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Laboratory Studies of Germination and Growth in Plant Species Associated with an Elevation Gradient in South West Saudi Arabia

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ABSTRACT. Germination response of seeds of 15 wild species were tested on a temperature gradient. Growth rates of seedlings were evaluated at the optimum temperature for germination for each species. These species include 14 perennials and one annual found at various elevations between 20 and 2700 meters above sea level in the following order: *Cassia italica, Salvadora persica, Calotropis procera, Datura innoxia* (annual), *Moringa peregrina, Lawsonia innermis, Abutilon pannosum, Acacia tortilis, Acacia ehrenbergiana, Acacia asak, Cucumis prophetarum, Coccinia grandis, Nepeta deflersiana, Verbascum nubicum*, and *Jasminum grandiflorum*.

Seeds of most plants found at low elevation germinate best within a relatively narrow range of temperature at the warm end of the temperature gradient. Seeds collected from intermediate elevation show broader response to temperature and germinate at moderate temperature. Seeds collected from high elevation germinate best at low temperature. A relatively higher root/shoot ratio was recorded among plants of high elevation. Plants at different positions along the gradient showed different attributes indicating strategies for survival under the rather harsh and unpredictable environments at low and high altitudes. Among such attributes are rapid germination, germination under a broad range of temperature, germination in darkness, and high rate of root elongation.

The Asir area of the south west of Saudi Arabia is characterized by complex topography and environment, which consequently leads to the formation of diverse vegetation types (Abulfatih 1979 and 1981). Along the elevation gradient in the Asir area, the climate changes drastically from warm dry in the lowland to cool temperate in the highland. Vegetation zonation is distinctive along the gradient (Abulfatih 1984).

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It was shown in a previous work on germination (Abulfatih 1983) that seeds of the common species found at 2200 meters above sea level, can germinate at a relatively low temperature and high soil moisture content. Some of the widely distributed species also exerted ecotypic variation along elevation gradient (Mahmoud *et al.* 1981). As a general principle, in each type of habitat the process of plant demography is affected by a number of variables such as seed production, seed reserve, seed dormancy, seed dispersal, seed survival, survival to maturity, predation, and microhabitat (Beatley 1974, Harper 1977, Nelson and Chew 1977, Abulfatih and Bazzaz 1979, Loria and Noy-Meir 1979).

In the present study, we examined some aspects of germination and seedling growth of fifteen species distributed along an elevation gradient, between 20 and 2700 meters above sea level, in the attempt to understand some of the strategies exhibited by these plants in the complex environments available.

Material and Methods

Seed germination experiment was conducted on freshly collected seeds of fifteen common species distributed from Jizan to Al Soudah along an elevation gradient between 20 and 2700 meters above sea level. These species were trees: (*Moringa peregrina, Acacia tortilis, Acacia ehrenbergiana* and *Acacia asak*), shrubs (*Cassia italica, Salvadora persica, Calotropis procera, Lawsonia innermis, Abutilon pannosum* and *Jasminum grandiflorum*) and herbs (*Datura innoxia, Cucumis prophetarum, Coccinia grandis, Nepeta deflersiana*, and *Verbascum nubicum*).

Seed germination was measured on a temperature gradient using an aluminum bar with one end immersed in water maintained at −10°C and the other in cooking oil at 60°C. The surface of the bar was covered with a sheet of filter paper. The sheet extended from the sides into a container of distilled water to keep the seeds continually moist. A number of small plastic containers of distilled water were laid on the filter paper toward the warm end to overcome the problem of excessive evaporation. Filter paper, water containers and seeds were all covered with a lid of plexiglass to keep the air around the seeds moist. For each species batches of 50 seeds each were placed at 9 locations across the bar. Temperature was measured at each seed batch using an infrared thermometer, model IT-3 made by Barnes Eng. Co., Stanford, Connecticut, U.S.A. The temperature was within a standard deviation of ± 1°C and ranged from 10°C under the first batch to 40°C under the ninth. Light was provided by two 40 W, cool-white fluorescent tubes turned on all the time throughout the experiment. Seeds were monitored until no further germination was observed. Details about the construction of the temperature bar were given in the works of Abulfatih and Bazzaz (1979) and Goloff (1973).

Seeds with hard seed coats and failing to germinate were scarified by file. Each seed was scarified until cotyledons were partially exposed. Moreover, seeds which failed to germinate under the light were enclosed in moist filter paper and aluminum foil and then placed on the temperature gradient bar.

