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Physiological and Ecological Studies in Environmental Adaptation of Plants

I. *Germination Behavior of Weed Seeds Collected from Different Altitudes.*

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Abstract

Weed seeds of 9 species were collected from several sites having different altitudes on the line of about 36°15'N, and the relation between the optimum temperature for seed germination and the altitude of the seed origin was investigated in each species.

The seeds of the most species from the lowest site required from 25° to 30°C for optimum germination. As their habitats got higher, in general, the optimum temperature had a tendency to transfer or extend into a lower range. A stratification preceding the germination test was effective in the germination of the seeds of some species, and, in some of these, a more intense stratification was required for their germination as their habitat got higher.

The different behavior of seed germination to incubation temperature and the requirment for stratification seem to be adaptively caused by the temperature of the habitat, and the difference seems to be specific for each species. In most species used here, however, the seeds from 30m habitat on the Japan Sea side were different in their germination behavior from those on the Pacific Ocean side, inspite of the same altitude. This difference is considered to be caused by specific meteorological conditions on the Japan Sea side.

Introduction

Growth and development of plants are affected by many enviromental factors. Of these factors, temperature is considered to be the most important because the level of temperature represents a limiting factor in plant life by controlling directly or indirectly the degree of plant growth and development. For example, the lowering of air temperature in the field generally results in a shortening of the convenient period for plant growth, in a decrease of CO_2-assimilation products, and, in some cases, in an unfinished life cycle of plants for the year although some species of plants can complete their life cycle at a low temperature. In order to survive at that low temperature, plants must change their physiological function so that they complete their life cycle within a year. Some workers[5,7,9] have reported that the optimum temperature for photosythesis was adaptively determined by temperature in habitats.

In the vertical distribution of the same plant species, an altitudinal difference of distribution between the highest and the lowest habitat is fairly large, and air temperature also makes a fairly large difference between the highest and the lowest habitat. Nevertheless, the plants in these habitats can complete their life cycle.

A relatively few reports have been made on ecological studies of seed germination although a number of reports are made on physiological ones. MIROV[6] has reported that the seeds of plant species distributing in high altitudes had a higher percentage in germination than ones in lower altitudes, after a stratification of the seeds. VAN ABRANS and HAND[10] have suggested a relation between Rosa seed germination and climatic factors, especially temperature. On the other hand, SHIBATA and ARAI[8] have reported the germination behavior of *Polygonum reynoutria* seeds collected from different altitudes, and they have shown that the seeds from low altitude habitats required a stratification to germinate while ones from high altitude habitat germinated at a high rate without the stratification.

This paper reports on the germination behavior of weed seeds collected from the same species of plants growing at various altitudes, and will discuss the changeable behavior of seed germination with environmental temperature.

Materials and Methods

In order to characterize seed collection sites according to climatic condition caused by vertical difference alone, several species of weed seeds were collected from different altitudes on the line of about 36°15′N (Fig. 1). The collection sites

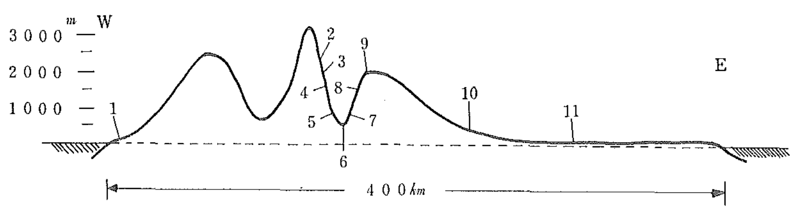

Fig. 1. Seed collection sites (1—11) on a transverse profile of Japan at about 36°15′N. Local names and altitudes for these sites are cited in Table 1.

Table 1. Collection sites of weed seeds in a latitudinal range from 36°10′N to 36°20′N.

	Location	Altitude	To Fossa Magna zone	Symbol for location
1.	Kaga, Ishikawa Pref.	30m	west	30W
2.	Mt. Norikura, Nagano Pref.	2350	west	2350W
3.	Mt. Norikura, Nagano Pref.	2000	west	2000W
4.	Mt. Norikura, Nagano Pref.	1500	west	1500W
5.	Misato, Nagano Pref.	900	west	900W
6.	Matsumoto, Nagano Pref.	600	bottom	600
7.	Utsukushigahara, Nagano Pref.	900	east	900E
8.	Utsukushigahara, Nagano Pref.	1500	east	1500E
9.	Utsukushigahara, Nagano Pref.	2000	east	2000E
10.	Matsuida, Gunma Pref.	300	east	300E
11.	Nogi, Tochigi Pref.	30	east	30E

Table 2. Plant species used for germination test.

