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Germination of *Anastatica hierochuntica* from Saudi Arabia

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ABSTRACT. *Anastatica hierochuntica* is an annual plant which is widely distributed in Saudi Arabia and is associated with habitats where runoff water collects. The seeds of *A. hierochuntica* do not have genetically fixed innate dormancy to offset the possibility of population extinction owing to complete germination followed by complete mortality under desert conditions. However, laboratory and field experiments showed that the regulation of germination by hydration of the woody persistent pods of the indurated fruiting plants links germination to the time when abundant water is available and restricts the distribution of the species to habitats which normally receive abundant runoff water so that successful subsequent seedling establishment is possible. Dissimination is delayed until adequate moisture is available during the rainy season.

The wide amplitude of *A. hierochuntica* with regard to its germination temperature responses, coupled with the synchronization of germination with the season of optimal conditions, contribute to its success and wide distribution in Saudi Arabia.

The salt tolerance of *A. hierochuntica* is affected by temperature. When moisture and temperature conditions are favourable, its seeds are capable of germination in salinities greater than those encountered by, and tolerated by, the adult plants.

Anastatica hierochuntica L., which is commonly known as 'Jericho-rose', is a small annual herb a few cm high. It has a wide distribution in Saudi Arabia. According to Migahid (1978), its distribution includes the northern region (N), eastern region (E), South Hijaz (SH), North Hijaz (NH), Najd (NJ) and Al Rub Al Khali (R) (Fig. 1). The species is associated with habitats which collect runoff; water runnels of different order and depressions.

The establishment of any species whithin a geographical region depends on its closely adapted responses to temperature, day length and rainfall. Thompson

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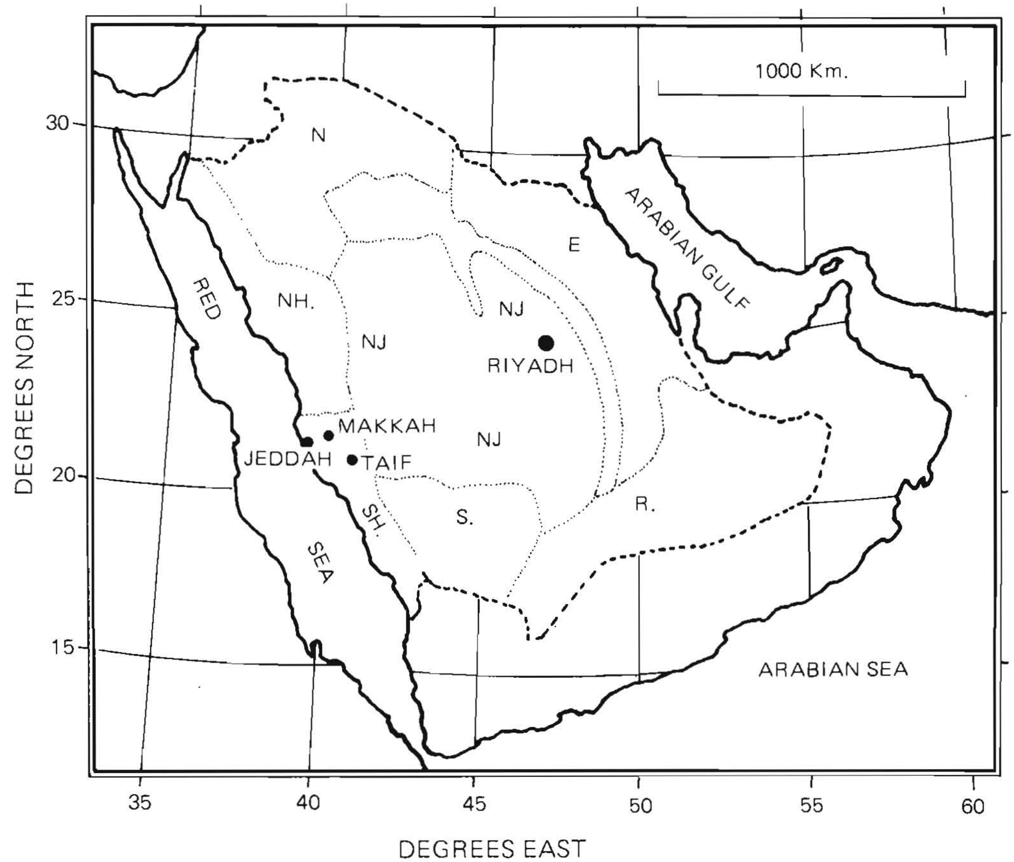

Fig. 1. Geographical distribution of *Anastatica hierochuntica* in Saudi Arabia.
N = Northern region, including Tabouk, Al-Jawf and Skakah areas.
NH = North Hijaz, representing the western part of Saudi Arabia that extends alongside the Red Sea coast north of Jeddah region extending south of Jeddah till Yemen boundaries.
SH = South Hijaz, representing the southern part of the western region extending south of Jeddah to the Yemen boundaries.
E = Eastern region, between Dahna and the Arabian Gulf.
NJ = Najd.
R = Al-Rub Al-Khali, representing most of the southern and south-eastern parts of Saudi Arabia. (Redrawn with permission from Migahid's *Flora of Saudi Arabia*, 2nd ed. 1978 copyright author).

(1970) showed that the geobotanical distribution of different species of Caryophyllaceae in Europe was reflected in their germination temperature responses. The mechanisms which synchronize germination with the season of optimal environmental conditions for subsequent growth and establishment of seedlings are of great importance amongst the many processes which constitute the adaptation of plants to the desert environment (Koller 1969, Mahmoud 1977, Mahmoud and El-Sheikh 1978, Mahmoud *et al.* 1983a, b). 'Amongst the mechanisms responsible for coordination of germination with physical parameters of the environment, two of the most important are the temperature response characteristics and the proportion of the seeds with dormancy restrictions on the growth of one kind or another' (Thompson 1973). The work described below reports an attempt to investigate the germination temperature responses of the seeds of *A. hierochuntica* and dormancy mechanisms, if any, which regulate its seed germination.

Saline habitats are very common in Saudi Arabia; the control of germination by high salinities constitutes a major factor in the occurrence and zonation of plants in saline habitats (Toole *et al.* 1956, Kassas and Zahran 1967). The ability of the seeds of the species to germinate under different salinities was examined.

Methods

Experiment 1

Procedure

The seeds were liberated from freshly collected pods; this allowed the selection of fully developed seeds for the tests. The seeds were sorted to reject those broken or insect-damaged; there was no discrimination between large and small seeds.

