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Thermo-control of Germination of *Avena fatua* Seeds in Relation to After-ripened Period

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Abstract

The germination response of *Avena fatua* seeds (caryopsis) to exposure to a range of temperatures (5°C to 30°C) or alternating low temperatures (5°C or 15°C) and 30°C was examined in relation to their different after-ripened periods.

Fresh seeds, one week after harvest, did not germinate at temperatures above 10°C. Seeds after-ripened for more than 4 months germinated optimally at 15°C or thereabouts. However, even the seeds after-ripened for 28 months or more never germinated at 30°C.

Exposure to 5°C followed by 30°C resulted in germination at 30°C in regardless of the after-ripened period. Exposure to 15°C, referred to as chilling, followed by 30°C, or the reverse to 7–8 month-seeds resulted in qualitative and quantitative inhibition at 30°C, whereas exposing 31–32 month-seeds to alternating temperatures resulted in promotion of germination at 30°C.

Diurnal thermoperiodic exposure of the seeds after-ripened for 8 months, chilling and 30°C, resulted in germination within a narrow time range of chilling from 16 h to 24 h, irrespective of the number of cycles. However, diurnal exposure to the seeds after-ripened for 32 months resulted in germination at a wider time range of chilling from 2 h to 24 h depending upon the number of cycles.

The roles of low temperatures and high temperatures, and of their interaction on the germination of *A. fatua* seeds with particular regard to the after-ripened period are discussed.

Key words: After-ripened period-*Avena fatua*-Dormancy-Seed germination-Temperature.

Introduction

The growth of many plant species ceases or is delayed under unfavorable climatic conditions such as temperature, photoperiod or moisture, after which their growth resumes under more suitable conditions[7,12]. It has been postulated that the dormancy of many plants induced by severe conditions implies a delicate adaptation of the species to their surrounding conditions[11]. This is true for the seed germination of cereals: wheat and oats are often dormant when freshly harvested so that they can germinate only at low temperature[3] and require for several months after harvest to germinate at higher temperatures, but even after that dormancy has again been induced at temperatures above the optimum[2,5,6]. Seed dormancy of wild oats, *Avena fatua* have been studied by botanists since early this century[1].

The germination response of *Avena fatua* seeds to various constant-temperatures, as well as to alternating low and high temperatures, in relation to their after-ripened periods, is reported here.

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Materials and Methods

The original seeds of *Avena fatua* were obtained as a gift from Emeritus Professor I. Nishiyama, Laboratory of Genetics, Kyoto University. The oat plants were grown in fields every year. Mature seeds (caryopsis) with hulls were harvested usually between the middle to the end of June. They were kept in a paper bag with silica gel as the desiccant and stored in a wooden box at room temperature. Seeds stored for various periods after the harvest were dehulled and 25 to 30 seeds with the embryo upwards were placed on a layer of filter paper (Toyo No 3) moistened with 5 ml of distilled water in a flat petri dish of 9 cm in diameter. The dishes were exposed to various temperatures (5 to 30°C) for different periods (4 to 20 days) in darkness, and germination was examined daily under white fluorescent light of about 1000 lux. A few days after sowing, coleoptiles or coleorhiza protruded from the embryos and this manifestation was referred to as seed germination. Germination is represented as a percentage of the total number of seeds used.

Results

1. *Various constant-temperatures*

Fresh seeds of one week after harvest were sown and exposed to various temperatures of 5 to 30°C for 20 days. As represented in Fig. 1-a, only a few seeds germinated at 5 and 10°C after 12 days but germination did not occur at 15°C or higher. Germination of seeds after-ripened for 4, 16 and 28 months was examined when

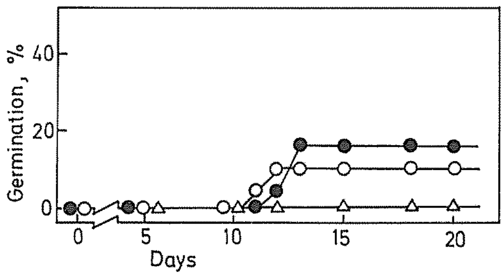

Fig. 1-a. Germination of *Avena fatua* seeds after-ripened for one week when exposed to various temperatures, 5 (●), 10 (○), 15°C and higher (△).