Species	Seed collection sites										
	30 W	2350 W	2000 W	1500 W	900 W	600	900 E	1500 E	2000 E	300 E	30 E
Plantago asiatica	—	—	—	—	—	—	—	—	—	—	—
Rorippa islandica	—	—		—	—	—	—	—		—	—
Portulaca oleracea	—				—	—	—			—	—
Chenopodium album				—	—	—	—	—	—	—	—
Achyranthes fauriei	—				—	—	—			—	—
Setaria glauca	—			—	—	—	—	—		—	—
S. viridis	—			—	—	—	—	—		—	—
Eragrostis ferruginea	—				—	—	—			—	—
Pennisetum alopecuroides	—				—	—	—			—	—

and the plant species were shown in Table 1 and 2, respectively. These seeds were harvested from the plants growing in sunny parts of the sites during October in 1976, 1977, and 1978, and were kept at room temperature before the germination test was done.

Seed germination was tested on a moist filter paper in a Petri dish at constant temperatures of 15°, 20°, 25°, and 30°C under about 2000lux illumination. Furthermore, seeds in some species were also tested at 10° or 35°C. The germination period took 20 days from sowing. Seeds in some species were given on stratification at various temperature, and the germination test following its treatment was undertaken at 25°C. The germination test could not be undertaken on some seeds because of very little harvest.

The moutain region of Japan runs from north to south, and divides Honshu island into two areas with remarkably different meteorological conditions : the Japan Sea side to the west and the Pacific Ocean side to the east. In central Japan, part of the Fossa Magna zone is located on the boundary line between the two areas. Therefore, some of the seed collection sites were chosen at the same altitude on both west and east sides of the Fossa Magna zone, and the temperature in winter was measured at the ground surface of 1500E and 1500W.

Results

At 1500m above sea level in both the areas divided by the Fossa Magna zone, the depth of snow cover in the winter of 1978 was about 100cm on the west side and about 15cm on the east side. The minimum temperature at ground level in the same season was −1. 5°C to the west and −13°C to the east, and at 5cm depth in soil was −1. 5°C to the west and −2°C to the east.

Plantago asiatica : The results were shown in Fig. 2. A high germination percentage was shown at 25°C except 1500-E and -W of the collection sites, and was as high as in germination percentage at 30°C. Remarkably low germination of the seeds in 2350W, however, was shown at 30°C. When the seeds kept at room temperature were tested in April of the next year, the germination level increased a little.

Rorippa islandica : The seeds of this species collected from all of the sites did not germinate at all at 15°, 20°, and 30°C, but at 25°C, the seeds in 30E, 300E and 900W germinated although their germination percentages were very low. A stratification at 4°C followed by seed incubation at 25°C increased the germination percentage by prolonging the period of the stratification (Fig. 3), and, generally, the effect of the treatment had a tendency to be greater on the seeds collected from higher altitude than lower one. The seeds from 1500E germinated only after 30

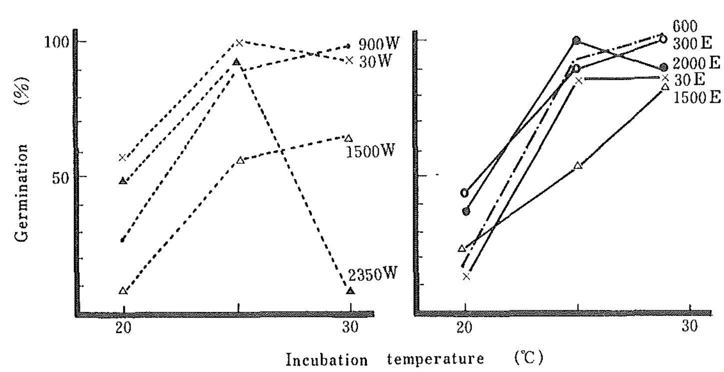

Fig. 2. Germination of *Plantago asiatica* seeds collected from various sites at different altitudes. The number by each curve refers to the collection site.

