The Desert Biome, Survival Adaptations and Strategies of Annual Plant Species

1.1 Introduction

1.1.1 The Environment in Deserts and Arid Zones

In general, deserts and arid zones are areas where the evaporation rates are higher than the annual amount of precipitation. The more extreme the desert area, the lower the annual precipitation and the higher the evaporation rates. According to Thornthwaite (1948), the ‘moisture regions’ of the world are dependent on the moisture index (I_m), which is dependent on (*s*) water surplus, (*d*) water deficiency and (*n*) the water need:

$$I_m=(100s-60d)/n.$$

The Negev Desert of Israel is in a region with an index between (−40) to (−60), which is classified as ‘arid’ (Evenari et al. 1982). The more extreme the desert, the higher is the fluctuation of the annual rainfall over the years. An example of such an area in the Negev is Sede Boker (34°46'E 30°51'N, 460 m a.s.l.) where the annual average rainfall is about 95 mm (Sect. 1.3.1). The term ‘desert’ differs among geographers, soil scientists, geologists and meteorologists (Kendrew 1942; Trewartha 1954; Griffiths 1972; Bryson and Hare 1974), and geobotanists (Zohary 1962).

There are hot deserts with mild winters, as in the Negev, in which the winter is the main season for plant germination and development. There are cool deserts, as in central Asia, with very low winter temperatures where the main season for plant development is either in the autumn or in spring.

1.1.2
Deserts with Winter or Summer Rain

There are desert areas with only winter rains, as in the northern part of the Sahara and Arabian Deserts. This is a belt of about 6000 km of the Saharo-Arabian phytogeographic region that receives between 50 to 100 mm of rain per year, and includes the Negev Desert. There are desert areas receiving only summer rains, such as the southern part of the Sahara Desert, which is the Eu-Sudanian province (Zohary 1972). Between these two belts there are areas of transition, some of which receive very small amounts of rain, sometimes less than 5 mm/year (Le Houérou 1982). A similar phenomenon of rain distribution in either summer or winter occurs in the deserts of South Africa, Australia, and North and South America (Fig. 1.1) (Evenari 1985).

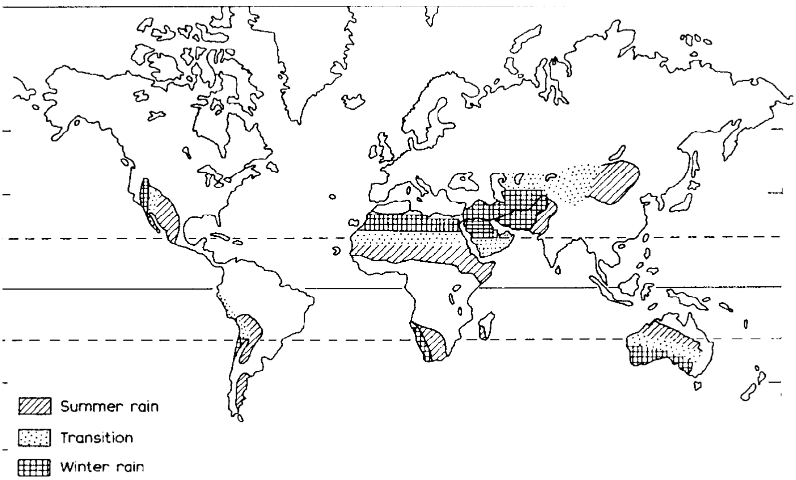

Fig. 1.1. Areas of deserts with summer rain, winter rain and their transition zones. (Evenari 1985)

1.1.3
Classification of Semi-Arid and Arid Zones According to the Amounts of Rain and Vegetation Zones

Zohary (1962) classified Israel into three vegetative zones according to the annual rainfall: (1) 1000–400 mm – subhumid zone, such as the Mediterranean phytogeographic region; (2) 400–200 mm – semi-arid zone, as in the Irano-Turanian region; (3) 200–25 mm – Saharo-Arabian, arid zone (Sect. 1.3.1).

1.1.4
Annuals in Deserts and Survival Adaptations Throughout the Stages of Their Life Cycles

The main object of this volume is to summarize various laboratory studies and field observations on annual plant species occurring in the Negev Desert of Israel. The intention has been to present adaptations and survival strategies that enable these plant species to survive under the extreme Negev Desert conditions and other similar deserts in the Saharo-Arabian region.

Over the last few decades many studies have been carried out on the annual plants of the Negev and other deserts. Various factors have been shown to exert considerable influence throughout the different stages of the life cycle of some of the most common annuals (Zohary 1937, 1962; Kadman 1954; Koller 1954, 1956, 1957, 1969, 1972; Kassas and Imam 1959; Fahn and Werker 1972; Friedman and Orshan 1975; Friedman and Stein 1980; Batanouny 1981, 2001; Friedman et al. 1981; Evenari et al. 1982, 1985; Danin 1983; Kassas and Batanouny 1984; Evenari 1985; Evenari and Gutterman 1985; Shmida et al. 1986; Kigel 1992; Gutterman 1993, 1994a, 1995, 1997a, 1998a,b, 2000a–d, 2001a–c; Gutterman and Shem-Tov 1996, 1997a,b; Baskin and Baskin 1998; Gutterman et al. 1998; Gutterman and Gozlan 1998, 1999; Huang and Gutterman 1998, 1999a,b, 2000; Danin and Orshan 1999; Gozlan and Gutterman 1999; van Rheede van Oudtshoorn and van Rooyen 1999; Shem-Tov et al. 1999; Huang et al. 2000). Some of the species studied have been found to have developed complementary sets of adaptation and survival strategies during different stages of their life cycles. These include: (1) flowering strategies (Chap. 2); (2) phenotypic plasticity of primary dormancy and seed germination as a result of (a) environmental conditions during seed development and maturation, (b) seed size, (c) seed position on the mother plant (Chap. 3); (3) seed post-maturation conditions (Chap. 4); (4) seed dispersal strategies (Chap. 5); (5) environmental factors during seed wetting and germination and seed secondary dormancy (Chap. 6); (6) seedling drought tolerance and seedling survival in competition (Chaps. 2, 6, 7); (7) complementary sets of adaptation and survival strategies of some of the common plant species (Chap. 8) (Fig. 1.2; Table 1.1).