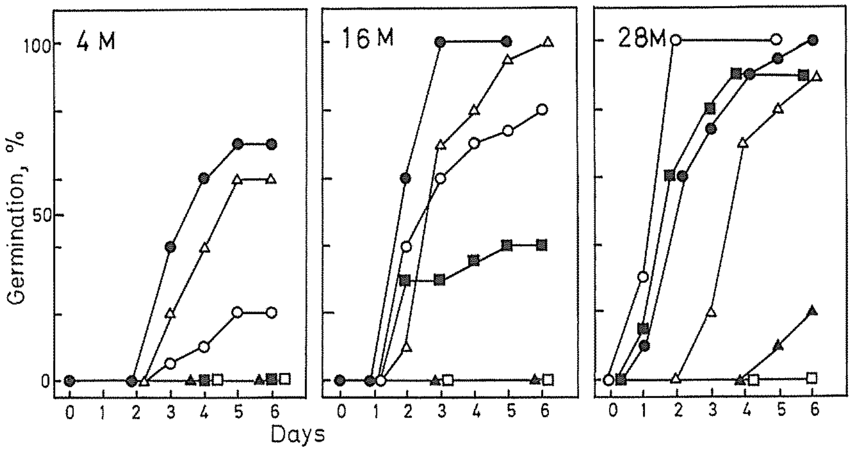

Fig. 1-b. Germination of *Avena fatua* seeds after-ripened for 4 (4 M), 16 (16 M) and 28 months (28 M) when exposed to various temperatures, 5 (▲), 10 (△), 15 (●), 20 (○), 25 (■) and 30°C (□).

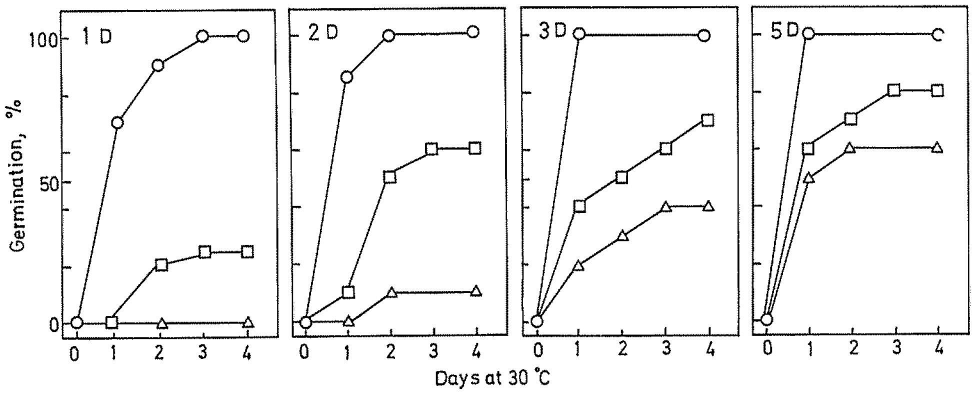

Fig. 1-c. Germination of *Avena fatua* seeds after-ripened for 4 (△), 16 (□) and 28 months (○) when exposed to 30°C for various days preceded by 5°C exposure for 1 (1 D), 2 (2 D), 3 (3 D) and 5 days (5 D).

exposed to various temperatures for 1 to 6 days. As represented in Fig. 1-b, about half number of 4 month-seeds germinated at 10 and 15°C but none of them did so at 5, 25 and 30°C. All 16 and 28 month-seeds germinated at 10 to 20°C and about half number of 16 month-seeds and almost all seeds of 28 month germinated at 25°C. However, only a few or none of these seeds germinated at either 5 or 30°C.

Effects of exposure to 5°C followed by 30°C were examined in the seeds after-ripened for 4, 16 and 28 months. The seeds were sown and exposed first to 5°C for 1 to 5 days and then to 30°C. As represented in Fig. 1-c, 4 month-seeds began to germinate even at 30°C after only one day when preceded by the exposure to 5°C for 3 days. Furthermore, 16 and 28 month-seeds also germinated at 30°C after only 1 or 2 days preceded by the exposure to 5°C for 1 day.

2. *Alternate chilling and 30°C*

As seen in Fig. 1-b, seeds after-ripened for more than 4 months germinated well at 15°C or thereabout and the optimum temperature for germination seems to become higher with increase of after-ripened month. Next, the effect of exposure to 15°C, referred to as chiling, was examined in the seeds after-ripened for more than several months. Germination of the seeds after-ripened for 8, 20 and 32 months were examined when exposed to chilling (15°C) for the first various hours followed by 30°C for the remaining hours of a 144 hours (Fig. 2-a). As represented in Fig. 2-b, 8 month-seeds germinated more with longer chilling but the remainder which failed to

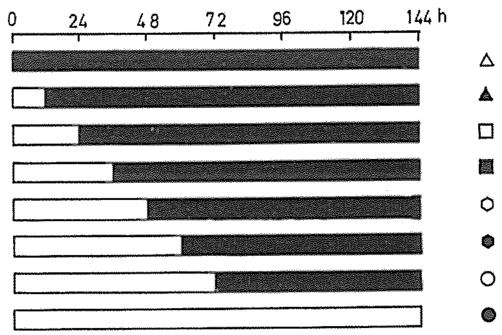

Fig. 2-a. Schedule of treatment involving exposure to chilling (15°C) for various hours (□) followed by 30°C (■). Right, symbols in Fig. 2-b.