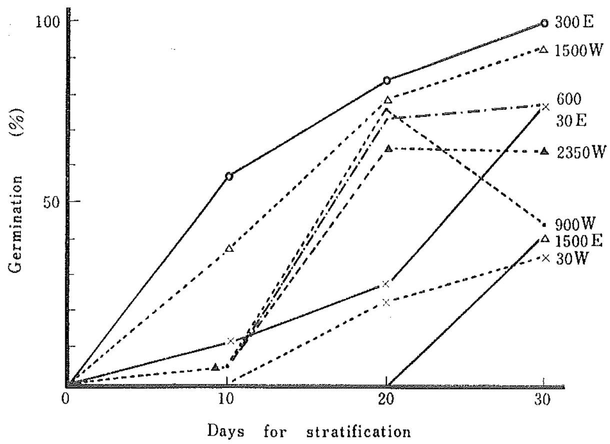

Fig. 3. Effects of a stratification at 4°C on germination of *Rorippa islandica* seeds at 25°C. The number by each curve refers to the collection site.

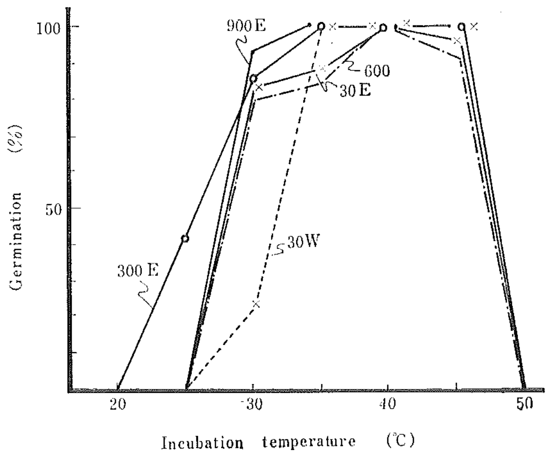

Fig. 4. Relation between incubation temperature and altitude of seed origin for the germination of *Portulaca oleracea* seeds.

days stratification. Without the stratification, very few seeds from any of the sites germinated even 4 months after collection.

Portulaca oleracea: The seeds collected from all of the sites did not germinate at all at 15° and 20°C, but at 25°C only the seeds from 300E germinate (Fig. 4). At 30°C, the seeds collected from all the sites except 30W germinated to a high level. The shortened number of days for germination and the increased level of germination were observed in seeds from all of the sites with the raising of the incubation temperature to 35°C, and the germination rates at 35°C came to 100 in only 6 days after sowing. At higher temperatures than 35°C, the number of days

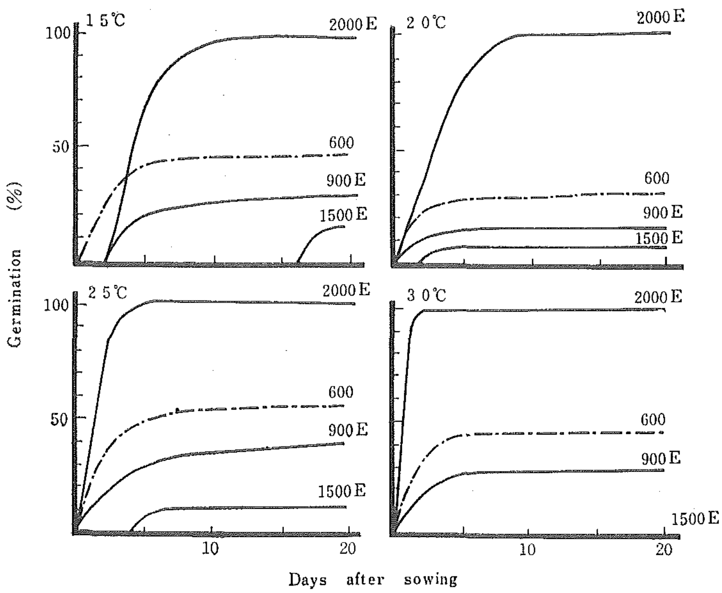

Fig. 5. Germination of *Chenopodium album* seeds collected from various sites at different altitudes.

Table 3. Germination of *Chenopodium album* seeds from 1500E at 25°C.

	Stratification	Germination (%)
Seed collected in November	none	8
	4°C, 10 days	18
	−1°C, 10 days	40
Seed collected in January	none	57

for germination increased till 45°C, and none of the seeds from any of the sites germinated at 50°C.