The seeds were germinated over the temperature range of 5-40°C at intervals of 5°C, and also over a range of (12 hr) alternating temperature regimes: 18/8, 21/10, 23/13, 26/15, 29/18, 33/22, 36/24 and 40/26°C. These alternating temperature

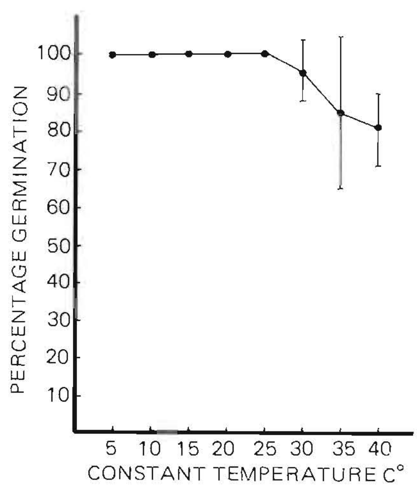

Fig. 2. Percentages of seeds of *Anastatica hierochuntica* germinating at different constant temperature regimes. 95% confidence limits are indicated by vertical lines.

regimes were selected after consideration of meteorological data at two stations within the habitat range of the species (Al-Sayl Al Kabīr in south Hijaz and Khurais, 150 km from Riyadh in Najd). The seeds were germinated in germination flasks in dark incubators maintained at the appropriate temperature regimes. Four replicates (25 seeds each) were used. A seed was considered to have germinated when the radicle emerged. Germinated seeds were discarded immediately and counts were made daily until no seed had germinated for seven successive days.

Counting involved the removal of the lid of the germination flask which allowed the change of air and briefly exposed the seeds to light.

Results

The seeds of *A. hierochuntica* showed no dormancy and germinated rapidly to high percentages at both the constant temperature regimes (Fig. 2, Table 1) and the fluctuating temperature regimes (Fig. 3 and Table 2).

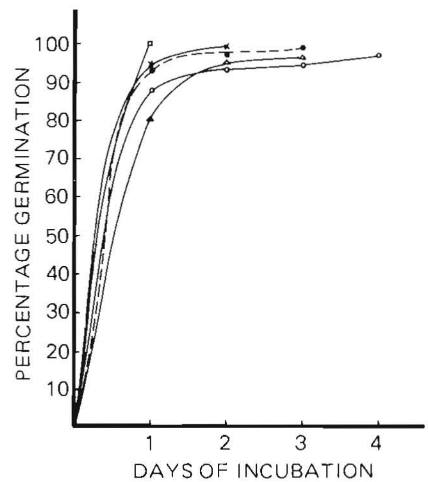

Fig. 3. Course of germination of seeds of *Anastatica hierochuntica* at the different fluctuating temperature regimes: 18/8°C x—x; 21/10, 23/13, 26/15, 33/22°C □—□; 29/18°C ●---●; 36/24°C △—△; 40/26°C ○—○.

Table 1. The periods of incubation (days) required by the maximum germinated seeds of *Anastatica hierochuntica*, at constant temperature range 5-40°C to attain 50% germination. Ninety-five percent confidence limits are included.

5°C	10°C	15°C	20°C
1.150 ± 0.080	0.675 ± 0.207	0.538 ± 0.103	0.575 ± 0.119
25°C	30°C	35°C	40°C
0.638 ± 0.260	0.850 ± 0.287	1.575 ± 0.766	1.200 ± 0.337

Table 2. The final germination percentages attained by seeds of *Anastatica hierochuntica* germinated at different fluctuating temperatures and also the periods of incubation (days) needed by the maximum germinated seeds to attain 50% germination. Ninety-five percent confidence limits are included.

18/8°C		21/10°C		23/13°C		26/15°C	
% Germination	Time for 50% Germination	% Germination	Time for 50% Germination	% Germination	Time for 50% Germination	% Germination	Time for 50% Germination
99 ±2.756	0.463 ± 0.034	100	0.450 ± 0.000	100	0.450 ± 0.000	100	0.450 ± 0.000
29/18°C		**33/22°C**		**36/24°C**		**40/26°C**	
% Germination	Time for 50% Germination	% Germination	Time for 50% Germination	% Germination	Time for 50% Germination	% Germination	Time for 50% Germination
99 ± 2.756	0.455 ± 0.079	100	0.438 ± 0.000	96 ± 4.500	0.436 ± 0.071	96 ± 0.000	0.438 ± 0.271

Experiment 2

Procedure

In annual plants such as *A. hierochuntica* it is on successful seed production, germination and subsequent establishment that the continued survival of the species depends completely. If all seeds produced annually by *A. hierochuntica* germinated promptly (Experiment 1), due to the hazardous environment of the desert, its continued survival would be uncertain. In this experiment, an attempt was made to examine the mechanism which restricts ill-timed and biologically undesirable wasteful germination. The fruiting plants are indurated being woody with branches incurved to form globular structures (Plate 1) and carry the persistent woody pods. The dry pods were detached from the plants and subjected to the following treatments:

(a) The pods were placed in petri dishes and flooded with distilled water (pods fully immersed) which was changed daily at 2 p.m.;

(b) Similar pods were placed in petri dishes and distilled water was added to immerse the bottom-half of the pod.

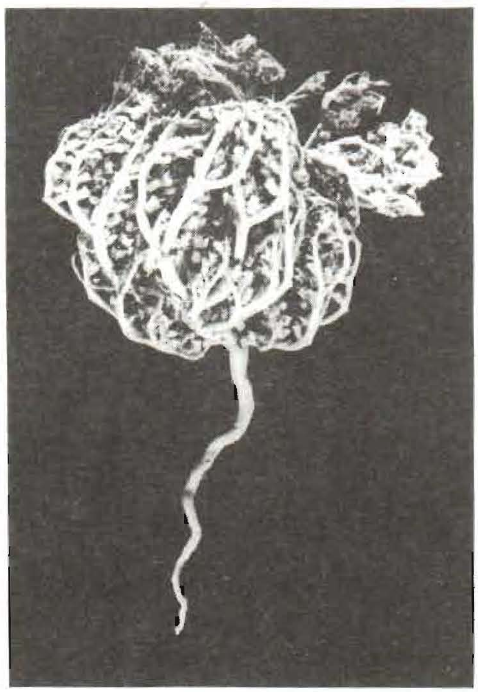

Plate 1. An indurated fruiting plant of *Anastatica hierochuntica* with its woody branches incurved to form a globular structure.

Four replicates (25 pods each) were used. The plant material was incubated in the dark at an alternating (12 hourly) temperature regime of 18/8°C. The seeds which germinated (when the radicle emerged when the pods dehisced) were discarded immediately and a seed count was made daily over 35 days from the start of the experiment. A similar experiment was set up but the pods were incubated at 25/15°C.