For the purpose of evaluating the rate of root and shoot elongation, the germination test was repeated for each species at the temperature of maximum germination determined by reference to the first set of results. Batches of 50 seeds were used. Rate of root elongation was obtained by dividing the root length over the period from the day of radicle emergence to the day of shedding of the seed coat in 50% of the seeds. Rate of shoot elongation was obtained by dividing the shoot length over the period from the day of plumule emergence to the day of shedding of the seed coat in 50% of the seeds. Then, the relative ratio of root length to shoot length was determined by dividing the rate of root elongation over the rate of shoot elongation. Seedlings were drawn to scale to show their morphology.

Climatic data for the Jizan area near the Red Sea and Al Soudah Mountain at 2700 m were supplied by the Ministry of Agriculture and Water, Department of Water Resources Development, Hydrology Division (Fig. 1). Rainfall was represented by averages of the years 1966 to 1970, 1978 and 1980. Mean maximum and minimum temperatures were represented by averages of 1978 and 1980. Rainfall and temperature of Jizan area were taken from Abu Arish and Malaki stations. Because of the scarcity of temperature data for Al Soudah Mountain, the mean maximum and mean minimum temperatures were estimated by extrapolation of the records of a nearby station at Abha, 2200 meters above sea level. Extrapolation was based on the assumption that air cools by about 1°C for each 150 meter rise in altitude.

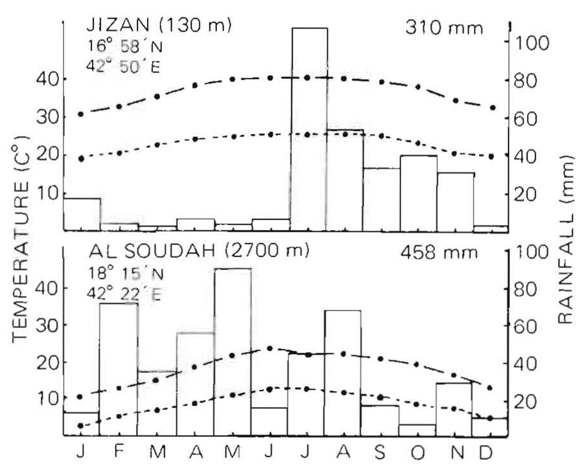

Fig. 1. Climatic records of Jizan and Al Soudah Mountain, showing rainfall (histogram), mean maximum temperature (❸—❻), and mean minimum temperature (❻---❸).

Results

Germination

Under the desert environment at elevations ranging between 20 and 200 meters above sea level, seeds of the perennial plants *Salvadora persica, Calotropis procera, Moringa peregryna, Lawsonia innermis* and *Cassia italica* germinate well under warm temperature at a generally narrow range between 30 and 40°C (Fig. 2). It was shown by Mahmoud *et al.* (1983) that seeds of *C. procera*, found in Riyadh area, germinate very well under a fluctuating temperature of 36/21 and 40/26°C.

