# Germination of *Francoeuria crispa* (Compositae) from Saudi Arabia

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ABSTRACT. *Francoeuria crispa* is a perennial bushy desert plant. Its distribution in Saudi Arabia includes the Northern, Eastern, and Nefud regions, North Hijaz, South Hijaz and Eastern Najd.

The freshly harvested seeds were germinated over a range of alternating temperatures (18/8, 21/10, 28/14, 32/16, 36/21, and 42/26°C) and also at varying salinity levels (2305.5, 4611, 9222.5, 18445, 27667 and 46112 ppm = 5, 10, 20, 40, 60 and 100 per cent seawater, respectively) at two fluctuating temperature regimes: 21/10 and 28/14°C.

The germination temperature responses of the nondormant seeds synchronize the event of germination with the season when environmental conditions are more favourable for subsequent growth and seedlings establishment.

At 21/10°C the seeds tolerated fairly high salinity levels which are far beyond those encountered and tolerated by the adult plants in their natural habitat. Increasing the incubation temperature to 28/14°C reduced drastically the salt tolerance of the seeds.

The inhibition of germination by excessive salinities (40, 60, and 100 per cent seawater) is due to the high osmotic potential of the medium.

The ecological significance of the responses of the seeds to the various environmental variables is discussed.

*Francoeuria crispa* (Forssk.) Cass. (= *Pulicaria crispa* (Forssk.) Benth. et Hook. F.) is a perennial bushy desert plant, cushion-shaped, 40-50 cm high. According to Migahid (1978), its geographical distribution in Saudi Arabia (Fig. 1) includes the Northern region (N), Nefud region (NF), North Hijaz (NH), Eastern Najd (NJE), Eastern region (E) and South Hijaz (SH).
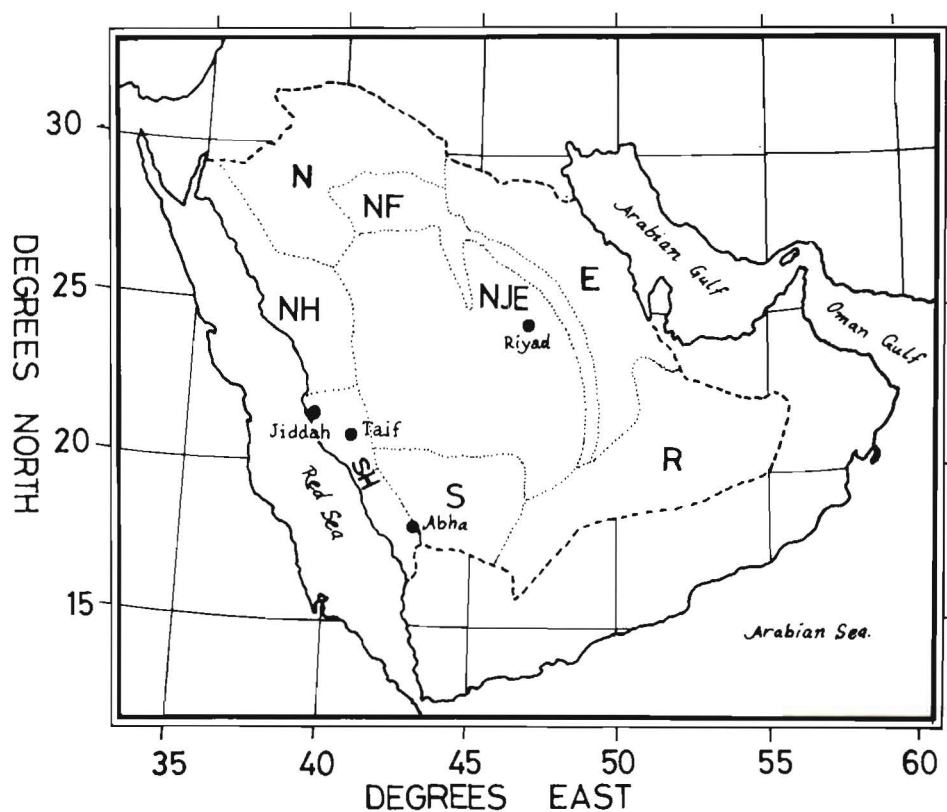
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**Fig. 1.** Geographical distribution of *Francoeuria crispa* in Saudi Arabia.

    N    =   Northern region including Tabouk, Al-Jawf and the region of Skakah.