Results

The data in Table 3 include the final germination and the periods (days) needed by seeds to attain 50 percent germination (based on the maximum number of seeds germinating). Figure 4 shows the course of germination. Subjecting the pods to different watering regimes caused dehiscence of the pods and subsequent exposure of the seeds which absorbed water and germinated. The seeds from the completely immersed pods germinated faster and to higher percentages than those partly immersed (Fig. 4, Table 3); on the other hand, the germination was better in both immersion regimes at 25/15°C than at 18/8°C.

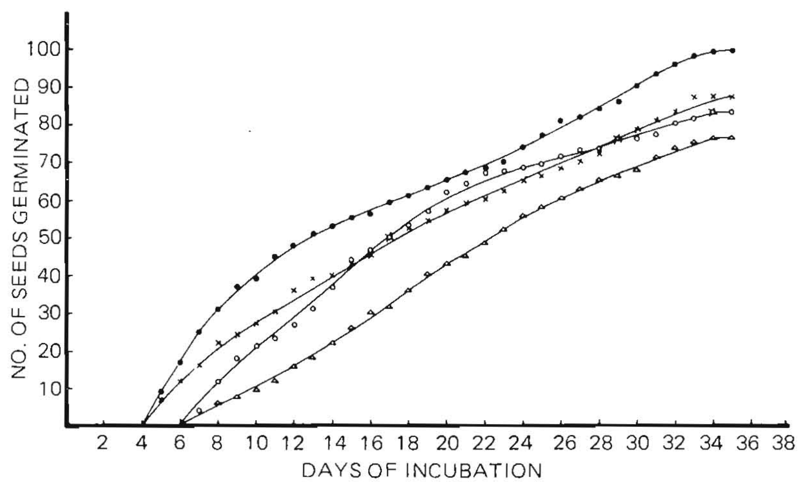

Fig. 4. Course of germination of the seeds obtained from fruits of *Anastatica hierochuntica* incubated at an alternating (12 hourly) temperature of 25/15°C and which were fully immersed ●—● and partially immersed x—x in distilled water, and of those incubated at 18/8°C and fully immersed O—O and partially immersed △—△.

Table 3. The final germination of seeds obtained from fruits of *Anastatica hierochuntica* which were fully immersed and those partially (half) immersed in distilled water, incubated at two fluctuating temperature regimes. Ninety-five percent confidence limits are included.

Temperature (°C) of incubator	Fruits fully Immersed in distilled water		Fruits half Immersed in distilled water	
	Number of seeds germinated	Time for 50% germination	Number of seeds germinated	Time for 50% germination
18/8	83 ± 3.375	14.900 ± 1.158	76 ± 2.104	18.600 ± 0.636
25/15	99 ± 0.222	12.450 ± 0.428	87 ± 4.773	15 ± 1.475

Experiment 3

Procedure

Dry matched fruiting plants of *A. hierochuntica* which were set in equal volumes of clay soil contained in drained 20.3 cm diameter plastic pots were subjected to the following watering regimes. (Four replicates were used for each treatment).

a) Flooding once daily with distilled water;

b) Flooding once weekly with distilled water;

c) Spraying the plants once daily with distilled water; which maintained the soil at field capacity and kept its surface wet;

d) Watering the soil once daily to its field capacity with distilled water which was not sprayed directly on the plants, but was found to wet the lower parts of the incurved branches.

The experiment was conducted in a controlled environment cabinet. Light intensity over a 12 hr day was 17000 lux (47.5 Wm^{-2} visible). Relative humidity was always kept above 70 per cent. The temperature alternated between 25 and 15°C. Seedlings produced were counted daily over 27 days.

Results

Figure 5 shows the course of seedlings development. Table 4 includes the final number of seedlings and the periods (days) for 50% seedling development. The highest number of seedlings was obtained from plants flooded daily, followed by that of plants sprayed daily until soil was maintained at field capacity. Flooding the plants once a week produced a remarkably small number of seedlings.

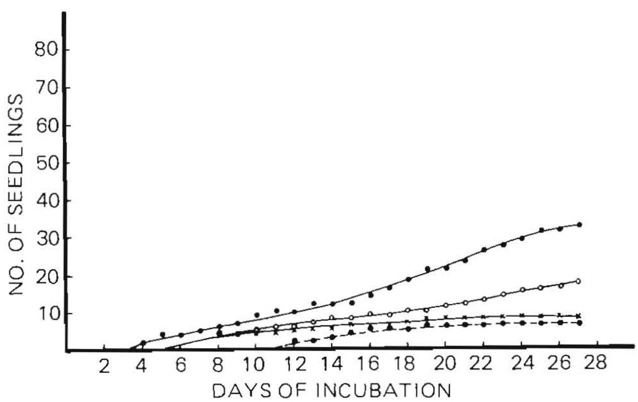

Fig. 5. Numbers of seedlings developed from seeds obtained from dry fruiting plants of *Anastatica hierochuntica* subjected to different watering regimes in a growth cabinet maintained at 25/15°C. ●—● flooding once daily with distilled water; ●---● flooding once weekly; O—O spraying the plant once daily maintaining the soil at field capacity; x—x watering the soil once daily to field capacity, the plants were not sprayed, but lower branches wetted.

Table 4. Numbers of seedlings obtained from matched dry fruiting plants of *Anastatica hierochuntica* subjected to different watering regimes, in a growth room at 25/15°C. Ninety-five percent confidence limits are included.

Watering regime	Number of seedlings	Time for 50% seedling development
Fruiting plant flooded daily with distilled water	32 ± 5.454	16 ± 2.099
Fruiting plant flooded weekly	6 ± 1.949	14 ± 1.258
Fruiting plant sprayed daily with distilled water until soil was at field capacity	17 ± 4.125	14 ± 2.179
Soil watered to field capacity daily (lower parts of branches wetted)	8 ± 1.125	8.250 ± 0.398

Experiment 4

Procedure

Experiment 3 was supplemented by an outdoor experiment in which four matched dry fruiting plants were planted in line at varying elevations descending from the side of a depression (plate 2) in the desert near the University staff residence 15 km from Riyadh. The experiment was run from the beginning of March to the end of April 1983. During this period there were four heavy showers which drained into the depression.

Results

The number of seedlings produced by each plant was proportional to the moisture available within the microhabitat; the plant at the lowest elevation and which was flooded (No. 1 Plate 2) expanded its hygroscopic branches and produced the highest number of seedlings (36), and the one next to it, but at a slightly higher elevation (No. 2 Plate 2) produced considerably fewer seedlings (5). However, the two plants at the highest elevation (successively No. 3 and 4 Plate 2) remained with their incurved branches forming a globular structure and did not produce seedlings. The seedlings eventually developed to the flowering stage and produced fruits.

