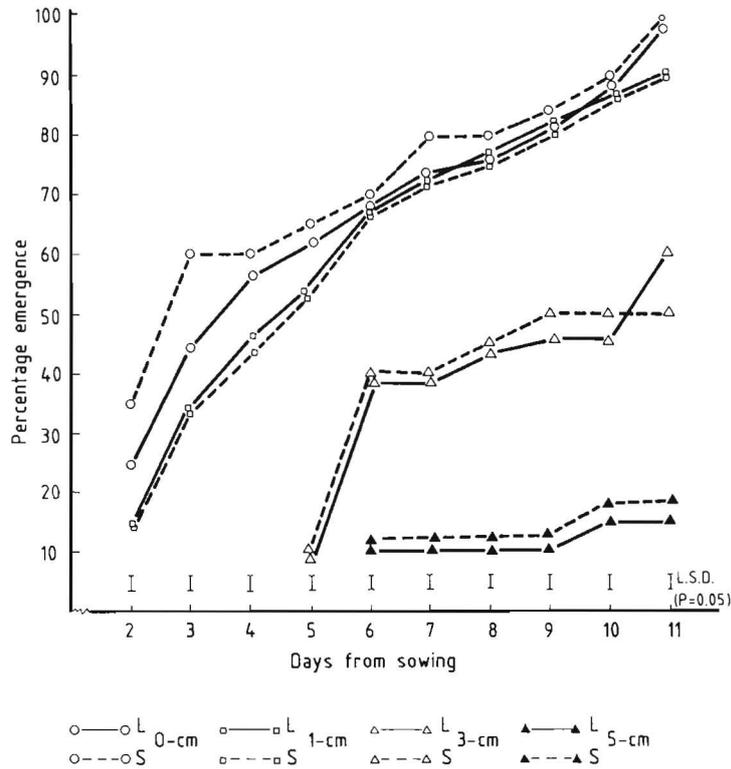


Fig.2 The influence of depth of sowing (0, 1, 3 and 5 cm) on germination.

L = Large seed

S = Small seed

5. The Pattern of Water Uptake

Dormant seeds (untreated with H_2SO_4) of both categories absorbed less water than the treated seeds. The stages of the water uptake were as follows:

1. The weight of the dormant seeds decreased slightly between 0-4 hr and increased slightly between 24-28 hr.

2. The weight of the treated seeds was: (a) reduced sharply between 0-4 hr and this was more pronounced in the small seed than the large seed; (b) reduced gradually between 4-8 hr; (c) increased sharply in the small seed between 8-24 hr, gradually in the large seed between 8-24 hr and sharply between 24-28 hr.

3. The emergence of the radicle from the small seed was observed at 24 hr after sowing while that of the large seed was observed at 28 hr. No radicles emerged from untreated seeds by 28 hr after sowing (Fig. 3).

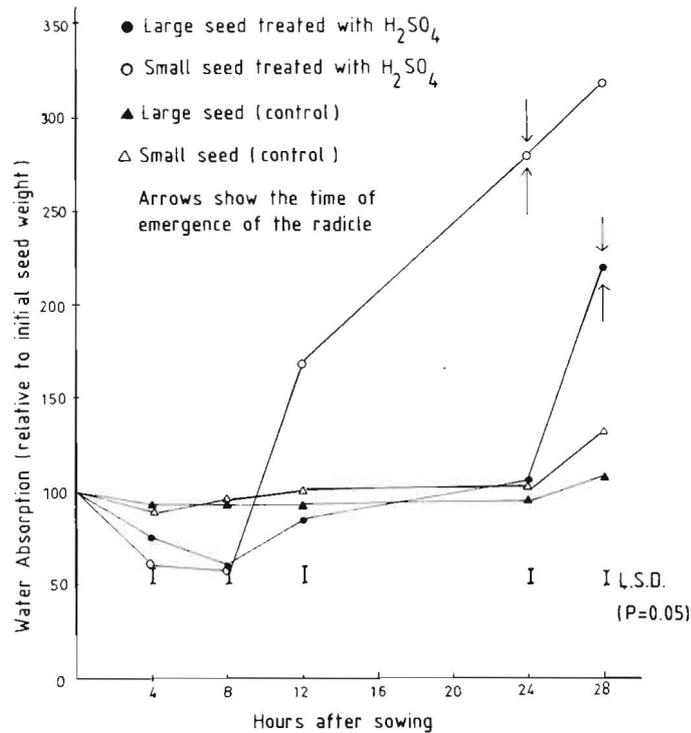


Fig.3 The effect of H₂SO₄ on water uptake of seeds of *Prosopis juliflora*. Results are expressed relative to the initial weights of the seeds (taken as 100).