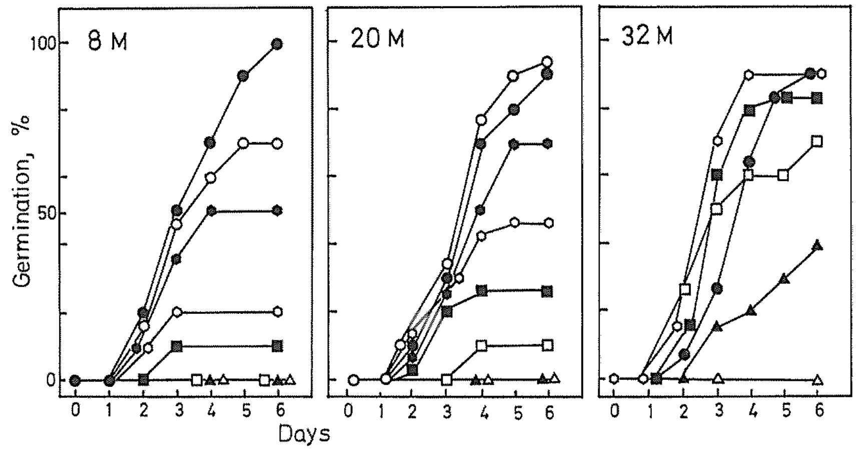

Fig. 2-b. Germination of *Avena fatua* seeds after-ripened for 8 (8 M), 20 (20 M) and 32 months (32 M) when exposed to 15°C for 0 (△), 12 (▲), 24 (□), 36 (■), 48 (⬡), 60 (⬢), 72 (○) and 144 h (●) followed by 30°C.

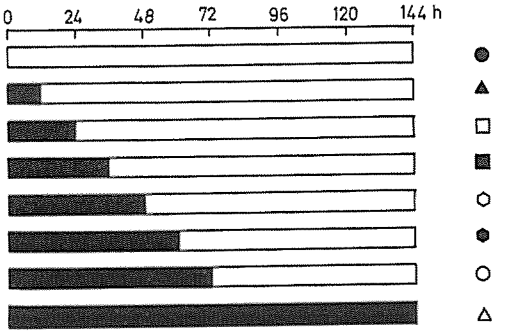

Fig. 3-a. Schedule of treatment involving exposure to 30°C for various hours (▬) followed by chilling (▭). Right, symbols in Fig. 3-b.

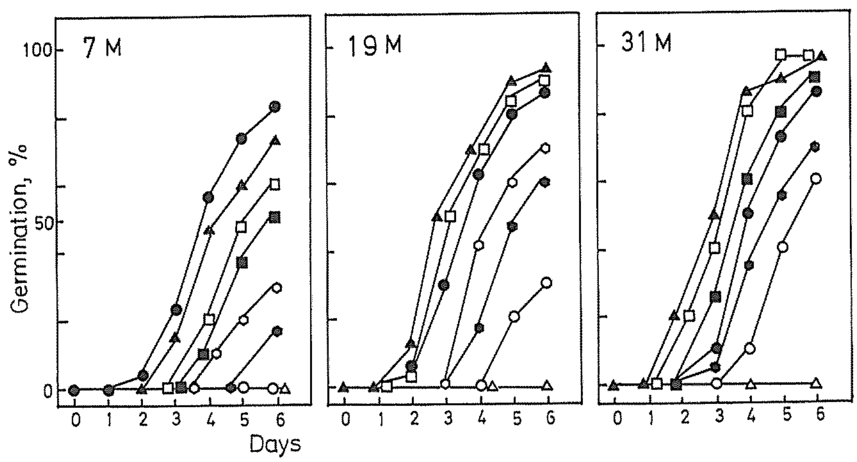

Fig. 3-b. Germination of *Avena fatua* seeds after-ripened for 7 (7 M), 19 (19 M) and 31 months (31 M) when exposed to 30°C for 0 (●), 12 (▲), 24 (□), 36 (■), 48 (⬡), 60 (⬢), 72 (○) and 144 h (△) followed by chilling.

germinate never did so after exposure to 30°C following the chilling. Thus the germination did not exceed that of the seeds exposed to continuous chilling without exposing to 30°C. Whereas, 20 month-seeds germinated during chilling and after 72 h chilling followed by 30°C the seeds germinated more than the seeds exposed continuously to the chilling. Thirty two month-seeds were able to germinate even at 30°C after only 12 h of chilling and the germination at 30°C after 36 and 48 h of chilling exceeded that of the seeds exposed to continuous chilling.