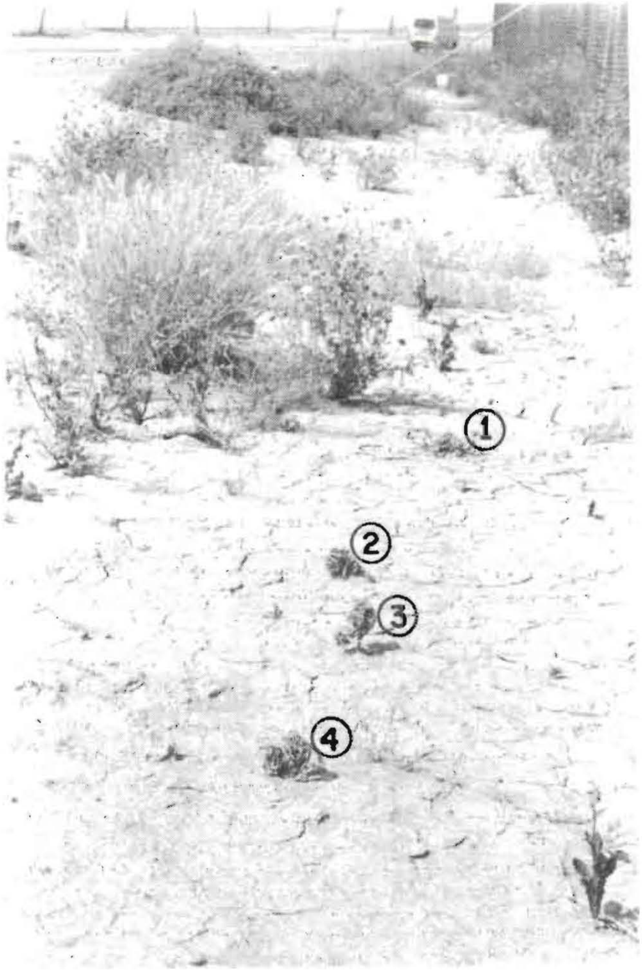

Plate 2. Four (1-4) dry fruiting specimens of *Anastatica hierochuntica* planted in line at varying elevations descending from the side of a depression in the desert, 15 km from Riyadh.

Experiment 5

Procedure

The seeds of *A. hierochuntica* were germinated over the following range of salt concentrations obtained by diluting Red Sea Water: 2305.5 ppm (= 5 percent seawater), 4611 (= 10 percent), 9222.5 (= 20 percent), 18445 (= 40 percent), 36890 (= 80 percent), and 46112 (= 100 percent). Germination took place in germination flasks in a dark incubator maintained at alternating (12 hourly) temperature regimes: 18/8°C and 33/22°C. The selection of these temperature regimes was based on the germination temperature responses of the seeds in distilled water, the two regimes representing the upper and the lower limits of the optimal temperature range for germination. The procedure then adopted was similar to that in Experiment 1.

Results

The graphs in Fig. 6 show the course of germination of the seeds of *A. hierochuntica* in the various salinities and temperature regimes. Table 5 shows the final germination percentages and the periods (days) of incubation needed for 50 percent germination.

At 18/8°C, the seeds in 5, 10 and 20 percent seawater and in distilled water germinated rapidly to high germination percentages (> 90 percent), though the speed of germination decreased with increased salinity [Table 5 and Fig. 6(a)]. However, increasing the temperature to 33/22°C strikingly decreased the salt tolerance of the seeds and their speed of germination [Table 5, Fig. 6(b)].

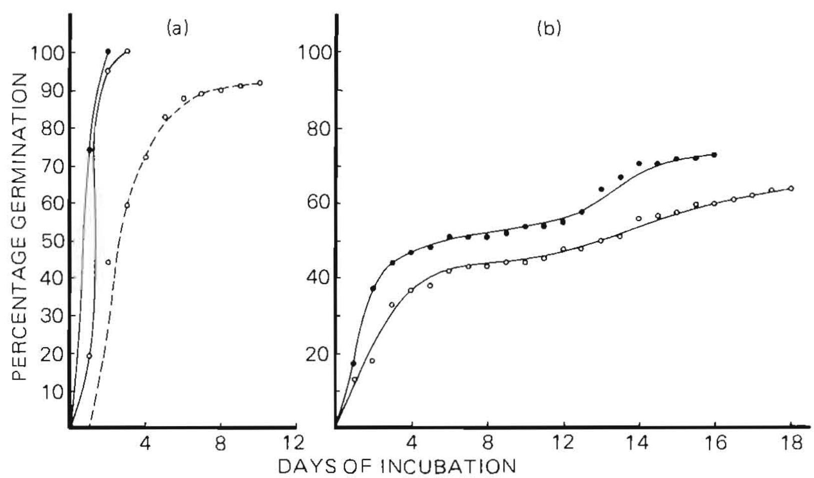

Fig. 6. Progress of germination of seeds of *Anastatica hierochuntica* at different salinities: ●—● 2305.5 ppm (5% seawater); O—O 4611 (10%); O---O 9222.5 (20%), all incubated at two fluctuating temperature regimes: 18/8°C (a) and 33/22°C (b).

Table 5. The final germination percentages attained by seeds of *Anastatica hierochuntica* at two fluctuating temperature regimes in different salinities; the periods (days) of incubation required by the maximum germinated seeds to reach the 50% level as well as the 95% confidence limits are also included.

	Distilled water		2305.5 ppm (5% seawater)	
Temperature (°C)	**% germination**	**Time for 50% germination**	**% germination**	**Time for 50% germination**
18/8	99 ± 2.756	0.463 ± 0.034	100	0.596 ± 0.025
33/22	100	0.450 ± 0.000	73 ± 8.267	2.200 ± 0.225
	4511 ppm (10%)		**9225.5 ppm (20%)**	
Temperature (°C)	**% germination**	**Time for 50% germination**	**% germination**	**Time for 50% germination**
18/8	100	1.325 ± 0.261	92 ± 7.794	2.275 ± 0.638
33/22	65 ± 5.278	3.000 ± 0.574	No germination	

Experiment 6

Procedure

The seeds of *A. hierochuntica* which did not germinate in high salinities (40, 80 and 100 percent seawater at 18/8°C and in 20, 40, 80 and 100 percent seawater at 33/22°C) for 15 days were thoroughly washed with distilled water and then germinated at the same temperatures in distilled water. The procedure then adopted was similar to that in Experiment 1.

