GERMINATION OF NINE SPECIES OF A PIONEER PLANT COMMUNITY OF PLIOCENE CLAY SOILS OF CENTRAL WESTERN ITALY UNDER DIFFERENT PHOTO- AND THERMO-PERIODS¹

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ABSTRACT

Germination response under different photo- and thermo-periods was investigated in nine species of the association *Parapholido-Artemisietum cretaceae*, a typical plant community of clay badland vegetation in central western Italy. The species showed: (i) more rapid germination under the photo- and thermo-period emulating autumn conditions than under the one emulating early spring conditions; (ii) different germination rates under condition emulating periods with high diurnal insolation followed by high or low nocturnal heat dispersion: *Aegilops geniculata*, *Parapholis strigosa* and *Artemisia cretacea* were indifferent, *Hordeum maritimum*, *Trifolium scabrum*, *Brachypodium distachyum* and *Parapholis incurva* responded positively to higher thermal dispersion, whereas *Medicago minima* and *Scorpiurus muricatus* responded negatively; (iii) different responses to a constant low temperature of 2°C: *Artemisia cretacea*, *Parapholis incurva*, *Parapholis strigosa* and *Scorpiurus muricatus* showed complete or very high dormancy; the other species showed a germination capacity between 55 and 87% in the following decreasing order: *Medicago minima* > *Hordeum maritimum* > *Trifolium scabrum* > *Aegilops geniculata* > *Brachypodium distachyum*. All species had delayed and reduced germination responses at 2°C. Grasses showed prompt, quick and high germination as environmental conditions became more favourable; legumes showed a similar response when their coat-imposed dormancy was removed, while the asteracea *A. cretacea* showed only a moderate germination capacity and one of the lowest germination rates.

Nomenclature: Pignatti (1982).

KEY WORDS: germination, *Artemisia cretacea*, *Parapholis incurva*, *Parapholis strigosa*, *Parapholido-Artemisietum cretaceae*.

INTRODUCTION

Pliocene marine clay soils are widespread in peninsular Italy and are characterized by two typical erosion forms: calanchi and biancane (Alexander 1982, Rodolfi 1991). They are selective for plant life because of their low moisture and high surface salt concentrations in dry periods, with anoxia and marked erosion in wet periods (Ferrari and Grandi 1974).

The plant communities of these badlands are dominated by Mediterranean ruderal therophytes and continental stress-tolerant perennial species (Ferrari and Gerdol 1987). In central-western Italy, i.e. central and southern Tuscany, Umbria and northern Latium, extreme environmental conditions, such as severe soil erosion or deposition, high salt content and summer drought lead to the formation of an open pioneer vegetation type the *Parapholido-Artemisietum cretaceae* (Branconi et al. 1979). This plant community represents the equilibrium point between strong soil dynamics and plant colonization (Calzolari et al. 1994, Chiarucci et al. 1995a) and is

characterized by *Artemisia cretacea*, *Parapholis incurva*, and *Parapholis strigosa*. Other species (forbs, grasses and legumes) occur to a lower degree.

Seed germination is an important regeneration characteristic which contributes to plant species composition of phytocoenoses, as do other species attributes, much as modes of dispersal, relative growth rate, allocation patterns and nutrient-use efficiencies (Grubb 1977, Fenner 1985, Espigares and Peco 1993).

The aim of the present study, which is part of a research programme on vegetation and germination ecology in the badlands of central Italy (Chiarucci et al. 1995a, 1995b, Maccherini et al. 1995), was to investigate the germination response of some species of the association *Parapholido-Artemisietum cretaceae*, under several temperature and light regimes.

MATERIALS AND METHODS

Species tested

The species studied were: the asteracea *Artemisia cretacea*; the grasses *Parapholis incurva*, *Parapholis strigosa*, *Aegilops*

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geniculata, *Brachypodium distachyum*, *Hordeum maritimum*; and the legumes *Medicago minima*, *Scorpiurus muricatus* and *Trifolium scabrum*. *A. cretacea* is a chamaephytic endemic to the clay and halomorphic soils of southern Emilia Romagna, Tuscany, Umbria, Marche and northern Latium (Pignatti 1982). It yields many seeds in late October and early November, that mostly germinate the following spring, and shows efficient vegetative reproduction by rooting shoots (Ferri 1964), particularly when soil deposition occurs. The grasses are winter annuals and may be spring ephemerals, while the legumes are both winter and spring annuals. According to Pignatti (1982), *P. incurva* and *P. strigosa* are Mediterranean Atlantic salt-soil species; *A. geniculata* and *B. distachyum* are stenomediterranean species of dry habitats; *H. maritimum* is a west-eurimediterranean salt-soil species; *M. minima* is a eurimediterranean-central-Asiatic species of dry grasslands and *S. muricatus* and *T. scabrum* are eurimediterranean species common in dry marginal areas.