The reverse experiments, exposure to 30°C prior to chilling, were carried out according to the schedule shown in Fig. 3-a. As represented in Fig. 3-b, 7 month-seeds exposed to 30°C for only 12 h germinated during chilling to a lesser degree than the seeds exposed to continuous chilling and exposure to 30°C for 72 h resulted in no germination. On the contrary, 12 and 24 h exposure to 30°C of 19 month-seeds and 12, 24 and 36 h exposure of 31 month-seeds resulted in higher germination percentages than the seeds exposed to continuous

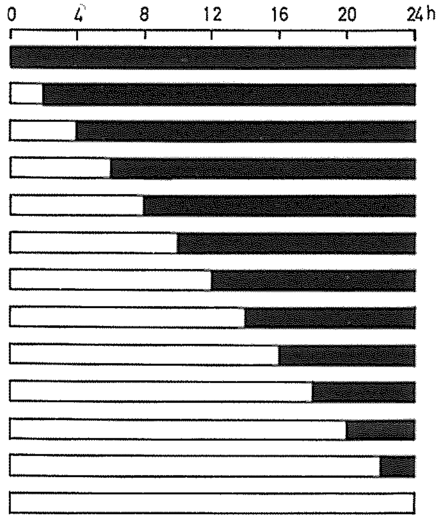

Fig. 4-a. Schedule of treatment involving thermoperiod of chilling for various hours (□) and 30°C for the remaining hours of a 24 h period (■).

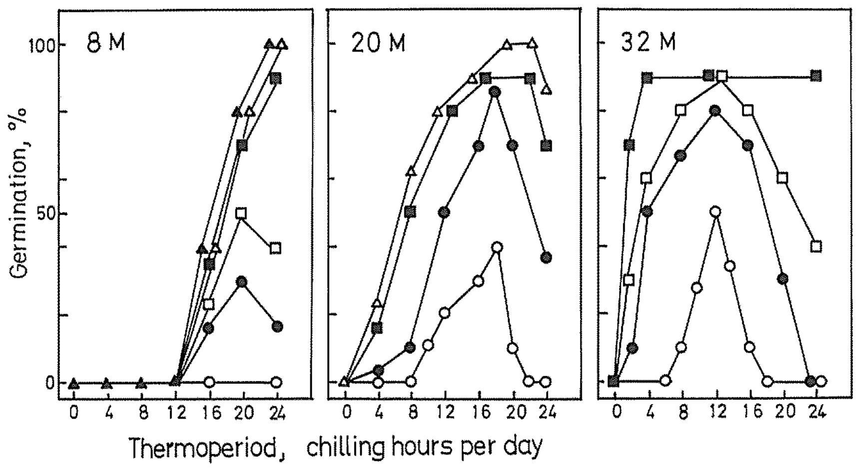

Fig. 4-b. Germination of *Avena fatua* seeds after-ripened for 8 (8 M), 20 (20 M) and 32 months (32 M) when exposed to thermoperiod of chilling for various hours and 30°C for the remaining hours of a 24 h period, which repeated for 2 (○), 3 (●), 4 (□), 6 (■), 10 (△) and 14 days (▲).

chilling, but 48 and 60 h exposure to 30°C resulted in less germination than in the seeds of continuous chilling.

The effects of diurnal thermoperiods of chilling and 30°C for the remaining hours of a 24 h period over 2 to 14 days were examined in the seeds after-ripened for 8, 20 and 32 months according to the schedule shown in Fig. 4-a. As represented in Fig. 4-b, 8 month-seeds began to germinate after 3 days at 16 to 24 h chilling with an optimum at 20 h during which germination was enhanced with a number of thermoperiod cycles. However, germination never occurred at less than 12 h chilling even after 14 cycles. Twenty month-seeds began to germinate after 2 days at 10 to 20 h chilling with an optimum at 18 h. Thirty two month-seeds began to germinate at 8 to 16 h chilling with an optimum at 12 h and the time range of chilling capable of germinating widened from 8–16 to 2–24 h with the increase in number of cycles for up to 6 days. Thus, the optimum chilling time on the less number of cycles of the thermoperiod decreased from 20 to 18 and 12 h with lengthening their after-ripening period from 8 to 20 and 32 months.