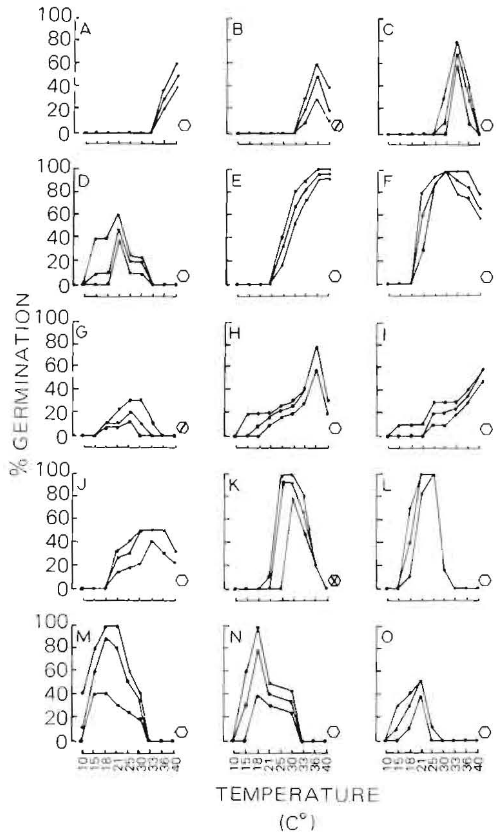

Fig. 2. Seed germination along temperature gradient. Three figures were drawn for each species, showing changes of germination with time. Each set of figures followed one of these sequences: 8, 12 and 18 (○); 4, 6 and 8 (⊘); and 4, 8 and 12 days after planting (⊗). (A) *Cassia italica*, collected from 20 m altitude; (B) *Salvadora persica*, 20 m; (C) *Calotropis procera*, 20 m; (D) *Datura innoxia*, 20 m; (E) *Moringa peregryna*, 50 m; (F) *Lawsonia innermis*, 50 m; (G) *Abutilon pannosum*, 200 m; (H) *Acacia tortilis*, 300 m; (I) *Acacia ehrenbergiana*, 300 m; (J) *Acacia asak*, 350 m; (K) *Cucumis prophetarum*, 1100 m; (L) *Coccinia grandis*, 1100 m; (M) *Nepeta deflersiana*, 2700 m; (N) *Verbascum nubicum*, 2700 m; (O) *Jasminum grandiflorum*, 2700 m.

Seeds of *Abutilon pannosum* required scarification and showed low percentage of germination. The latter species is common on disturbed ground, along roadsides and farms. The seeds of the winter annual *Datura innoxia* germinated well at 21°C in darkness. *Datura innoxia* is common in sandy soil along dry water courses.

Seeds of the perennial shrubs found under warm environment at elevations ranging between 300 and 350 meters above sea level (*Acacia tortilis, Acacia ehrenbergiana* and *Acacia asak*) responded to a wide range of temperature but germinated best toward the warm end of the gradient between 30 and 40°C. The broad response of *A. ehrenbergiana* seeds to temperature and their capacity to germinate without scarification may explain the abundance of this species in the area.

In species collected from elevations around 1100 meters above sea level, germination response showed a slight shift toward moderate temperature as in the perennial lianas *Coccinia grandis* and the creeping *Cucumis prophetarum* which showed maximum germination between 21 and 30°C. Seeds of both species germinated two days after planting, faster than any of the other species tested in this study. Seeds of *C. prophetarum* germinated in darkness. These characters are likely to be advantageous for plant establishment under the harsh environments experiencing warm temperature and sporadic rain.

It is clear from the germination tests for the perennial plants *Nepeta deflersiana, Verbascum nubicum*, and *Jasminum grandiflorum* found at 2700 meters above sea level, as well as for *Lavandula dentata, Rumex nervosus* and *Withania somnifera* found at 2200 meters above sea level or higher (Abulfatih 1983) that highest percentage of germination can take place at low temperature ranging between 8 and 20°C.

Seedling Development

Among all studied species *Cassia italica*, which is common in warm lowlands, had the highest rate of root elongation recording 1.08 cm day^{-1} (Fig. 3 and Table 1).

Rate of root elongation of *Acacia tortilis, Acacia ehrenbergiana* and *Acacia asak* trees were relatively high: 0.73, 0.77 and 1.07 cm day^{-1}, respectively. Among these *Acacia* species, it seems that there is a correlation between seed size and rate of seedling development. The larger the seed, the higher the rate of root and shoot elongation (Fig. 3). These trees are commonly found at elevations ranging between 300 and 350 m.

In *Coccinia grandis* and *Cucumis prophetarum*, which are found at elevations of about 1100 m, high rates of root elongation, 0.98 and 0.60 cm day^{-1}, respectively, were recorded.

Nepeta deflersiana and *Verbascum nubicum* which are found in cool places at an elevation of 2700 m exhibited high root/shoot ratios of 6.97 and 6.00, respectively.

Discussion

The experimental results and field observations indicate that, in the warm lowlands near the Red Sea, seeds of the majority of the perennials are wide ranging with respect to temperature response, and may germinate at any time of the year