    S    =   Southern region lying to the east of South Hijaz to the south of Najd and the north of Yemen. It includes the Abha and Bisha and Najran area.

    NH  =   North Hijaz, representing the western parts of Saudi Arabia that extend alongside the Red Sea coast north of Jeddah.

    SH  =   South Hijaz, representing the southern part of the western region extending south of Jeddah to the Yemen boundary.

    E    =   Eastern region, between Dahna and the Arabian Gulf.

    R    =   Al-Rub' Al-Khali representing most of the southern and south eastern part of Saudi Arabia. (Redrawn with permission from Migahid's *Flora of Saudi Arabia*, 2nd ed. 1978).

The mechanisms which regulate germination are of great importance amongst the many processes, which constitute the adaptations of plants to their arid environment (Koller 1969, Mahmoud 1977, Mahmoud and El-Sheikh 1978). '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

growth of one Kind or another' (Thompson 1973). Went (1949) showed that the germination temperature requirements of the seeds are very effective in determining the sequence of plant cover and the distribution of plant species spatially. The work described below comprises an attempt to investigate germination temperature responses of the seeds of *F. crispa*. Saline habitats (coastal or inland) are not out of reach of the widely spread, mobile, light wind-born achenes of *F. crispa* which are provided with pappus. In fact, within the most arid part of its range of distribution, *e.g.* outside south Hijaz, the species inhabits depressions and wadis which receive run-off water with its soluble salts. Control of germination by high salinities constitutes a major factor in the 'inhabitation' and zonation of plants in saline habitats (Toole *et al.* 1956, Kassas and Zahran 1967). The seeds of *F. crispa* were germinated in various concentrations of seawater at two fluctuating temperature regimes.

## Experiment (1)

### Methods

Freshly collected seeds of *F. crispa* were germinated on filter paper moistened with distilled water, in germination flasks. Germination took place in dark incubators variously maintained at the following (12 hourly) fluctuating temperature regimes: (18/8, 21/10, 28/14, 32/16, 36/21 and 40/26°C). These temperature regimes were selected from data obtained at Khurais station, 150 Km from Riyadh, within the habitat range of the species. Four replicates (25 seed 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 seeds were ob-

**Table 1.** Showing the final germination percentages attained by the seeds of *Francoeuria crispa* germinated at different fluctuating temperatures, and also the periods of incubation (days) required by the maximum germinated seeds to attain 50% germination; 95% confidence limits are included.

| Temperature °C | Final percentage germination | Time (days) required for 50% germination |
|---|---|---|
| 18- 8 | 82 ± 23.227 | 5.025 ± 0.630 |
| 21-10 | 88 ± 14.230 | 5.100 ± 0.308 |
| 28-14 | 40 ± 4.500 | 10.000 ± 5.924 |
| 32-16 36-21 40-26 | No germination | |

served to germinate over seven successive days. Counting involved removal of the germinator lid which allowed a change of air and briefly exposed the seeds to light.

## Results

Table 1 includes the final germination percentages of the seeds of *F. crispa* noted at the different fluctuating temperature regimes. Also included are the periods of incubation needed by the maximum germinated seeds to attain 50 per cent germination. The graphs in Fig. 2 show the course of germination. The seeds attained equally high germination percentages at equally high rates at the 18/8 and 21/10°C regimes. Increasing the incubation temperature to 28/14°C caused a remarkable decrease in both the final germination percentage and the speed of germination; germination was inhibited at 32/16°C.