Field observations indicate that seed ripening occurs in the first half of June in all annuals except *P. strigosa* in which it occurs in July. Propagules (spikes, spikelets, pods and seeds) are dispersed by the late summer/early autumn rains and buried by eroded soil. *P. incurva* and *P. strigosa* also are actively dispersed by ants.

Seed collection

Seeds of grasses and legumes were collected in July 1993 and seeds of *A. cretacea* in November 1993 in a study area located in the Orcia Valley, southern Tuscany (43° 00' N, 11° 45' E). They were stored in paper bags under laboratory conditions (20–23°C).

Germination tests

Germination tests were carried out in January–February 1994, using non dormant seeds. Preliminary germination tests showed that the legumes had a high percentages of hard seeds: 90% in *T. scabrum* and as high as 99% in *M. minima* and *S. muricatus*. In order to break coat-imposed dormancy, legume seeds were scarified under a binocular dissecting microscope, perforating their coat in the middle of the seed with a dissection needle (Olivares et al. 1990).

The seeds were surface sterilized in 2.5% (v/v) NaCl and placed in 9 cm Petri dishes on Whatman 42 filter paper moistened with deionized water. They were incubated in a temperature-controlled chamber at 5 different photo- and thermo-periods: (A) 10/5°C for 12/12h of light/dark; (B) 17/11°C for 10/14h; (C) 20/15°C for 16/8h; (D) 20/8°C for 16/8h and (E) constant 2°C for 12/12h. In treatments A and B, the temperature and light regimes emulated the most common mean and minimum temperatures in the distribution area of *Parapholido-Artemisietum cretaceae* and the average day length (sunrise to sunset) of two germination seasons: early spring and fall respectively. Treatments C and D emulated periods with intense diurnal insolation followed by low and high heat loss during the night respectively. Such condition are typical of the germination seasons. Treatment E was used to test the influence of a temperature low enough to be critical for germination. Four replicates of 40 seeds were used in each regime.

A seed was considered to have germinated when the radicle projected 1 mm outside the teguments. Germinated seeds were counted, and discarded daily for 20 days in treatments A, B, C and D, and for 75 days in treatment E. Deionized water was added when necessary to keep the filter paper wet.

Light (234 $\mu\text{mW cm}^{-2}$) was provided by four cool-white fluorescent tubes (OSRAM L 15W/77).

Data analysis

Germination capacity was expressed as the final germination percentage and germination rate as the Coefficient of the Rate of Germination (Bewley and Black 1985). The latter was calculated by the formula $\text{CRG} = 100(\sum n / \sum tn)$, where t is the time in days from sowing and n the number of seeds germinating on day t . The higher the value, the faster the rate of germination, with a possible maximum of 100. Germination percentages were transformed into angular values before ANOVA analysis; differences were tested by the Tukey-test among germination rates and by the LSD among germination percentages.

RESULTS

Alternating temperature treatments

The cumulative germination patterns are shown in Fig. 1. Germination capacity was high for all annual species under all treatments, ranging from 81 to 100%. For the perennial *A. cretacea* it ranged from 66% to 86%. *A. geniculata* and *M. minima* were the promptest species, with germination beginning 1–3 days after sowing under all treatments (Fig. 1). These two species together with *S. muricatus* showed the highest germination rates under all treatments (Fig. 2). Once started, the process was also very fast in the two *Parapholis* species and quite fast in *H. maritimum*. The germination patterns of *B. distachyum* and *T. scabrum* were clearly the most sensitive to experimental conditions, their germination rates differing significantly from one regime to another (Fig. 2).