Discussion

Qatar State lies between 50° 45' and 51° 40' E longitude and 24° 40' and 26° 10' N latitude and therefore is within the vast desert belt extending from North Africa to Central Asia (Batanouny 1981). The results show that the seeds of *Prosopis juliflora* have the capacity to germinate within the temperature range of 10-40°C. In view of

the arid climate of Qatar, and limited length of favourable growing season (desert conditions), the present study indicates that these seeds are suited to germinate in desert conditions. Went (1953) suggested that a wide temperature range permitting germination is a thermal adaptation of desert plants to their environment (Batanouny and Ziegler 1971). The results also indicate that *Prosopis juliflora* seeds have no special light requirements.

The germination capacity of these seeds did not exceed 40% prior to dormancy breaking. Mayer and Poljakoff-Mayber (1978) pointed out that the seed coats of members of the Leguminosae are very hard, resistant to abrasion and covered with a wax-like layer. Sulphuric acid has long been used to break the dormancy of hard-coated seeds and this proved the only seed treatment that effectively broke dormancy in *Prosopis juliflora*.

Harper *et al.* (1970) reported on variation in the seed size in the Leguminosae; in *P. juliflora* such variation occurs within one pod. In *Chenopodium* species the large brown seeds are located in specific parts of the inflorescence, *e.g.* the terminal flowers of *Chenopodium rubrum*; in *Salicornia europaea* the central flower within each cymule always has a larger seed than either of the laterals (Harper *et al.* 1970). In the present study, the effect of seed size on the response to treatment with H_2SO_4 was determined. The results show that after treatment with the acid the small seeds germinated more quickly than the large seeds. This difference in germination was observed within the first six days from sowing but by the end of the experiment the germination percentage of the small and the large seed was the same. This lack of any significant effect of seed size on overall germination matches very well with previous findings (Cideciyan and Malloch 1982).

The results also show that there is no consistent relationship between seed size and rate of seedling emergence (Rotunno 1924, Beveridge and Wilsie 1959), and the differential response of both categories of seeds to depth of sowing was the same. Weaver and Clements (1938) and Harper *et al.* (1970) stated that there is an optimal depth of sowing for germination of each species which varies with the habitat (soil type).

Harper and Benton (1966) indicated that water uptake by seeds may be obstructed by resistance across the seed-substrate interface which is affected by seed characters such as size and the presence of mucilage (mucilage in the seed coat promotes the ability to imbibe water). The results (Fig. 3) suggest that treatment with H_2SO_4 may completely softened the seed coat by removal of the waxy layer, thus rendering the testa permeable to water uptake. The results (Fig. 3) also suggested that the minimum uptake of water required for germination of the treated seeds was some 1.3-1.7 times the initial weight of the seed (Saha and Takahashi 1981). This level of uptake was not reached in the untreated seeds and no germination took place.

To investigate further and to elucidate the differential response by these two categories of seeds to the acid treatment, the thickness of their coats was examined by making measurements on longitudinal sections of the seeds by use of a vernier scale

(Fig. 4). Both seeds were exendospermic and it was found that the embryo of the small seeds was coated in a thin testa, whereas the embryo of the large seed was within a relatively thick testa (*c.f.* the weights). The small seeds after treatment with the acid were therefore likely to be more quickly permeable than large seeds to water uptake. This likelihood and the observation that the radicle of the small seed emerged earlier than that of the large seed (Fig.3) help to explain the performance of the small seed compared to the large seed in the first six days from sowing the treated seeds (Fig.1).

