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The impact of cardinal temperature variation on the germination of Haloxylon aphyllum L. seeds

Mansour Taghvaei and Masoumaeh Ghaedi
Department of Desert Region Management, College of Agriculture, Shiraz University, Shiraz 7144165186, Iran

Seed germination is a biological process that is affected by a variety of genetic and environmental factors. The cardinal temperature and thermal time are required for germination. The principal objective of this study was to identify and characterize variations in the base, optimum, and maximum germination temperatures of Haloxylon aphyllum L. from two seed sources, in order to establish models for use in predicting seeding dates. Mature H. aphyllum seeds were germinated at temperatures between 5 and 35°C. The germination behavior of H. aphyllum seeds to different temperature regimens in light was evaluated over a temperature range of 5-35°C at intervals of 5°C. The rate of germination increased between base and optimum thermal conditions, and decreased between optimum and maximum thermal conditions; the germination rate varied in a linear fashion at both sub-optimal and supra-optimal temperatures. The linear regression fit the range of germination rates at 5°C to 25°C and 25°C to 30°C, and thus the base temperature, optimum temperature, and maximum temperature for the germination of H. aphyllum were measured to be 0.6°C, 25.69°C, 37.90°C, and 1.76°C, 21.56°C, 37.90°C for Qom and the Fars dune desert respectively.

Key words: cardinal temperature, germination rate, Haloxylon aphyllum, seed germination

INTRODUCTION

Haloxylon aphyllum L. and Haloxylon persicum L. (family Chenopodiaceae) are leaf succulent dominant components of the vegetation predominating in sandy and clay deserts across Central Asia, from western China and Mongolia to the Caspian Sea (National Academy of Sciences 1980). These zones cover a total area of 1 million km² across the Turanian deserts, and can also be found in the hot deserts of the Middle East. In the dune desert areas of Central Asia, forests of Haloxylon species perform a critical function in the restoration of land degradation. Orlovsky and Birnbaum (2002) previously asserted that Haloxylon spp. are important for the control of desertification, by helping to fix shifting sands, increasing the biodiversity and biological productivity of arid and semi-arid zones, restoring degraded pastures and forests, and serving as a good source of fuelwood. The growth of ephemerals, annual, and shrub species occurs under closed Haloxylon canopies; hence, Haloxylon forests generate sustainable quantities of edible biomass for the grazing of domestic and wildlife species throughout the year. The principal objectives of this study were to characterize some pasture reclamation technologies in dune deserts, as well as methods utilized to improve rangelands in sandy and dune deserts, and to determine the ecological role of Haloxylon species in Central Asian deserts (Orlovsky and Birnbaum 2002, Huang et al. 2003). Haloxylon aphyllum is a xerophyte species; this quality makes it a useful plant in harsh environmental conditions, as it can adapt to drought, salinity, and poor nutritional conditions (Wu 1995, Huang et al. 2003). This plant
can survive under the extremely harsh conditions pertaining in arid zones, from temperatures of -25 to 50°C. *H. aphyllum* regenerates by seeding. The seeds begin to mature from late October until the first days of January. *H. aphyllum* seeds begin to germinate in these deserts in late February, and its leaves appear in May. In arid environments, the seedling is the most vulnerable stage in the plant life cycle, and germination determines when seedling growth begins (Gutterman 1993). Seed germination performs an important function in the regeneration of plant species, particularly under arid and unpredictable environmental conditions, most notably those of Mediterranean ecosystems (Gimenez-Benavides et al. 2005). The germination responses of species to environmental parameters determine their distribution in arid environments. Several environmental factors function as determining factors in germination (Bewley and Black 1994); seed germination is affected by light, temperature, and a host of other environmental factors (Bewley and Black 1994, Baskin and Baskin 1998). Among these factors, temperature is a crucial factor governing the maximum germination percentage (Heydecker 1977) and germination rate (Flores and Briones 2001, Phartyal et al. 2003). It has been recognized since as early as 1860 that three cardinal temperatures (minimum, optimum, and maximum) described the temperature range over which the seeds of a particular species can germinate (Bewley and Black 1994). Seeds of each species possess the capacity to germinate over a defined temperature range, which is referred to as the cardinal temperature (Alvarado and Bradford 2002). Finally, the cardinal temperature (minimum or basic temperature, optimum, and maximum) is the temperature range within which the seeds of a particular species can germinate. The minimum cardinal temperature is the lowest temperature at which crop growth can occur; this temperature is referred to as the base temperature (T_b), and no growth occurs below that temperature. The optimum cardinal temperature (T_o) is the temperature at which crop growth and performance are at their maximum. Finally, the maximum cardinal temperature (T_m) is the highest temperature at which plant growth can occur (Alvarado and Bradford 2002). Finally, growth and development processes are optimal when the temperature is between the minimum and maximum bounds of the range, and close to the optimum cardinal temperature. There are clear minimum and maximum temperatures for germination, and within the broad range between them all seeds can germinate. Seed germination begins at the minimum temperature and the germination rate increases with increasing temperature to the optimum, and then decreases with further rises in temperature to the maximum (Bewley and Black 1994). Some methods have been developed previously to describe species growth data (e.g. germination percentage, germination rate) in response to temperature, but among those methods the germination rate method is the most specifically salient to temperature (Covell et al. 1986), and a great deal of previous research has been done in efforts to understand these relations; regression analysis is generally recognized as the best statistical tool for the investigation of relationships among these variables. The data collected at sub-optimal and supra-optimal temperatures were used to construct two linear regressions to describe the increases and decreases in the germination rate at sub-optimal and supra-optimal temperatures, respectively. The optimum temperature is the temperature at which these two lines intersect (Covell et al. 1986). Roberts (1988) previously described a model elucidating the relationship between germination rate and temperature. The influence of temperature on germination rate and thermal time in plant species has been previously evaluated by a variety of researchers, including the common crupina (*Crupina vulgaris* Pers.) (Shafi and Price 2001), Himalayan elm (*Ulmus wallichiana*) (Phartyal et al. 2002), lentil seeds (Ellis and Barrett 1994), Kochia *Scoparia* L. (Al-Ahmadi and Kafi 2007), pumpkin (*Cucurbita pepo*) (Zehtab-Salmasi 2006). *H. aphyllum* is one of the predominant halophytic species in the salt dune desert surrounding Qom, Iran. Cardinal temperatures are critically important to the germination stage and seeding date. Ghaedi et al. (2009) reported that no significant differences were observed between light and darkness in terms of the seed germination rates of *H. aphyllum*, and the highest percentage of germination was observed at 25°C under light and dark conditions. However, no research has yet been conducted regarding the germination responses of *H. aphyllum* to cardinal temperature. The primary objective of this investigation, then, was to evaluate the relationship between the temperature and germination rate for two seed lots of *H. aphyllum*, and to estimate the values of base (T_b), optimum (T_o), and maximum (T_m) temperatures for them. Our methodology was designed to evaluate the variation in germination responses (*H. aphyllum*) to different temperatures, and to determine the seeding dates at which the soil temperature would be appropriate for optimal germination, and subsequent stand establishment in the field.

**MATERIALS AND METHODS**