Chenopodium album: The seeds from 2000E germinated fully at any temperature tested (Fig. 5), and the seeds at 20°C did so to 100% within only 6 days of sowing. Except for the seeds from 2000E, the germination rates at the same temperature decreased with the altitudinal increase of the seed collection site. Although the germination rate changed according to altitude, the optimum temperature for germination was about 25°C, except for the seeds from 2000E.

Germination of the seeds from 1500E, which occurred at a very low rate at all of the temperatures tested, was accelerated by a stratification at 4°C for 10 days, and furthermore by a stratification at −1°C for 10 days (Table 3). The germination

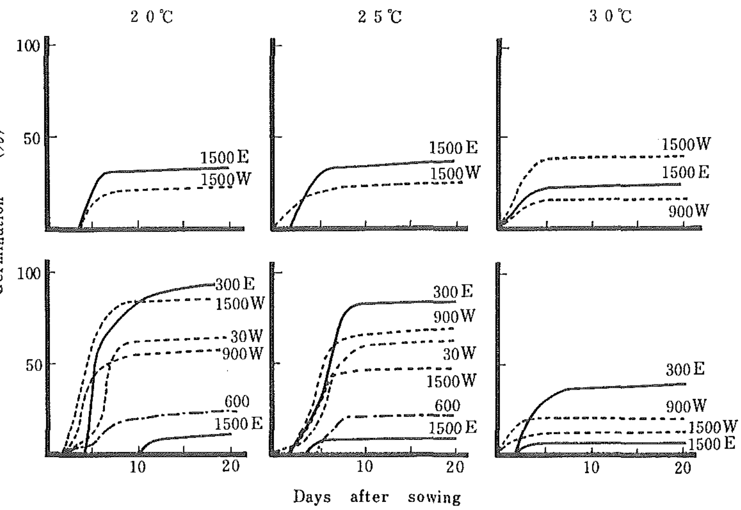

Fig. 6. Germination of *Setaria viridis* (upper) and *S. glauca* (lower) seeds collected from various sites at different altitudes. The number by each curve refers to the collection site.

level of the 1500E seeds collected in January was nearly equal to that of the seeds exposed to the stratification at −1°C.

Achyranthes fauriei : Germination level of the seeds from 30E was high at all the incubation temperatures, but that of the seeds from the other sites was highest at 25°C. The seeds from 300E germinated at a relatively high rate at 15° and 20°C, while the seeds from 30W and 900E did so at a low rate at these temperatures.

Setaria viridis and *Setaria glauca* (Fig. 6) : Generally, fewer *S. viridis* plants were found at 1500m altitude than *S. glauca*, which were easily found at the same altitudes.

In *S. viridis*, the seeds from the collection sites below 600m did not germinate at the temperature levels tested, while the seeds from the collection sites above 900m germinated at all of the temperature levels tested although their germination rates were low. The seeds from the collection sites below 600m germinated in 10–20% only after a stratification at 4°C for 20 days, while the effect of the stratification was never found on 1500–E and –W seeds.

The germination rate of *S. glauca* seeds was relatively high at temperatures below 25°C except in the seeds from 1500E and 600, which showed a very low level of germination at all the temperature levels tested. This germination behavior was scarcely changed by stratification for 20 days.

Eragrostis ferruginea : Of the seeds from all the collection sites, those from 30W showed the highest rate of germination at all the temperature levels tested

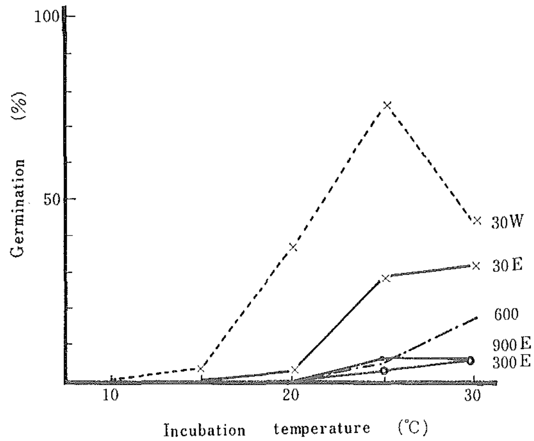

Fig. 7. Germination of *Eragrostis ferruginea* seeds collected from various sites at different altitudes. The number by each curve refers to the collection site.

