Mechanisms Regulating Seed Germination and Emergence of Some Summer Annual Weeds in Hokkaido

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One of the largest area of upland farming in Japan is located in eastern part of Hokkaido, where the upland farming was initiated in early days of modernization of Japan, with an attempt to introduce Western style farming.

Weed control was a big obstacle at the beginning because farmers who were settled in that area had no experience of large scale farming. Therefore, considerable attention has been concentrated to develop practical techniques of weed control, but only limited information has so far been available concerning ecological and physiological properties of weeds, particularly those related to germination and emergence. Prevalent species at present are mainly summer and winter annuals except few perennial ones.

Annual weeds propagate by seeds. Seeds of summer annuals usually do not germinate right after shedding even though environmental conditions are favorable for germination, because of the primary dormancy. Therefore the dormancy must have been broken before the germination takes place. Besides, there are many factors involved in the germination and emergence of seeds buried in soil. They are not yet completely clarified.[1]

In the present paper, (1) breaking of the primary dormancy in the field (2) germination behaviour of seeds in relation to temperature and light conditions after the primary dormancy is broken, and (3) comparison between the seasonal distribution of weed emergence actually observed in the field and that experimentally estimated, and induction of the secondary dormancy in buried seeds will be described with 3 important species of summer annual weeds, *Chenopodium album* L., *Echinochloa crus-galli* Beauv. var. *practicola* Ohwi and *Polygonum lapathiofolium* L.

Breaking of the primary dormancy in the field

In a laboratory experiment, the primary dormancy of seeds was broken easily by chilling them on moist filter paper at 10°C for a month in *Chenopodium album*, for 2 months in *Echinochloa crus-galli* var. *praticola*, and at 1° or 5°C for 2 months in *Polygonum lapathifolium*[2]. In the field, therefore, the dormancy breaking can occur under the moist and low soil temperature condition during the winter season, whenever the seeds in the soil layer or on the soil surface are exposed to such conditions required for breaking the dormancy.

Results of the field experiment[3] showed that the seed dormancy of *Chenopodium album* and *Echinochloa crus-galli* var. *praticola* was broken, more rapidly in the soil layer than on the soil surface, in the period from early November to early December before soil freezing occurred (Table 1). On the contrary, the seed dormancy of *Polygonum lapathifolium*

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* This study was undertaken by the author when he belonged formerly to the Hokkaido National Agricultural Experiment Station.

Table 1. Changes in percent germination of seeds in the course of natural breaking of primary dormancy in the field from winter to spring

Species	Place of seeds in the soil	Time of germination tests				
		Oct. 5 '70	Nov. 9 '70	Dec. 11 '70	Apr. 16 '71	May 15 '71
		%	%	%	%	%
Chenopodium album	Surface	4.8	23.0	36.2	4.2	12.9
	15 cm depth	4.8	66.8	62.4	41.3	85.1
Polygonum lapathifolium	Surface	0	1.5	67.0	97.6	92.9
	15 cm depth	0	0.3	41.0	97.5	85.4
Echinochloa crus-galli var. *praticola*	Surface	0	9.2	63.6	73.8	98.2
	15 cm depth	0	29.0	92.8	98.1	100

Note: 1) Seeds used for the experiment were placed on or in soil on October 5, 1970.
2) Percent germination was determined under diurnal temperature change (11–28°C) with 6000 lux fluorescent light for a month, but without light for *Polygonum* seeds.

was mostly removed in mid-April during the thawing of snow which had covered the field during the winter (Fig. 1).

These seeds which had lost the dormancy were supposedly remained in the field in the state of the enforced dormancy until soil temperature rises.

Germination behaviour in relation to temperature and light conditons after the primary dormancy is broken

Seeds were buried in the soil in Wagner pots and held in incubators at 5°C or 10°C. After 70–80 days, the seeds were taken out to examine their response to temperature conditions in the dark. Prior to the incubation, half the seeds were pre-irradiated by the sunlight for 5 minutes, and the temperature

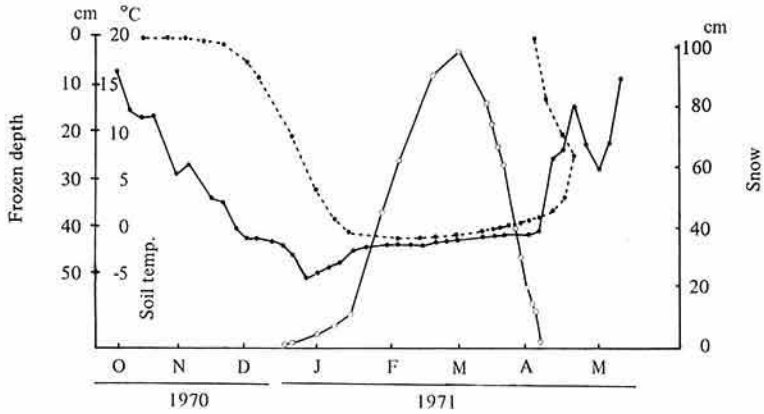

Fig. 1. Changes in the frozen depth of soil (●---●), the temperature of the soil surface layer (●—●) and the depth of snow cover (○—○) at the experimental place.

conditions included 21 treatments composed of 6 constant temperatures, 5°, 10°, 15°, 20°, 25° and 30°C, and 15 different combinations in alternating temperatures.