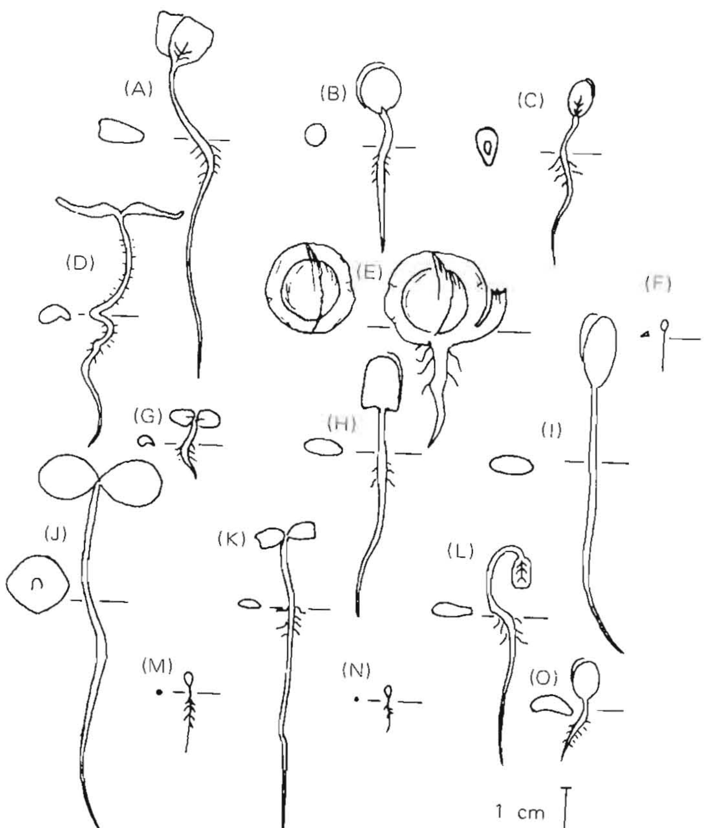

Fig. 3. Drawings of dry seeds and growing seedlings on the temperature bar at the optimum temperature of germination for each species. Seedlings were drawn four days after germination. (A) *Cassia italica*, at 40°C; (B) *Salvadora persica*, 36°C; (C) *Calotropis procera*, 33°C; (D) *Datura innoxia*, 21°C; (E) *Moringa peregryna*, 40°C; (F) *Lawsonia innermis*, 33°C; (G) *Abutilon pannosum*, 25°C; (H) *Acacia tortilis*, 36°C; (I) *Acacia ehrenbergiana*, 40°C; (J) *Acacia asak*, 33°C; (K) *Cucumis prophetarum*, 30°C; (L) *Coccinia grandis*, 21°C; (M) *Nepeta deflersiana*, 18°C; (N) *Verbascum nubicum*, 18°C; (O) *Jasminum grandiflorum*, 21°C.

Table 1. Showing seed weight and length, days needed for seeds to germinate, rate of shoot and root elongation, root/shoot ratio, temperature of maximum germination of species distributed along elevation gradient.

Species, Family and Growth Form	Mean seed weight (g)	Mean seed length (mm)	Time of germination (days)	Rate of root elongation cm day^{-1}	Rate of shoot elongation cm day^{-1}	Root/shoot ratio	Temperature of maximum germination (°C)	Altitude at which seeds were collected
Cassia italica (Leguminosae) SH	0.0306	7	5	1.08	0.61	1.77	40	20
Salvadora persica (Salvadoraceae) SH	0.0177	4	5	0.36	0.28	1.30	36	20
Calotropis procera (Asclepiadaceae) SH	0.0432	6	3	0.52	0.25	2.08	33	20
Datura innoxia (Solanaceae) H,D	0.0120	4	5	0.62	0.44	1.40	21	20
Moringa peregryna (Moringaceae) T	0.1104	10	3	0.52	0.22	2.36	40	50
Lawsonia innermis (Myrtaceae) SH	0.0050	1	3	0.14	0.10	1.41	33	50
Abutilon pannosum (Malvaceae) SH,S	0.0021	1.5	3	0.14	0.13	1.07	25	200
Acacia tortilis (Leguminosae) T,S	0.0162	5	3	0.73	0.32	2.28	36	300
Acacia ehrenbergiana (Leguminosae) T	0.0250	5	5	0.77	0.50	1.54	40	300
Acasia asak (Leguminosae) T	0.0541	7	5	1.03	0.50	2.06	33	350
Cucumis prophetarum (Cucurbitaceae) H,D	0.0075	4	2	0.98	0.43	2.28	30	1100
Coccinia grandis (Cucurbitaceae)	0.0167	7	2	0.60	0.27	2.22	21	1100
Nepeta deflersiana (Labiatae) H	0.0005	1.5	5	0.23	0.03	6.97	18	2700
Verbascum nubicum (Scrophulariaceae) H	0.0001	0.4	5	0.09	0.01	6.00	18	2700
Jasminum grandiflorum (Oleaceae) SH	0.0287	5	5	0.22	0.17	1.29	21	2700

D: Darkness required for germination; S: Scarification required for germination; H: Herbs; SH: Shrubs; T: Tree.

after rain. Such findings coincide, to a certain extent, with the results of Went (1948) concerning the desert plants of Joshua Tree National Monument of California. Moreover, most of the lowland plants are characterized by their high rate of root elongation.