Discussion

In the dormant seeds and buds of many species, it is common that the range in temperature capable of germinating and sprouting was widened with an increase in the after-ripened period[10]. Germination behaviour of the present *Avena fatua* seeds was also the case. In fresh seeds soon after harvest, only a few seeds could germinate at 5 and 10°C after 10 days and none was able to germinate at any higher temperatures (Fig. 1-a). However, as the after-ripened period was lengthened, the seeds germinated optimally at 15°C (chilling) or thereabouts. Even seeds after-ripened for 28 months never germinated at 30°C (Fig. 1-b). The failure of these seeds after-ripened for many months to germinate at 30°C must be referred to as second dormancy which is also common in seed germination and bud sprouting of many plant species[10].

At 5°C, most seeds regardless of after-ripened period did not germinate, whereas at 30°C, none of them germinated (Figs. 1-a and b). However, germination could occur even at 30°C after only a few days when preceded by the exposure to 5°C (Fig. 1-c). This evidence suggests that exposure to 5°C allows early germination processes to initiate, then that to 30°C could promote subsequent processes.

Exposure of the seeds after-ripened for 7 or 8 months to 30°C after or before exposure to 15°C inhibited germination qualitatively as well as quantitatively (Figs. 2-b, 8 M and 3-b, 7 M), suggesting that a 30°C exposure has always an inhibitive effect on any germination processes in seeds after-ripened for only several months. However, the inhibitory effect of 30°C decreased with increase of after-ripening period and exposure of 31 and 32 month-seeds to 30°C for some hours resulted in promotion of germination processes (Figs. 2-b, 32 M and 3-b, 31 M). The longer the after-ripened period, then the higher the temperature favorable not only for subsequent germination processes but also for its initial processes. Sensitivity of biosensors to high temperature present in the seed coat or embryo of dried seeds must alter gradually in the after-ripening period. There have been many reports concerned with the improvement of seed germination with alternation between low and high temperature rather than at any constant temperature in many plant species[3,9,12]. So far, little is known on the physiological basis of this phenomenon. These plant seeds seem to respond similarly to alternating temperatures in our *Avena* seeds after-ripened for many months.

Exposure of 8 month-seeds to chilling and 30°C in diurnal thermoperiod was antagonistic (Fig. 4-b, 8 M). The interaction of these two temperatures in the germination processes of the seeds after-ripened for only 8 months is supposed to become in equilibrium at 12 h of each exposure. The wider time range of chilling for germination in 20 and 32 month-seeds (Fig. 4-b, 20 M and 32 M) suggests that these two temperatures operate synergistically to induce germination processes. Constant critical hours of chilling in the thermoperiod at a certain plant age and widening of the time range of chilling with the increase in plant age as shown here for *A. fatua* seeds, have been also observed in floral induction by chilling at the shoot apex of *Pharbitis* plants[8]. These phenomena are likely similar in the manifold thermo-morphogenesis of plant species induced by chilling.

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野生エンバクの種子発芽に及ぼす温度と後熟期間の作用

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5°C から 30°C の各種の一定温度，及び 5°C 後の 30°C，15°C 後の 30°C 或いは 30°C 後の 15°C の温度変化に対する野生エンバク（*Avena fatua*）の種子（えい果）の発芽反応を，収穫後の期間（後熟期間）が異なる種子を用いて調べた。

収穫後 1 週間の種子は，10°C より高い温度で発芽しなかった。4 か月以上経過した種子は 15°C，或いはその近くの温度で最も強く発芽した。しかし24か月以上の種子でも 30°C では発芽しなかった，即ち 2 次休眠に入った。

いずれの後熟期間の種子でも，5°C の後 30°C に置くと短期間で発芽した。この結果は，発芽の初期過程は低温によって誘導され，その後の過程は高温によって促進されることを示唆している。

15°C 後の 30°C，或いはその逆の温度変化に対して，7－8 か月の種子の発芽は，30°C によって質的並びに量的に抑制された。しかし，後熟期間が経過するにつれて，30°C の抑制は減少し，31–32か月の種子の発芽は，30°C によってむしろ促進された。また，15°C と30°C の日周的温周期に対して，8 か月の種子は，15°C が16時間から24時間の狭い時間範囲でのみ発芽し，それ以下の時間では，この温周期の回数を増加しても発芽しなかった。これに対して，32か月種子の発芽の時間範囲は温周期の回数の増加にともない広くなり，6 回の温周期で，2 時間から24時間の範囲で発芽した。この実験結果は，短い後熟期間の種子の発芽過程では，15°C と 30°C は相互に拮抗的に作用するが，長い後熟期間の種子の発芽過程では，この両者の温度は相助的に作用することを示唆している。