## Experiment (2)

## Methods

This experiment was conducted in order to assess the effect of salinity on germination of *F. crispa*. Seeds of the species were germinated over the following range of salt concentrations obtained by diluting Red Sea water, collected from
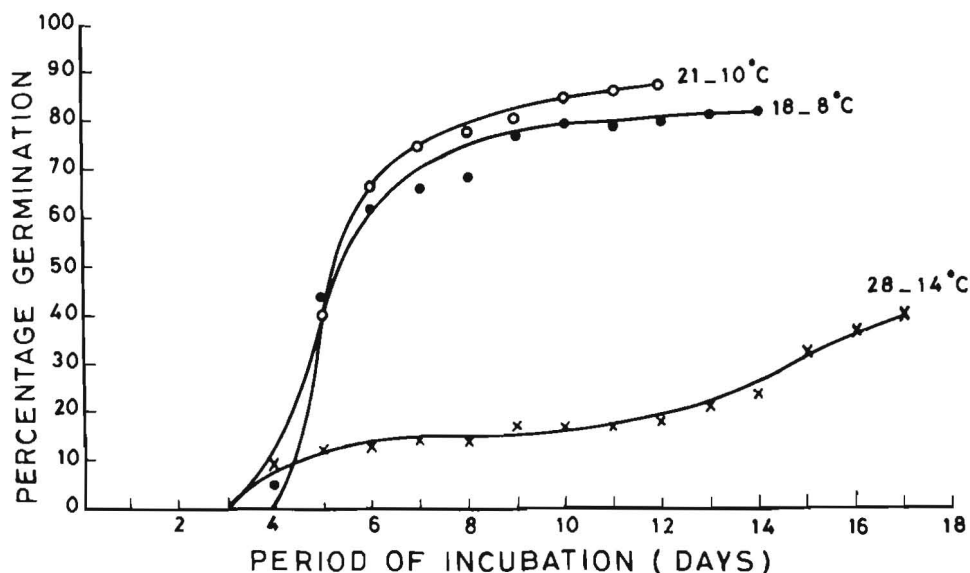


**Fig. 2.** Progress of germination of the seeds of *Francoeuria crispa* at different fluctuating temperatures:
18-8°C ●——●,  21-10°C o——o,  28-14°C x——x

Rabigh. 2305.5 ppm (= 5 per cent), 4611 (10 per cent), 9222.5 (20 per cent), 18445 (40 per cent), 27667 (60 per cent) and 46112 (100 per cent). Germination took place in germination flasks in dark incubators maintained at 21/10 and 28/14°C. Procedure then adopted was similar to that in experiment 1.

## Results

Final germination percentages at the different salt concentrations and fluctuating temperature regimes, and the periods required by the maximum germinated
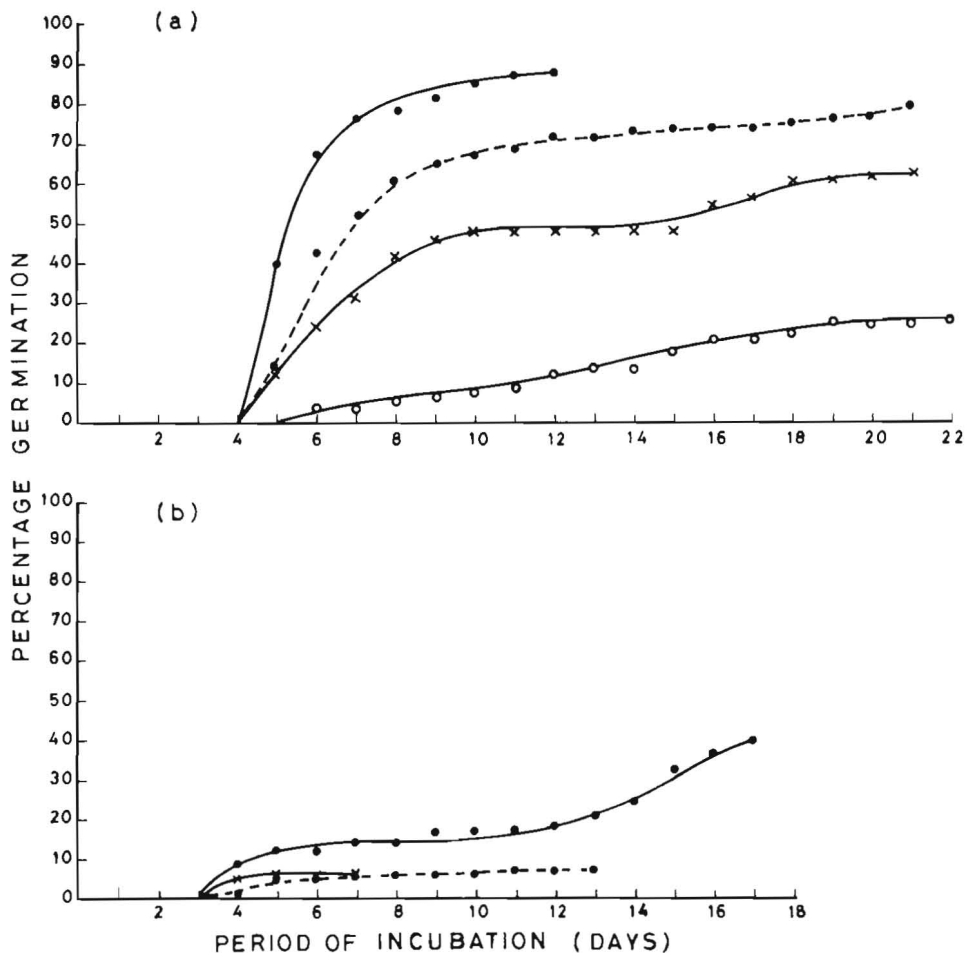