Under regime A germination rate was at its lowest in all species (Fig. 2) and *A. geniculata* also showed its lowest germination capacity (Fig. 1). Under regime B, all species except *A. geniculata* had a lower germination rate. Comparing treatments C and D, *M. minima* and *S. muricatus* had higher germination rates in the former; *H. maritimum*, *T. scabrum*, *B. distachyum* and *P. incurva* in the latter; while *A. geniculata*, *P. strigosa* and *A. cretacea* did not show significant differences.

Constant temperature treatments

A constant temperature of 2°C delayed, slowed down and reduced germination in all species (cf. Figs 3, 1 and 4, 2). *M. minima* showed the highest germination capacity and rate response: germination started 11 days after sowing and reached a high final percentage (87%). In the other species, germination was progressively slower from *A. geniculata* to *P. incurva* in the order shown in Fig. 4. Germination capacity was 70–75% in *H. maritimum* and *T. scabrum* respectively, about 55–60% in *A. geniculata* and *B. distachyum* and very low in the other species (20% or less). *P. incurva* was the most affected by cold, with a germination capacity of only 2%.

DISCUSSION

Four of the species examined in this study have also been examined by other authors. Datta et al. (1970), working with seeds of *A. geniculata* collected in Jerusalem, Israel, reported maximum germination at temperatures between 10 and 25°C, a negative effect of low temperatures (5°C) and different influences of light in relation to seed type. These results agree

with our findings as far as temperature is concerned, since similarly high germination responses were found under 20/15, 20/8 and 17/11°C thermoperiods, which are within or nearly within the above range. Similarly, a low response was observed at low temperature. Onnis and Bellettato (1972) working with *H. maritimum* and Bocchieri (1977) and Bocchieri et al. (1981a, 1981b) working with *P. incurva* and *P. strigosa*, found that there was an after-ripening period in summer and that germination was affected by salt solution. They argued that these two factors favour germination in autumn when the risk of ephemeral rain and high surface soil salinity, due to summer evaporation, is reduced. Our data also showed that the promptest and quickest germination occurs in these three species in autumn.

Experimental conditions emulating early spring (10/5°C; 12/12 h) were found to yield slightly but significantly slower germination in nearly all species, with respect to conditions emulating the fall. Some species (*A. geniculata* and *T. scabrum*) responded with slower, and others with delayed germination (*H. maritimum*, *P. incurva*, *P. strigosa*, *M. minima* and *S. muricatus*). In others (*B. distachyum* and *A. cretacea*) germination was both slower and delayed. Under these cooler conditions *A. geniculata* also showed a moderate decrease in germination capacity. Although prudence is advisable in extrapolating laboratory results to the field, it seems that slower spring germination could impede normal plant development and also reduce seed production. This could occur if the growing season is shortened by spring frost and/or early

Fig. 1. Cumulative germination pattern of nine species under four treatments. Bars represent LSD at $P < 0.05$.

Fig. 2. Coefficient of the rate of germination (CRG) of nine species in the four treatments. Different lower case letters indicate significant differences at $P < 0.05$ between species under the same treatment. Different capital letters indicate significant differences at $P < 0.05$ between treatments for a given species. Mm, *Medicago minima*; Ag, *Aegilops geniculata*; Sm, *Scorpiurus muricatus*; Hm, *Hordeum maritimum*; Ts, *Trifolium scabrum*; Ps, *Parapholis strigosa*; Bd, *Brachypodium distachyum*; Pi, *Parapholis incurva*; Ac, *Artemisia cretacea*.

Fig. 3. Cumulative germination pattern of nine species in treatment E (2°C 12/12h). Bar represents LSD at $P < 0.05$.

Fig. 4. Comparison of the rate of germination (CRG) of the species investigated in treatment E. Bars with different lower case letters indicate significant difference at $P < 0.05$. Symbols as for Fig. 2.

summer drought (which is not rare in the habitat of *Parapholido-Artemisietum cretaceae*).