1.2 Plant Adaptations and Survival Strategies

The abiotic and biotic environmental factors of extreme deserts may greatly influence the adaptation and survival strategies of the plant species that grow there. Such adaptations arise during the different stages of the life cycles of particular annual species. Different plant species occurring in the Negev Desert and similar desert areas have developed adaptations of different kinds. Many of the common ones have developed 'protective' strategies for their seeds and different mechanisms and strategies of seed dispersal. Others produce tiny, dust-like, seeds with 'escape' dispersal strategies (Chap. 5) (Fig. 1.2).

The long-term persistence of an annual plant species in any particular area or habitat of a desert environment depends on at least four main factors: (1) the existence of long-living and sufficiently large seed banks, (2) successful development of enough plants to complete their life cycle and produce new mature seeds for the species' long-term seed bank. (3) Seeds that are buried in depressions may be re-dispersed by the turnover of soil by animals (Gutterman 2001a) onto or near the soil surface, where they may be able to germinate. (4) A further contribution to the long-term seed bank of a plant species may be the mass introduction of seeds from nearby areas or from more distant habitats by wind or floods.

The continuity of a plant species in the desert does not depend merely on a single survival strategy. A single species may exhibit a complementary set of adaptations during the different stages of its life cycle. These enable the species to survive despite the presence of selective biotic factors such as massive seed consumption, as well as abiotic factors. The latter include extreme and unpredictable amounts and distribution of rain (Sect. 1.3.1). Further, the mature seeds of some species are retained on the dead and lignified mother plants. Here, they act as a long-term protected aerial seed bank from which seeds are dispersed in small amounts over the years. Other seeds germinate in situ from the seed bank in dry and lignified parts of the mother plants situated under the soil surface. Still other species produce dust-like seeds that escape in massive numbers from seed predators when they disperse after maturation (Chap. 5) (Fig. 1.2; Table 1.1).

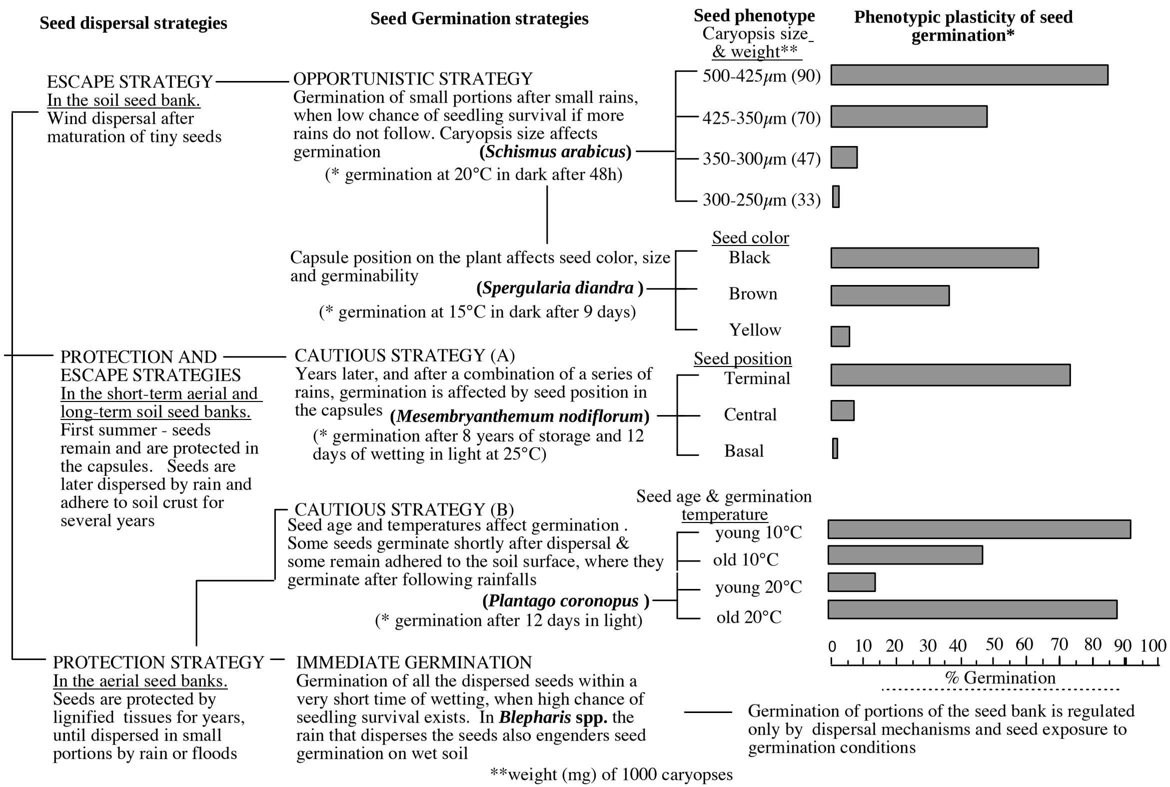

Fig. 1.2. Seed dispersal and germination strategies of some of the common annual species of the Negev Desert of Israel; seed phenotypes and their phenotypic plasticity of germination (Sect. 1.14; Chaps. 3, 5, 6). (After Gutterman 2000b)