**Fig. 3.** Progress of germination of the seeds of *Francoeuria crispa* at different salinities: 2305.5 ppm ●---●, 4611 ppm x——x, 9222.5 ppm o——o, distilled water ●——●, at two fluctuating temperature regimes (a) 21-10°C and (b) 28-14°C.

**Table 2.** Showing data concerning the final germination percentages attained by the seeds of *Francoeuria crispa* germinated at two fluctuating temperature regimes in different salinities; the periods in days needed by the maximum germinated seeds to attain 50% germination as well as the 95% confidence limits are also included.

| Temperature °C | Distilled water | | 2305 ppm (5%) | | 4611 ppm (10%) | | 9222.5 ppm (20%) | | 18445 ppm (40%) | | 27667 ppm (60%) | | 46112 ppm (100%) | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination |
| 21-10 | 88 ± 4.230 | 5.100 ± 0.308 | 80 ± 15.912 | 5.775 ± 0.101 | 63 ± 16.462 | 6.175 ± 0.983 | 26 ± 3.180 | 12.625 ± 3.150 | No germination | | No germination | | No germination | |
| 28-14 | 40 ± 4.500 | 10.075 ± 5.924 | 7 ± 5.276 | 4.125 ± 3.150 | 6 ± 3.557 | 3.623 ± 0.330 | No germination | | No germination | | No germination | | No germination | |

**Table 3.** Showing data concerning the final germination percentages attained by the seeds of *Francoeuria crispa* which were pre-incubated for 15 days at 21-10°C and 28-14°C in salinity levels (18445, 27661 and 46112 ppm = 40, 60 and 100 per cent seawater, respectively) and then germinated at 21-10°C after they were thoroughly washed from salt with distilled water. The periods in days required by the maximum germinated seeds to reach 50% germination as well as 95% confidence limits are also included.

| Temperature treatment | 40% seawater then in distilled water | | 60% seawater then in distilled water | | 100% seawater then in distilled water | |
|---|---|---|---|---|---|---|
| | % germination | Time for 50% germination | % germination | Time for 50% germination | % germination | Time for 50% germination |
| 21-10°C in salt then at 21-10°C in distilled water | 77 ± 5.276 | 3.600 ± 0.106 | 76 ± 21.107 | 3.000 ± 0.112 | 74 ± 22.274 | 3.300 ± 0.405 |
| 28-14°C in salt then at 21-10°C in distilled water | 94 ± 9.546 | 3.325 ± 0.911 | 79 ± 2.515 | 2.900 ± 0.276 | 81 ± 13.779 | 3.150 ± 0.138 |

seeds to attain 50 per cent germination are shown in 'Table 2'. The graphs in Fig. 3 show the course of germination. Seeds of *F. crispa* incubated at 21/10°C in the two salinity treatments, 5 and 10 per cent and in distilled water, attained equally high germination percentages, which were reached at comparable rates. Increasing the salinity to 20 per cent caused a remarkable decrease in both the germination percentage and the speed of germination; no seeds germinated at 40 per cent salinity (Table 2, Fig. 3a). Increasing the temperature to 28/14°C decreased drastically the salt tolerance of the seeds (Table 2 and Fig. 3).

## Experiment (3)

### Methods

Seeds of *F. crispa* preincubated at 21/10 and 28/14°C in 40, 60 and 100 per cent salt concentrations and which did not germinate for 15 days (Experiment 2) were thoroughly washed with distilled water and then germinated on filter paper moistened with distilled water in germination flasks at 21/10°C. The procedure then adopted was similar to that in Experiment 1.

### Results

Data in Table 3 includes final germination percentages and the periods required by the maximum germinated seeds to attain 50% germination. Fig. 4 shows the course of germination. The seeds pregerminated in the different salinity levels (40, 60 and 100 per cent seawater) at the two temperature regimes (21/10 and 28/14°C), when regerminated in distilled water at 21/10°C, showed comparable final germination percentages which were attained at similar speeds. These percentages were not significantly different from those attained by the seeds which were germinated in distilled water at 21/10°C (Experiment 1), but they were attained at a faster rate (Fig. 4).