Trees of *Acacia tortilis, Acacia ehrenbergiana* and *Acacia asak* are common at elevations ranging between 300 and 350 m. Their seeds can germinate between 30 and 40°C, and their rates of root elongation were relatively high: 0.73, 0.77 and 1.03 cm day^{-1}, respectively. Such wide temperature response and relatively high root elongation probably confers an advantage on the *Acacia* species allowing seedlings to rigidly gain access to subsoil moisture and explains in part their commoness in the area. It is known that *A. tortilis* can be found in various geographical areas in the Arabian Peninsula, Palestine, Sudan and Sinai desert (Zohary 1972, Halevy and Orshan 1972 and 1973, Mahmoud 1977).

In the species from elevations of 2700 m, seed germination and rate of seedling development were greatest in conditions corresponding to the season of relatively high rainfall and low temperature which occurs between February and May. Growth rates indicated that more materials were allocated to the roots early in the life time of the individual plants, a phenomenon which was particularly obvious in case of *Nepeta deflersiana* and *verbascum nubicum* which recorded the highest root/shoot ratio, 6.97 and 6.0, respectively.

Conclusion

Plants from different environments along an elevation gradient in the south west of Saudi Arabia showed different germination and seedling emergence strategies. Evidence of such strategies is based on the following:

1. Superimposing the climatic data (Fig. 1) over the germination responses of seeds of the lowlands (Fig. 2), it becomes obvious that the period of high rainfall and high temperature between July and August is the best period for seed germination and seedling establishment for the majority of the species. On the other hand, the climatic data of the highlands along with the experimental results and field observation indicate that germination and seedling establishment of the majority of the species occur between February and May, when temperature is low and rainfall is high.

2. There is a gradual shift in the temperature required for germination from warm to cool as we proceed up the elevation gradient.

3. The high rate of root elongation shown by *Cassia italica, Acacia tortilis, Acacia ehrenbergiana*, and *Acacia asak* probably facilitates seedling establishment after rain showers. In that, it appears to allow roots to penetrate to deeper layers of the soil before the soil surface dries out.

4. Germination across a broad range of temperatures was common among the widely distributed plants such as *A. tortilis* and *A. ehrenbergiana* which are known to be able to germinate at any time during the year if water is available.

5. Dark requirement for germination seems advantageous for *Datura innoxia* which occupies dry wadis and for *Cucumis prophetarum* which exploits dry slopes. For both of these species, the burial of seeds deep in the soil could allow the seeds to gain more moisture and germinate.

6. *Cucumis prophetarum* and *Coccinia grandis* seeds can germinate two days after planting. It seems likely that this may allow seeds of these species to germinate after very brief showers.

7. The results obtained in the present study are consistent with the hypothesis that perennial plants found at high elevation form a relatively high root/shoot ratio early in their life time, a strategy which allows the plant to over winter in a rosette form and then produce leaves and stems later in the year.

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الإنبات والنموعلاقته بمدرج الارتفاع، فى الجنوب الغربى للمملكة العربية السعودية

حسين على أبوالفتح وفخري البزاز

كلية التربية - جامعة الملك سعود - فرع أبها - أبها - المملكة العربية السعودية

يتناول البحث دراسة العلاقة بين نسبة الإنبات والنمو ودرجات الحرارة لخمسة عشر نوعاً من النباتات البرية الشائعة فى الجنوب الغربى للمملكة العربية السعودية، ابتداء من ارتفاع ٢٠ مترا قرب شواطىء البحر الأحمر وحتى ارتفاع ٢٧٠٠ متر فوق مستوى سطح البحر عند جبال السودة. يتبين من نتائج هذا البحث أن بذور أغلب النباتات الموجودة قرب شواطىء البحرتنبت تحت تأثير حرارة دافئة وضمن مدى حرارى ضيق، وبذور المناطق المتوسطة الارتفاع تنبت تحت تأثير حرارة معتدلة وضمن مدى حرارى واسع، وبذور المناطق الجبلية العالية تنبت تحت تأثير حرارة منخفضة ومدى حرارى ضيق نسبيا. كذلك سجلت نباتات المناطق الجبلية العالية رقما عاليا للعلاقة بين طول الجذر إلى طول الساق فى المراحل الأولى من النمو مقارنة بنمو نباتات المناطق الأخرى. إضافة إلى ذلك، فإن هناك مميزات أخرى أظهرتها بعض أنواع النباتات، ومثال ذلك، الحاجة إلى الظلام التام أو إزالة قشرة البذور بطرق ميكانيكية قبل أن تتم عملية الإنبات.