It is known (see Thompson et al., 1977) that species growing in open habitats, such as the present badlands, are often stimulated to germinate by high diurnal fluctuations of temperature. Comparing our treatments emulating high insolation followed by high or by low heat dispersion during the night, (20/8 and 20/15°C thermoperiods), we found differences only in germination rate. With respect to this feature, some species responded positively to high diurnal fluctuation of temperature, others negatively and others were indifferent. Very different responses were also found with respect to low temperature. *M. minima* germinated well at low temperature, which suggests that it does not have winter dormancy. After a long

seed quiescence of nearly a month *H. maritimum* showed a good response. Winter dormancy can also be excluded in *T. scabrum*, *A. geniculata* and *B. distachyum*. On the contrary, *S. muricatus*, *P. strigosa*, *A. cretacea* and *P. incurva* were clearly affected by low temperature. This sensitivity may also be related to the geographical distribution of the species. In fact, it is widely reported in the literature (see for instance Baskin and Baskin 1978, 1988, 1989, Bewley and Black 1985, Grime et al., 1981, Karssen 1980/81, Thompson, 1970a, 1970b) that low temperatures ($< 5^{\circ}\text{C}$) do not prevent germination of Mediterranean winter annuals, but may induce secondary dormancy in those with northern distribution. Our data corroborates this finding for the northern Mediterranean-Atlantic *P. incurva* and *P. strigosa* and most of the steno- and eurimediterranean species.

All the grasses tested germinated promptly and quickly, especially under the warmer conditions emulating the fall. The legumes showed a similar pattern once their coat-imposed dormancy was removed. One of them, *M. minima*, also germinated at low temperature. Surprisingly, the asteraceae *A. cretacea*, did not have a very high germination capacity, especially under the higher temperature treatments approximating late spring which is when this species germinates. Perhaps high germination is not an important evolutionary factor in this species because of its efficient vegetative reproduction and abundant seed production? Moreover, its sensitivity to low temperatures, coupled with late autumn seed dispersal, tends to shift its germination to the following spring.

With regard to the occurrence of annual species in *Parapholido-Artemisietum cretaceae*, our results showed that the abundance of grasses may be related to their prompt germination especially under autumn conditions, and that the low occurrence of legumes may be associated with their coat-imposed dormancy.

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WPLYW FOTO- I TERMOPERIODYZMU NA KIEŁKOWANIE DZIEWIĘCIU GATUNKÓW
PIONIERSKIEGO ZBIOROWISKA ROŚLIN NA PLEISTOCENSKICH GLEBACH GLINIASTYCH
W ŚRODKOWO-ZACHODNIEJ ITALII

STRESZCZENIE

Kiełkowanie w warunkach różnego foto- i termoperiodyzmu badano u dziewięciu gatunków z zespołu *Parapholido-Artemisietum cretaceae* z typowego zbiorowiska na gliniastych nieużytkach w środkowo-zachodniej Italii. Gatunki te wykazywały: (1) szybsze kiełkowanie w warunkach foto- i termoperiodyzmu odpowiadającego jesieni niż wczesnej wiosny; (2) różne tempa kiełkowania w warunkach naśladujących okresy wysokiego nasłonecznienia dziennego, po których następowała wysoka lub niska utrata ciepła: *Aegilops geniculata*, *Parapholis strigosa* i *Artemisia cretacea* zachowywały się obojętnie, *Hordeum maritimum*, *Trifolium scabrum*, *Brachypodium distachyum* i *Parapholis incurva* reagowały pozytywnie na wyższą utratę ciepła, podczas gdy *Medicago minima* i *Scorpiurus muricatus* reagowały negatywnie; (3) różne reakcje na stałą, niską temperaturę 2°C: *Artemisia cretacea*, *Parapholis incurva*, *Parapholis strigosa* i *Scorpiurus muricatus* wykazywały całkowity lub prawie całkowity stan spoczynku; pozostałe gatunki wykazywały zdolność kiełkowania pomiędzy 55 a 87% w następującej malejącej kolejności: *Medicago minima* > *Hordeum maritimum* > *Trifolium scabrum* > *Aegilops geniculata* > *Brachypodium distachyum*. Wszystkie gatunki cechowała opóźniona i obniżona zdolność kiełkowania przy temperaturze 2°C. Trawy wykazywały natychmiastowe, szybkie i wysokie kiełkowanie wraz z poprawą warunków środowiska; w podobny sposób, ale po usunięciu łupiny nasiennej, reagowały rośliny motylkowate, podczas gdy wśród złożonych *A. cretacea* wykazywała tylko umiarkowaną zdolność i bardzo niskie tempo kiełkowania.

SŁOWA KLUCZOWE: kiełkowanie, *Artemisia cretacea*, *Parapholis incurva*, *P. strigosa*, *Parapholido-Artemisietum cretaceae*.