### Discussion

Under the harsh desert environment the event of germination marks the transition from the relatively safe state of the dormant embryo within the testa to the metabolically highly active seedling which tends to be highly susceptible to environmental stress. Since survival of the young seedlings of desert plants depends on the hazardous conditions of this environment, represented in temperature extremes, in addition to the uncertainty factor inherent in the pattern of rainfall, it is important for germination of these plants to be controlled by precise perception of the environment. One very common mechanism which regulates germination and contributes to the survival of species under desert conditions, is the presence of water-soluble water-leachable germination inhibitors in the seeds of these plants,
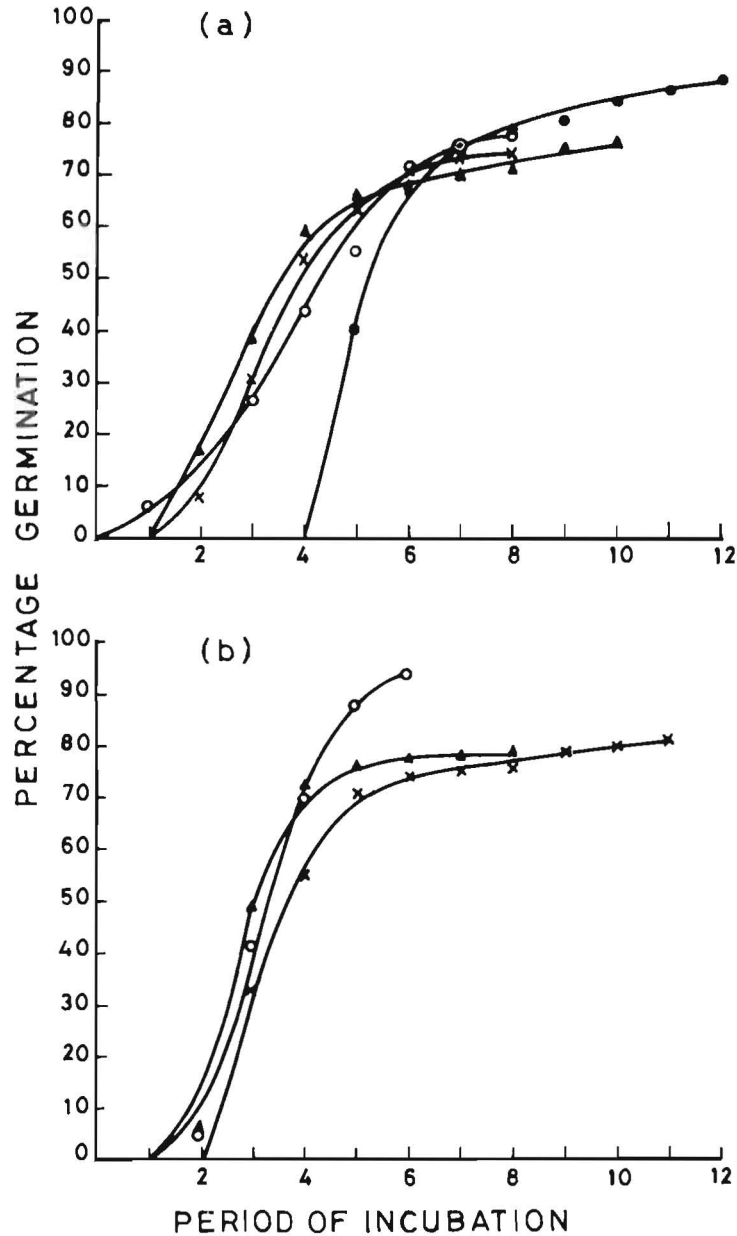
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**Fig. 4.** Course of the germination of the seeds of *Francoeuria crispa* which were preincubated for 15 days at (a) 21-10°C and (b) 28-14°C in the three salinity levels (18445 ppm o——o , 27667 ppm ▲——▲ , 46112 ppm x——x = 40, 60 and 100 per cent seawater) and then germinated at 21-10°C in distilled water after they were thoroughly washed from salt with distilled water.

which need minimal levels of precipitation to leach them out of the seed and its bed (El Naggar 1965, and Koller 1969). Thus, these inhibitors would act under natural conditions as 'built-in raingauges', permitting germination only after sufficient rain has leached them out, and hence increasing the possibilities of subsequent seedlings establishment. Other mechanisms which prevent undesirable, hasty germination, involve seedcoat impermeability to water (Koller 1969, Mahmoud 1977; Mahmoud and El-Sheikh 1978).