Results

Figure 7 shows the course of germination and Table 6 includes the final germination percentages as well as the periods (days) required to reach the 50 percent germination level. At 18/8°C, the seeds which did not germinate in 40 percent seawater germinated rapidly to completion after transfer to distilled water, but the germination capacity of those seeds preincubated in 80 and 100 percent seawater was not fully restored. At 33/22°C, full germination was obtained in seeds transferred from 20 percent seawater to distilled water, while, at the same temperature, the transfer of the seeds into distilled water, which did not germinate, in 40, 80 and 100 percent seawater, increased germination only a little in the first two salinities and there was no germination at all of seeds previously in 100 percent seawater [Table 6 and Fig. 7(b)].

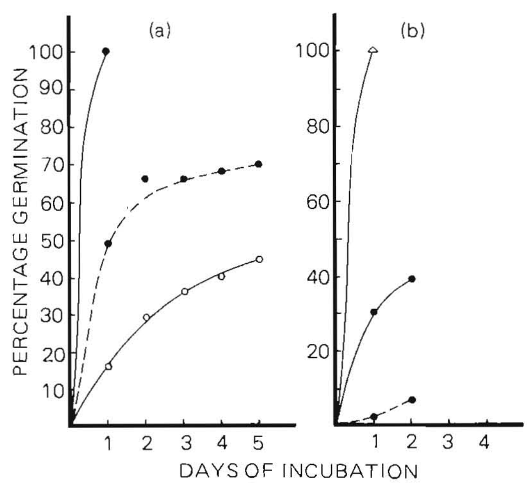

Fig. 7. Course of germination of seeds of *Anastatica hierochuntica* which were preincubated for 15 days and did not germinate at (a) 18/8°C in 18445 ppm (40% seawater) ●—●; 36890 (80%) ●---● and 46112 (100%) ○—○, and at (b) 33/22°C in 9222.5 ppm (20%) △—△; 18445 ppm, 36890 ppm and 46112 ppm and then germinated at the same temperatures in distilled water after they were thoroughly washed free from salt by distilled water.

Table 6. The final germination percentages of the seeds of *Anastatica hierochuntica* which did not germinate when preincubated for 15 days at 18/8 and 33/22°C in different salinity levels and then germinated at the same temperatures in distilled water after being washed free from salt by distilled water. The periods in (days) required by maximum germinated seeds to reach the 50% level as well as the 95% confidence limits are also included.

	9222.5 ppm (20% seawater) then in distilled water		**18445 ppm (40% seawater) then in distilled water**	
Temperature (°C)	**% germination**	**Time for 50% germination**	**% germination**	**Time for 50% germination**
18/8	No treatment		100	0.450 ± 0.000
33/22	100	0.450 ± 0.000	39 ± 5.276	0.550 ± 0.178

	36890 ppm (80% seawater) then in distilled water		**46112 ppm (100% seawater) then in distilled water**	
Temperature (°C)	**% germination**	**Time for 50% germination**	**% germination**	**Time for 50% germination**
18/8	70 ± 16.534	0.675 ± 0.105	45 ± 11.582	1.700 ± 0.574
33/22	7 ± 5.276	0.900 ± 0.159	No germination	

Discussion

In annual plants, as in the case of *A. hierochuntica*, it is on successful seed production, germination and subsequent establishment that the continued survival of the species depends completely. The seed or fruit offers the only means of "carrying over" the species from one season to another. And in the adverse and unreliable desert environment it is these very points in the life-cycle that determine the degree of success of the species and establish which plants will eventually die out and disappear. Perpetuation and expansion of annual species in the desert environment relies upon a regular supply of viable seeds, efficient and effective means of dispersal, germination characteristics relevant to the seasonality of the habitat in which the species is growing and effective means of establishment' (Cloudsley-Thompson and Chadwick 1964). Because of the unreliable (unpredictable) nature of the desert rain, the rainfall which is adequate to induce germination may be followed by a period of drought in which soil moisture becomes inadequate for completion of the life-cycle of a desert annual (Tevis 1958a, b, Beatley 1967). "Thus, if a species germinates too readily in response to a shower, it may risk local extinction. It seems then, that long-term survival in desert annual species might be ensured by allowing only a proportion of the seeds to germinate in each season with the rest remaining as a viable reserve" (Freas and Kemp 1983). These authors reached this conclusion after consulting the probability models (Cohen 1966, 1968, Levins 1969) "which predict that the evolutionary response to increasing environmental uncertainty would be an increased innate seed dormancy with only a part of the seed population available to germinate each year". However, as reported by Freas and Kemp (1983), other models developed for desert annuals which predict that seed dispersal (MacArthur 1972, Venable and Lawlor 1980) or the ability of the seeds to germinate in response to those environmental signals which indicate the potentials for favourable environment (Cohen 1967, Venable and Lawlor 1980, Mahmoud *et al.* 1983a, b), would negate the necessity for innate dormancy.

The liberated freshly harvested seeds of *A. hierochuntica* do not appear to have a genetically fixed mechanism of innate dormancy, and were found to germinate rapidly to near completion over constant temperatures between the range 5-40°C (Fig. 2 and Table 1) and also over the whole range of alternating temperature regimes (Fig. 3 and Table 2) which represent the temperature cycles that prevail naturally during the rainy and dry season (Fig. 8). This implies that moisture is the overriding environmental factor for its germination. If the seeds germinate too readily in response to a shower or to an occasional rainstorm at the beginning of the dry season, the species may risk local extinction. Therefore, in the absence of a mechanism in the seeds of *A. hierochuntica*, which allows germination to take place only when ecological conditions are such that successful germination and establishment are more likely to occur, the very survival of this desert annual is at stake. The present authors fully agree with Koller (1955), that "if all the seeds produced annually by the desert evading species germinated promptly, not only would considerable wastage of resources take place, but also, owing to the vagaries of the desert environment, continued survival would be by no means certain." However, in *A. hierochuntica,* reductions in this waste are achieved by mechanisms which are not related directly to the germination characteristics of the seeds, that are relevant to the favourable season for successful establishment. The fruiting plant is indurated being woody with branches incurved to form a globular structure (Plate 1), thus raising the persistent woody pods above the soil surface; the hygroscopic dry woody branches will expand when they are sufficiently moistened with rain water during the rainy season, thus bringing the branches and fruits onto or near to the moist soil surface (Experiments 3 and 4). When the water supply is cut off, the branches become incurved and assume a globular structure. The pods will dehisce (Fig. 9) and expose and/or liberate the non-dormant seeds, which will then germinate, only when they are sufficiently moistened for a long time.