Table 4. Effects of a stratification (4°C, 10 days) on germination of *Eragrostis ferruginea* seeds at 25°C.

Seed collection sites		30E	30W	300E	600	900E
Germination (%)	without stratification	26	58	4	28	2
	with stratification	96	74	60	78	48

(Fig. 7), and a little germination took place at 15°C, whereas the seeds from the other collection sites never germinated at this temperature. The germination level of the seeds from 30E was next highest to that of the seeds from 30W, but the difference between the levels was much larger. The germination rate of the seeds from all the collection sites was highest at about 28°C, and gradually increased as time passed after seed collection. The stratification for 10 days was remarkably effective on their germination (Table 4). In these tests, the seeds from 30W without the stratification always showed the best germination.

Pennisetum alopecuroides : The seeds from all the collection sites except 30W showed a very high level (80–100%) of germination at all the temperature levels tested. The germination of the seeds from 30W was low (60–74%) at 15° and 30°C, while at 20° and 25°C, it was as high as those from the other sites. The optimum temperature for germination was in the range from 20° to 25°C irrespective the seed origin.

Discussion

The environmental differences in the seed collection sites chosen for this study seem to be mainly caused by altitudinal characteristics, because the collection sites were chosen along a line of nearly the same latitude. The meteorological conditions, however, are clearly different on the Japan Sea side and on the Pacific Ocean one, and the difference is evident in many meteorological factors. In the present data, the difference was found in the minimum temperature at ground surface level and in the depth of snow cover.

A relation between the germination behavior of seeds and climate has been reported by some workers[1,2,4], and it has been suggested that environmental temperature plays an important role in the germination behavior of seeds. From the present data, the optimum temperature for the germination of the weed seeds was suggested to be about 25°C in seeds from the sites below 300m altitude except *P. oleracea*, but varied in the seeds from the sites above 300m.

In plants in high altitudes compared to those in low altitudes, a transference of the optimum temperature for seed germination to a lower level or an extension of that to a lower range was observed on *S. glauca*, *P. oleracea*, and *P. alopecuroides*. These changes correspond to the lower environmental temperature in proportion to the elevation of the habitat, and seem to be induced adaptively. Among these three species, *P. alopecuroides* is considered to have a germination ability in the widest range of temperature.

In the field, the charactor of the low-temperature requirment for seed germination is considered to result in the suppression of germination within the year, and to result in a high level of germination the next spring. Of the weeds tested here, *R. islandica*, *C. album* except for those from 2000E, *S. viridis* from low altitudes, and *E. ferruginea* required a pretreatment at a low temperature for seed germination. The germination of *R. islandica* and *C. album* seeds, especially those from high altitudes, were much accelerated by such intense stratification as much lower temperatures or longer periods of exposure. On the other hand, only *S. viridis* required the stratification for the germination of the seeds from low altitudes, and their germination behavior was similar to that of *Polygonum reynoutria* seeds[8]. The reason for this difference in seed germination behavior between *S. viridis* and the other species is not clear at present.

In *C. album* seeds from 1500E, a stratification at −1°C for 10 days preceding the germination test resulted in a higher level of germination than the treatment at 4°C, and the germination rate was nearly equal to that of the seeds collected from 1500E in January. These reuslts suggest that the low temperature in the field during winter plays an important role in the seed germination of some species. SHIBATA and ARAIe[8] have reported the similar effect of winter temperature on seed germination of *Polygonum reynoutria*. The fact that *C. album* seeds from 2000E germinated fully at all the incubation temperatures without a stratification may suggest that the seeds had been already exposed to a low temperature for a satisfactory period to germinate at the collection time.

Most of the species tested here had different germination behavior on the Pacific Ocean side and on the Japan Sea side, and between the east and the west of Fossa Magna, although these seeds originated from the same altitude and the same latitude. In general, the germination behavior of the seeds from the western area appeared similar to those from a warmer habitat. This difference can probably be explained as a botanical element of the Japan Sea side, which according to plant-geographical considerations was induced by the unique environment of the area. Certainly, a relatively high temperature at ground surface level in winter in the west may be convenient for the survive of plants of southern origin, and for keeping their southern characteristics. Accordingly, the fact that *P. oleracea* seeds from 30W required such a high temperature as 35°C for their germination seems to be due to their southern characteristics.

Literatures

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