Evidence from this work indicates that the germination of the nondormant seeds of *F. crispa* is regulated by the responses of its seeds to the characteristics of the ambient daily temperature cycles of the species habitat; these responses synchronize the event of germination with the season of optimal environmental conditions for subsequent growth and establishment of seedlings. The final germination percentages were high at the 18/8 and 21/10°C regimes, but the final percentage as well as the speed of germination dropped remarkably at the 28/14°C regime (Table 1, Fig. 2). The 18/8°C regime simulates the temperature cycles which prevail, during the months of December and January (18°C = mean maximum, 8°C = mean minimum air temperature) and 21/10, 28/14 and 32/16°C represent respectively those for February, March and April (Fig. 5a). The high germination percentages attained rapidly at 18/8 and 21/10°C indicate that the bulk of the seeds (80-88 per cent) in the natural habitat of the species in Najd, may start to germinate at the beginning of the rainy season in December (Fig. 5b) and that the five months (December to April) of the comparatively cool moist season are utilized for subsequent growth and establishment of seedlings. The prompt germination, as soon as favourable conditions of the environment are available, would appear to be of high survival value for this species under desert conditions, where initial rate of root penetration may be critical allowing it to use water over the longest period of time. A small proportion of the seeds (40 per cent) may germinate in March, as a late attempt at establishment, and makes use of the short remaining part of the rainy season (March-April). Late spring rains in April (Temperature regime 32/16°C) marking the end of the rainy season (Fig. 5a & b) will not cause undesirable wasteful germination.

Thus, the control of germination of the seeds of *F. crispa* by temperature responses of the seeds serves as a seasonal indicator; and temperature is thus used by the seed to sense and identify its germination environment. These germination temperature responses serve as a mechanism specific to environmental signals resulting in the selective usage of the reproductive capacity of the seed population in the favourable season and its conservation in the unfavourable season. However, in South Hijaz, which represents that part of the habitat range of the species, which experiences a comparatively more wet and a longer rainy season than the other parts, and in which temperature is very much ameliorated by altitude (Fig. 5c and d), germination may begin after adequate rains in January, but successful attempts at germination and establishment may continue until the end of spring in May.
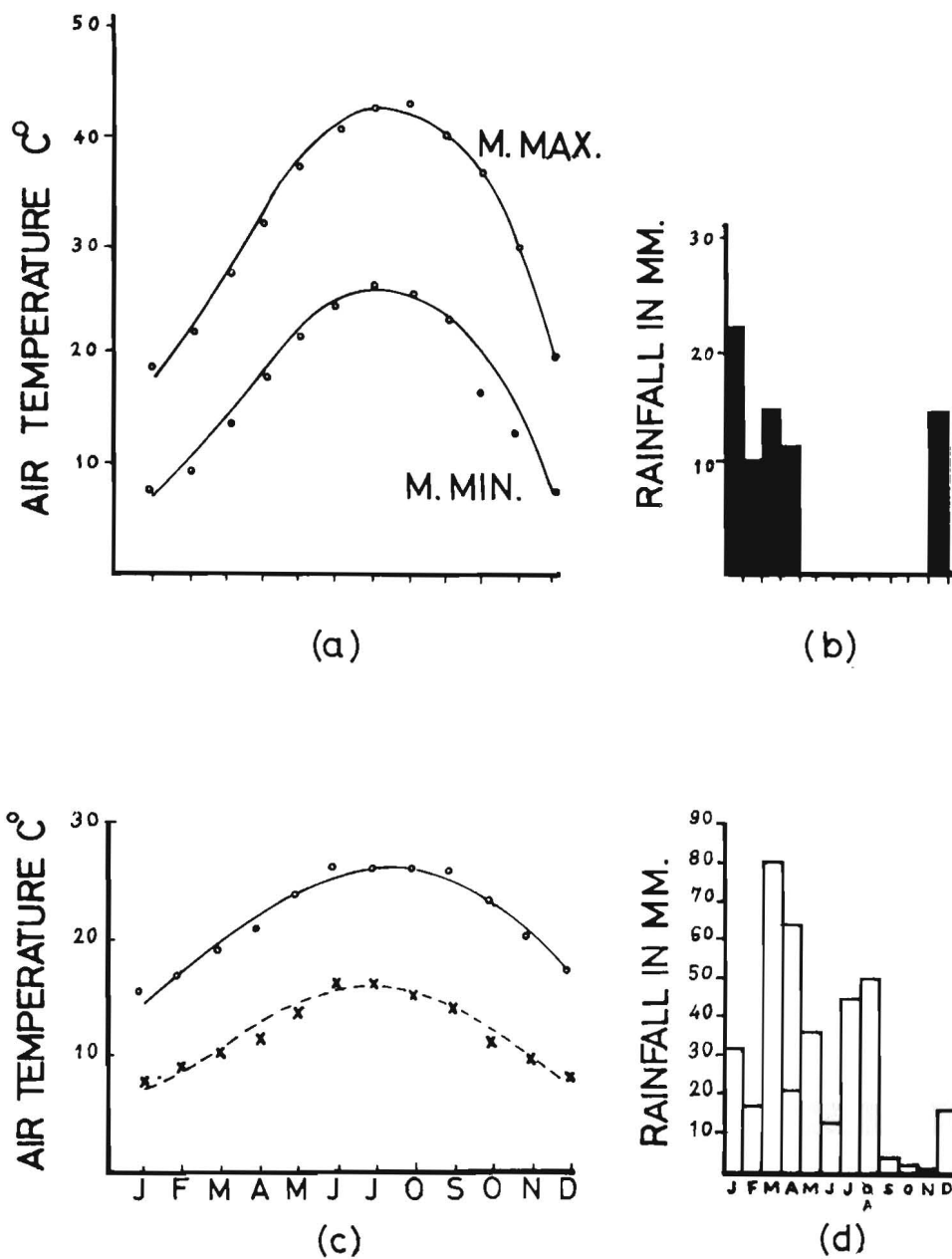
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Fig. 5. Meteorological data obtained at Khurais (a & b) station 150 kilometer from Riyadh, and Abha. (c & d); (a) and (c) represent the mean daily temperature maxima and minima; (b) and (d) represent monthly rainfall. (Data are averages of the records 1969-79).