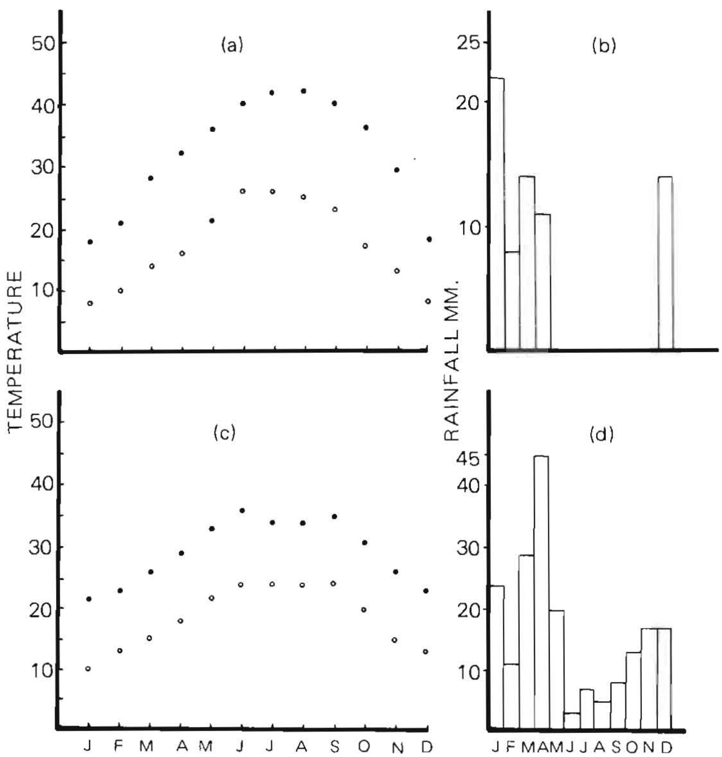

Fig. 8. Meteorological data obtained at Khurais station (a & b) 150 km from Riyadh and at Al Sayl al Kabır (c & d) in south Hijaz, within the habitat range of *Anastatica hierochuntica*; (**a**) and (**c**) represent the mean daily temperature maxima and minima; (**b**) and (**d**) represent monthly rainfall. (Data are averages for 1969-79).

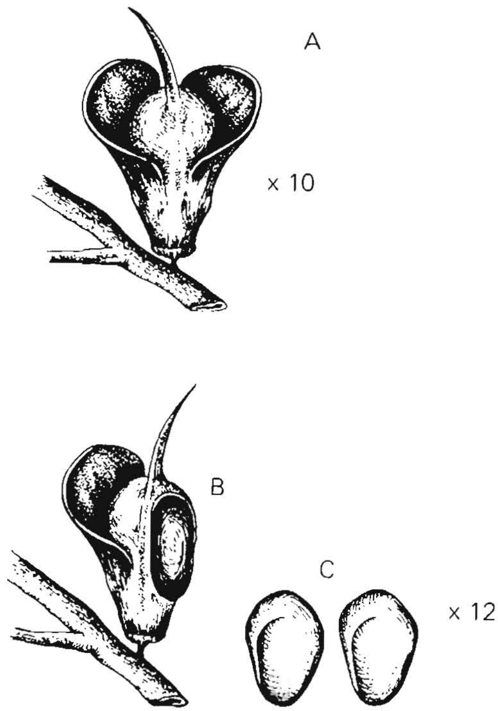

Fig. 9. (**A**) A dry woody pod of *Anastatica hierochuntica* which did not dehisce. Observe the persistent style. ×10.
(**B**) Partially dehisced 2-celled pod; note the two liberated seeds (**C**). X12.

In Experiment 2, the dehiscence of the pods, and hence the subsequent seed germination, progressed with their time of exposure to moisture (Fig. 4), and the pods which were completely immersed dehisced faster than those which were partially (half) immersed. Dehiscence was faster when the pods were incubated at 25/10°C than at 18/8°C.

The data from Experiments 3 and 4 indicate that the number of seedlings produced, which resulted from dehisced pods, was proportional to the amount of the available moisture and its duration. The plants which were flooded once daily with distilled water produced the highest numbers of seedlings (Experiment 3, Fig. 5); the next highest numbers were from plants sprayed once daily until the soil was maintained at field capacity. Plants flooded once weekly produced a considerably smaller number of seedlings (Fig. 5). In the outdoor experiment (Experiment 4) the fruiting plant (No. 1 Plate 2) at the lowest elevation in the depression which was flooded by rain water produced the highest number of seedlings (36). The plant next to it (No. 2 Plate 2) at a slightly higher elevation produced, in comparison, only 5 seedlings. The other two plants (No. 3 and 4, Plate 2) which occupied successively the highest elevations produced no seedlings, and maintained their globular structure.

Since the fruit dehiscence and subsequent seed germination take place after prolonged wetting during the rainy season, the dry fruits of *A. hierochuntica* tie the seed germination to the time when abundant water is available and restricts the distribution of the species to the habitats which normally receive abundant water so that successful subsequent seedling establishment is possible. The present authors observed that only after a season of heavy rains does any substantial seed germination take place in the field. Also within its natural range, *A. hierochuntica* is associated with habitats which collect runoff: water runnels of different order and depressions, whose water resources are thus greater than the actual local rainfall. Plate 3 shows a rich growth of *A. hierochuntica*, in a depression within Riyadh district; this growth resulted from a substantial seed germination during the good rainy season of 1983.

Thus, this control of germination by hydration is effected by indehiscence of the fruit when it is dry, which seems to act in a similar manner to the impermeable seed-coat in many desert plants (Koller 1962 and 1969, Mahmoud 1977, Mahmoud and El-Sheikh 1978) and the water-soluble germination inhibitors in the fruits and seeds of several desert plants (El-Naggar 1965), in constituting a 'built-in' rain gauge. Germination takes place only when sufficient rain has fallen or runoff water collected in the habitat to make the fruits soft enough to dehisce, so germination is restricted to times when conditions are favourable for successful establishment.

The production by *A. hierochuntica* of the woody pods which dehisce after hydration can be considered to be a 'random' strategy well adapted to areas of irregular rain-fall because, in the natural habitat of the species, the complete dehiscence of all the fruits carried by each individual, affected by high humidity and temperature and probably by increased activity of soil micro-organisms, may take from a few months to several years (flooding plants daily for 27 days did not cause the dehiscence of all their fruits (Experiment 3), and the same was true for the plants flooded in the lowest part of the depression, in the outdoor Experiment (4). Consequently, seeds from one single generation are released and so germinate over a long period of time and it is likely that a few plants will establish successfully. This scattered germination will thus ensure the distribution in time of viable easily germinable propagules; the dehiscence mechanism results in some seeds effectively remaining dormant to provide propagules for subsequent attempts at seedling establishment. One well-established characteristic of desert plants is their long-range scatter of germination in time which increases their chance of survival under conditions which are extremely variable from year to year (Koller 1969). The "long-term survival in a desert annual species might be ensured by allowing only a proportion of the seeds to germinate in each season with the rest maintained as a viable reserve" (Freas and Kemp 1983).