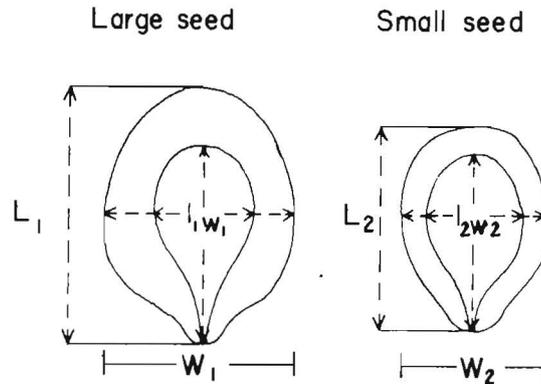


Fig.4 Dimensions of features of the seed of *P. juliflora* (from longitudinal sections)

$L_1(\text{mm}) = 6.18 \pm 0.26$ (maximum length of large seeds)

$L_2(\text{mm}) = 4.74 \pm 0.40$ (maximum length of small seeds)

$I_1(\text{mm}) = 3.34 \pm 0.18$ (maximum length of the embryo of large seeds)

$I_2(\text{mm}) = 3.24 \pm 0.14$ (maximum length of the embryo of small seeds)

$W_1(\text{mm}) = 2.72 \pm 0.12$ (maximum width of large seeds)

$W_2(\text{mm}) = 2.48 \pm 0.10$ (maximum width of small seeds)

$w_1(\text{mm}) = 2.24 \pm 0.16$ (maximum width of the embryo of large seeds)

$w_2(\text{mm}) = 2.16 \pm 0.18$ (maximum width of the embryo of small seeds)

The present study shows the extent to which the seeds of *P. juliflora*, an introduced species to Qatar, can germinate under various conditions and seedlings can emerge from different depths; it is also proposed that dormancy is an advantage under the adverse environmental conditions prevailing. It is further suggested that the adaptive significance of seed dimorphism in *P. juliflora* may be related to different ecological roles, *i.e.* different dormancies, different weights and hence germination occurs at different times. These findings may provide information on the ecological significance of hard-coat dormancy in leguminous species and may explain how seed impermeability may be involved in the population dynamics of leguminous species such as *P. juliflora*. The results reported show that seeds of different weight have embryos of much the same size but possess coats of widely differing thicknesses. The differential effect of

acid treatment is easily explained in terms of seed coat thicknesses. Ballard (1973) and Grime *et al.* (1981) indicated that although the role of impermeable seed coats under field conditions was still uncertain, there could be little doubt that this characteristic was often conducive to delayed germination and incorporation into persistent seed banks. A further insight into the ecological significance of the hard seed coats of legumes is provided by studies such as those of Hamly (1932), Hagon and Ballard (1969) and Hagon (1971), which have shown that permeability depends upon the condition of the strophiole, the only point of entry of water into the unscarified seeds of many legumes. The results reported in this study are consistent with the suggestions of Grime *et al.* (1981) who pointed out that seed-coat impermeability in the legumes facilitated the persistence of seed reserves in the habitat (desert environment) and might also provide a mechanism of gap-detection by surface-lying or buried seeds.

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تأثير الكُمون وحجم البذور على كل من كيفية الإنبات وعمق البذور المستتبته لنبات القاف في قطر

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تنتج شجرة القاف *Prosopis juliflora* (من فصيلة البقوليات) نوعين من البذور، بذرة صغيرة وبذرة كبيرة، يبدو أن كمونها يرجع إلى وجود غطاء للبذرة يعمل كحاجز مانع لنفاذية الماء. درست الظروف الملائمة للإنبات البذور، فُعْرَضت لمستويات مختلفة من درجات الحرارة، ثم بعض الكيماويات المنشطة للإنبات. والنتائج المتحصل عليها هي:

- ١ - المدى الحرارى لإنبات هذه البذور واسع.
- ٢ - حمض الكبريتيك هو أفضل كاسر لكمون البذرة صغيرة كانت أم كبيرة.
- ٣ - يؤثر حجم البذرة في تطور الإنبات اليومي، ولكنه لا يؤثر على النتيجة النهائية للإنبات.
- ٤ - تقل نسبة الإنبات بزيادة العمق، وكانت أعلى نسبة إنبات على سطح التربة، حيث بلغت ١٠٠٪، وأقلها عند عمق ٥ سم، حيث بلغت ١٣٪.

ومن هنا نتبين أن غطاء البذرة في شجرة القاف يُعتبر مسبباً رئيسياً للكمون، بالإضافة إلى دوره البيئي في عملية احتفاظ البذرة لموادها الغذائية المعقدة لفترة أطول تحت ظروف صحرواية، مثل الظروف السائدة في قطر.