The degree of salt tolerance of the seeds of *F. crispa* depends in part on temperature (Table 2, Fig. 3, Experiment 2). The seeds incubated at 21/10°C in 5, 10 per cent seawater and in distilled water attained equally high germination percentages, which were reached at comparable rates. Increasing the temperature to 28/14°C caused a drastic decrease in the salt tolerance of the seeds ($7 \pm 5.276$ per cent germination in 5 per cent seawater as compared with $80 \pm 15.912$ per cent in the same salinity but at 21/10°C). Interaction between temperature and salinity has been well documented (Uhvits 1946, Hayward and Bernstein 1958, Boorman 1968, Ungar 1967, Mahmoud *et al*. 1983).

The retardation of germination when high temperature stress is coupled with that of salinity, appears to be of survival value for the species; wasteful germination towards the end of the rainy season (March = 28/14°C regime) is thereby restricted. Within the natural range of distribution of *F. crispa*, where conditions are more arid (*e.g*., outside South Hijaz), the species inhabits depressions and wadis which receive run-off water with its soluble salts. Because of excessive evaporation, particularly towards the end of the rainy season, salts accumulate within the upper surface layer of the soil (seed bed 0-1.0 cm), from where, because of the extremely small size of the seeds of *F. crispa*, successful emergence of its seedlings is more likely to take place.

However, when temperature and moisture conditions are favourable, the seeds of *F. crispa* are capable of germination in salinities beyond those encountered and tolerated by adult plants in their natural habitat. The data in Table 4 show the total water soluble salts in soil samples collected towards the end of the dry season in the first of October 1982, from the natural habitat of the species within Riyadh district.

Successful germination of the seeds of *F. crispa* may thus occur in their native habitats with the advent of winter rains, even without earlier leaching of the soil.

The data in Table 5 indicate that the absence of *F. crispa* from highly saline habitats, *e.g*. the coastal salt marsh at Rabigh on the Red Sea coast, and probably other similar saline lands of the Red Sea coast within the range of distribution of this species, is probably attributed to the failure of its seeds to germinate because of the excessive salinities in the upper surface layer of the soil (seed bed 0-5 cm). It seems that, here, the leaching of salts in the upper surface layer of the soil during the comparatively cool rainy season is not enough to reduce the salt content to levels within the salt tolerance of the seeds. However, field experiments which follow germination and seedling establishment will help to resolve this problem.