Since the fruiting plants of *A. hierochuntica* are indurated and fruits are persis-

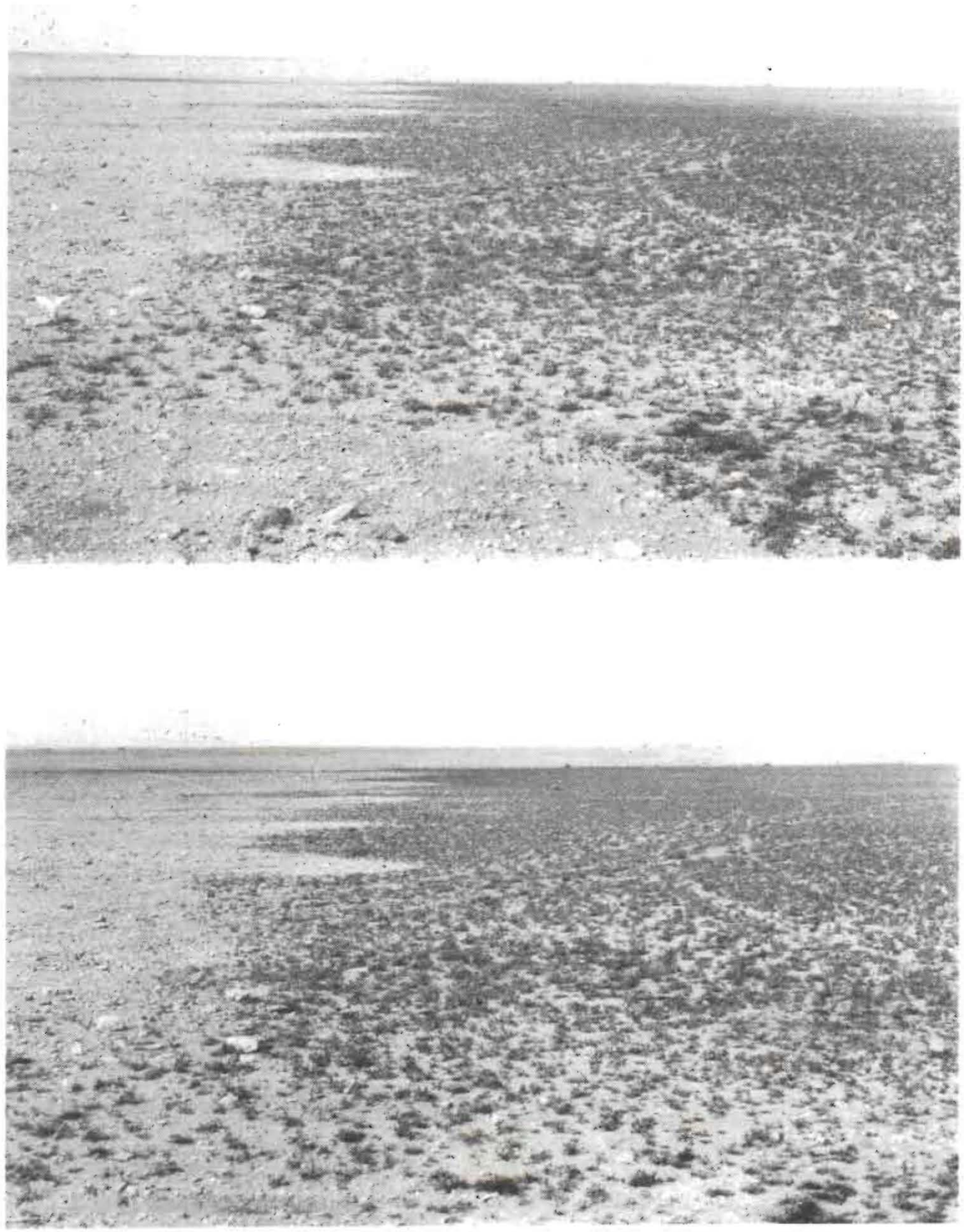

Plate 3. Rich growth of *Anastatica hierochuntica* in a depression, within Riyadh district, which resulted from a substantial seed germination during the good rainy season of 1983.

tent, and since seed dissimination is delayed until adequate moisture is available during the rainy season, the seeds have little chance of being transported long distances and remain near the parent plant; the seedlings which result from germinated seeds are very close to the parent (Fig. 10 and Plate 4). In actual fact, seedlings may sprout from seeds which did not detach from the dehisced fruits that are still attached to the parent plant (Fig. 10). These seedlings are likely to encounter much the same habitat conditions as those that allowed the parent plant to flourish and set seeds; these habitats of proven favourability are more likely to provide a suitable environment in succeeding years. The challenge of the adverse desert environment, as noted by Cloudsley-Thompson and Chadwick (1964) is met by a conservative "policy" of safety first rather than an adventurous opportunism. However, occasionally, the whole plant comes loose from the ground and is capable of being blown along the surface carrying its disseminules with it. These will allow the species to "sample" other environments and act as colonizers. Still germination will be tied to the rainy season and to habitats which collect runoff.

The wide amplitude of *A. hierochuntica* with regard to its germination temperature responses, coupled with the synchronization of the event of germination with the season of optimal environmental conditions for subsequent growth and establishment, contribute to the success and wide distribution of the species in Saudi Arabia.