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

**Table 4.** Total water soluble salts in soil samples collected within the habitat range of *Francoeuria crispa* in Riyadh district, October 1982.

| Soil sample No. | Depth cm | Total soluble salts ppm | Habitat |
|---|---|---|---|
| 1 | 0- 5 | 800 | Dariya reservoir. |
| 2 | 5-25 | 800.8 | |
| 3 | 0- 5 | 131.2 | Depression along Riyadh, |
| 4 | 5-25 | 108.8 | Solboukh road, 20 km from Riyadh. |
| 5 | 0- 5 | 275.2 | Terrace of a main desert wadi |
| 6 | 5-25 | 76.8 | 20 km east of Al-Kharj. |
| 7 | 0- 5 | 275.2 | Bed of the abovementioned |
| 8 | 5-25 | 76.8 | wadi. |
| 9 | 0- 5 | 224.0 | Shallow depression near |
| 10 | 5-25 | 67.2 | Dariya reservoir. |
| 11 | 0- 5 | 163.2 | Bed of large depression near |
| 12 | 5-25 | 57.6 | Dariya. |

**Table 5.** Total water soluble salts in soil samples (0-5 cm depth) collected within the habitats of two halophytes (*Halopeplis perfoliata*) (Forssk.) Bge Ex Schweinf. and *Limonium axillare* (Forssk.) Ktz (= *Statice axillaris* Forssk.) at Rabigh salt marsh, Red Sea coast, 150 km north of Jeddah (Mahmoud *et al.* 1983).

| Species | Habitat | Soil sample No. | Total water soluble salts ppm |
|---|---|---|---|
| *Halopeplis perfoliata* | Shore line | 1 | 112000 |
| | | 2 | 128000 |
| | | 3 | 134400 |
| | Shallow creek | 4 | 102400 |
| | | 5 | 89600 |
| *Limonium axillare* | Mud flat | 1 | 22400 |
| | | 2 | 35200 |
| | | 3 | 24000 |
| | | 4 | 52160 |
| | | 5 | 28800 |

*et al.* 1983). Evidence from Experiment 3 indicates that the inhibition of the germination of the seeds of *F. crispa* by excessive salinities (40, 60 and 100 seawater) is due to the high osmotic potential of the medium.

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# إنبــات بذور *Francoeuria crispa* من المملكة العربية السعودية

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*F. crispa* نبات معمر ينتشر في المملكة العربية السعودية في كل من المنطقة الشمالية والشرقية وفي شمال وجنوبي الحجاز وشرق نجد وفي النفود .

تمت دراسـة تأثيـر أنظمـة مختلفـة من درجـات الحرارة المـتبـادلـة ( ١٨ / ٨ ، ٢١/١٠ ، ٢٨ / ١٤ ، ٣٢/ ١٦ ، ٤٢/ ١٦ مْ ) على إنبـات البذور وكذلك تأثير تركيزات مختلفة من مـاء البـحـر ( ٥ ، ١٠ ، ٢٠ ، ٤٠ ، ٦٠ ، ١٠٠٪ ) على الإنبات تحت نظامين حراريين ( ١٠ / ٢١ ، ١٤ / ٢٨ مْ ) .

اتضح أن استجابة البذور لدرجة حرارة البيئة الخارجية تُنظم عمليـة الإنبـات وتجعلهـا مُمكنة فقط حين حلول ظروف البيئـة المثلى ( حلول فصـل الأمطـار وتـوفـر المـاء ) التي تمكن البادرات المنبثقة من البذور من أن تنمو وتتوطن .

عنـد درجـة الحرارة ١٠ / ٢١ مْ تحملت البذور تركيزات عاليـة من الملوحـة تفـوق كثيراً ماتتحمله وتـواجهـه النباتات البـالغـة في بيئاتها الطبيعية ، لقد قلل ارتفاع درجة الحرارة إلى ١٤ / ١٨ مْ من قدرة البذور على تحمل الملوحة بدرجة كبيرة .

وقد تمت مناقشة هذه النتائج وأهميتها بالنسبة للنبات في بيئته الطبيعية .