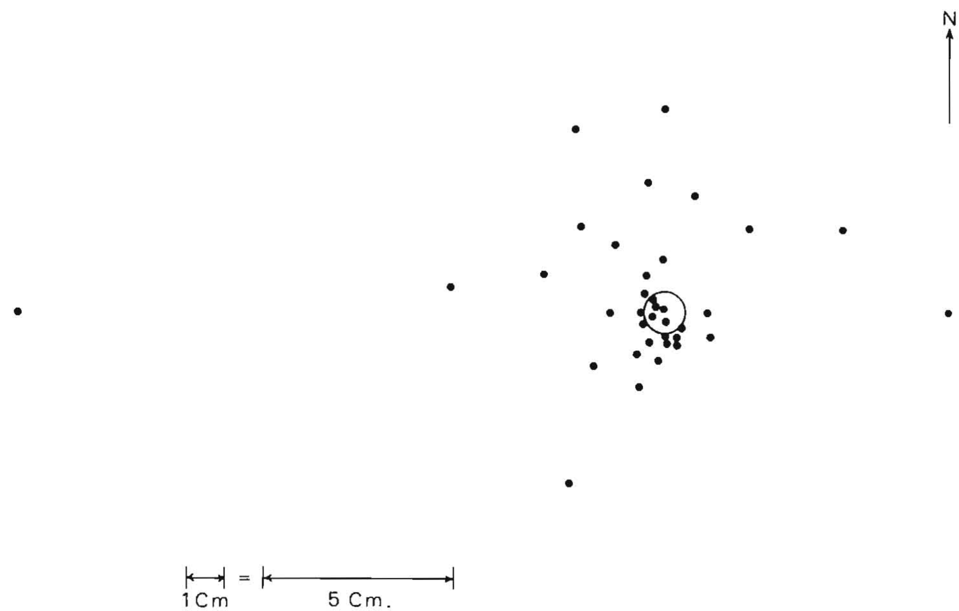

Fig. 10. Distribution of seedlings produced by a fruiting individual of *Anastatica hierochuntica* (circle) planted in the lowest part from the side of a depression (Experiment 4). Filled circles inside the large circle (representing the parent plant) indicate seedlings sprouting from seeds which did not scatter from the dehisced pods, attached to the parent.

Plate 4. Growth of plants of *Anastatica hierochuntica* around the parent plant in a depression during the good rainy season of 1983 (Plate 3).

The rapid germination of the seeds of *A. hierochuntica* (Experiment 2) when conditions of the environment are favourable and the ability of the species to grow quickly to complete its life cycle within a short time (Experiment 4), contribute to the long-term survival of this desert annual.

The salt tolerance of *A. hierochuntica* is affected by temperature. At 18/8°C, temperature cycles similar to the air temperatures during the rainy season, [Fig. 8a and b; (18°C = mean maximum, 8°C = mean minimum)], the seeds in 5, 10 and 20 percent seawater (and in distilled water) germinated rapidly to high percentages (> 90 percent), though the speed of germination decreased with increased salinity [Table 5, Fig. 6(a)]. However, increasing the temperature to 33/22°C, the temperature cycle of the dry reason (Fig. 8, c and d) decreased strikingly the salinity tolerance of the seeds as well as their speed of germination, extending germination over a long period [Table 5, Fig. 6(b)]. Interaction between temperature and salinity has been well documented (Uhvits 1946, Hayward and Bernstein 1958, Boorman 1968, Mahmoud *et al.* 1983c).

When moisture and temperature conditions are favourable the seeds of *A. hierochuntica* are capable of germination in salinities greater than those encountered and tolerated by the adult plants in their natural habitat [Table 5, Fig. 6(a), (b), Table 7]. The data in Table 7 show the total water soluble salts in soil samples collected during the dry season (May 1983) from the natural habitat of the species within the Makkah-Jeddah and Riyadh regions. Successful germination of the seeds may occur in their natural habitat with the advent of winter rains even without earlier leaching of the soil.

Table 7. Total water soluble salts in soil samples collected within the habitat range of *Anastatica hierochuntica.*

Habitat	Profile no.	Depth (cm)	Total water soluble salts (ppm)
Channel of a narrow water runnel along	1	0-5	3200
Rabigh Jeddah road		5-25	3136
Depression along Jeddah Makkah road	2	0-5	5566
		5-25	3136
	3	0-5	3520
		5-25	3200
Depressions within Riyadh district	4	0-5	3840
		5-25	2880
	5	0-5	3648
		5-25	3584

A salty habitat can inhibit germination in two ways: (a) by poisoning the embryo due to toxic effects of certain ions (Uhvits 1946) or (b) by preventing uptake of water due to high osmotic potential of the medium (Ayers and Hayward 1948, Ayers 1952, Ungar 1962, Boorman 1968, Macke and Ungar 1971, Mahmoud *et al.* 1983c). Inhibition of germination by excessive salinities shown in Experiment 6 may be due to either osmotic or toxic ionic effects. At 18/8°C and 33/22°C, the seeds transferred respectively from 40 and 20 percent seawater to distilled water germinated rapidly to completion (Table 6 and Fig. 7); here the inhibition was probably due to osmotic effects. At 18/8°C, the ability of the seeds pretreated in 80 and 100 percent seawater to germinate when transferred to distilled water decreased with increased salinity, while at the higher temperature regime (33/22°C) the germination of seeds pretreated in 40, 80 and 100 percent seawater when so transferred was very low in the first two salinity levels and there was no germination at all of seeds subjected to the highest salinity treatment. The inhibition here may be due to toxic ionic effects. However, irreversible damage may also be caused in seeds even by pure osmotic stress of the medium. "This is supported by the fact that transfer of caryopses of *Aeluropus litoralis* into distilled water, which did not germinate in mannitol solution, raised germination percentages only slightly, if at all " (Waisel 1972).

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إنبات بذور نبات كف مريم من المملكة العربية السعودية

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نبات كف مريم من النباتات الحولية واسعة الانتشار فى المملكة العربية السعودية، ويقترن نموه بأماكن تجمع مياه الأمطار. لاتتمتع بذوره بظاهرة الكمون التى تنظم عملية الإنبات فى الصحراء، ولكن بيَّنت التجارب المختبرية وتلك التى أجريت فى الحقل أن تنظيم عملية الإنبات يتم عن طريق حاجة الثمار الجافة الصلدة المرتبطه بالنبات الجاف، للترطيب بماء الأمطار ولفترة طويلة قبل أن تنفتح وتحرر البذور التى تتشرب الماء وتنبت. وبذلك لا تتم عملية الإنبات إلا فى المكان والزمان المناسبين لتوفير أفضل الظروف البيئية التى تمكن البوادر المنبثقة من البذور من أن تكمل دورة حياتها بمشيئة الله.

إن قدرة البذور على الإنبات على مدى حرارى واسع بالإضافة إلى تنظيم عملية الإنبات تحت الظروف البيئية الملائمة كلها تساعد على توسيع رقعة انتشار نبات كف مريم فى المملكة العربية السعودية.

تعتمد قدرة تحمل بذور نبات كف مريم للملوحة على درجـة الحرارة، وحينما تتوفر الرطوبة ودرجة الحرارة المناسبة تستطيع بذور هذا النبات الانبات عند درجة ملوحة تفوق كثيرا تلك التى تتحملها النباتات فى بيئاتها الطبيعية.