Percent germination was considerably influenced by the temperature conditions in the dark as shown in Fig. 2. In *Chenopodium album*, the germination rate was very low at any constant temperature, but it increased remarkably when 5°C was combined with higher temperatures in the alternating temperature treatment: that of 5°/30°C gave the highest germination, followed by 5°/25°, 5°/20°, 5°/15° and 5°/10°C in the decreasing order. In *Echinochloa crus-galli* var. *praticola*, very low germination rate at constant temperature of 5–20°C was increased by the combination with 25° and 30°C, and the increase was greater when lower temperature was combined with higher temperature, showing 100% germination at 5°/30°C. In *Polygonum lapathifolium* the reaction of seeds to temperature was similar to *Chenopodium album* at 15° and 20°C, and to *Echinocholoa crus-galli* var. *praticola* at 25° and 30°C respectively. Accordingly seeds of *Chenopodium album* need the most limited range of temperature for germination.

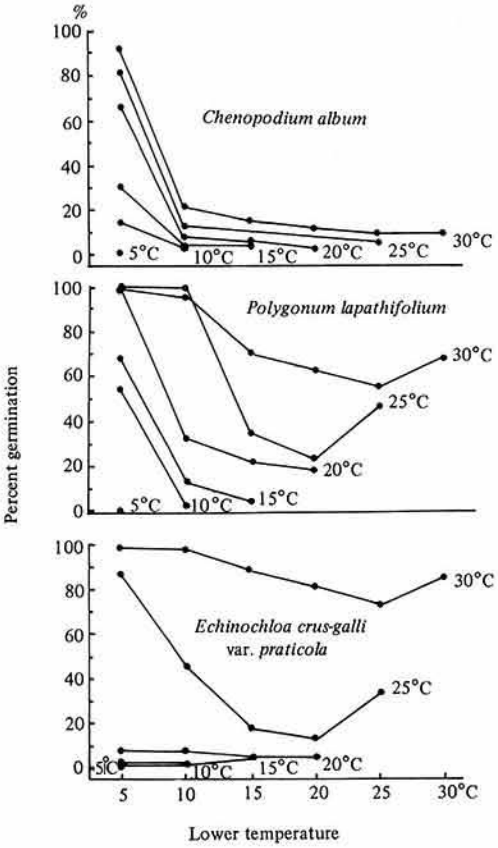

Fig. 2. Germination in relation to different temperature treatments in the dark, after the seed dormancy was broken.

Note: Lower temperatures (for 16 hr) in the alternating temperature treatments are shown on abscissa, and higher temperatures (for 8 hr) are shown on the right side of each line, indicating percent germination. The right hand terminal point on each line gives constant temperature treatment.

Pre-irradiated seeds showed a great increase in germination over the wide range of the temperature conditions examined[6].

Using the same materials used in the above experiment, some possible involvement of light in germination was experimentally ascertained. Most of the seeds were stimulated in their

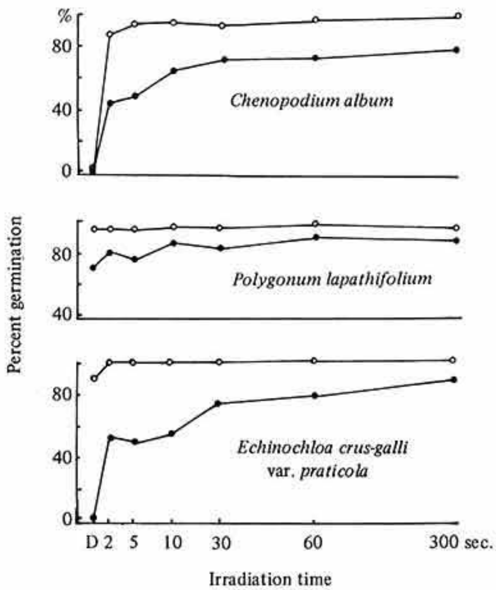

Fig. 3. Effect of red light (660 nm) irradiation (400 μW) on germination of seeds incubated at the alternating temperature of 25°C for 8 hr/10°C for 16 hr (○—○), and at 20°C constant (●—●) for 10 days after irradiation.

germination when an ambient temperature was maintained at 20°C and illumination of 400 μW per unit area was provided for 5 min. The most effective wave length of light was 660–690 nm for germination of *Chenopodium album* and *Echinochloa crus-galli* var. *praticola*, while only weak stimulation by 490–660 nm was found in *Polygonum lapathifolium* seeds[7].

A brief irradiation such as 400 μW at 660 nm for 2 sec was sufficient to elicit germination about 50% of the seeds, and that for 60 sec induced over 70% as seen in Fig. 3. On the other hand, high rate of germination was obtained at the alternative temperature conditions regardless of the pre-irradiation. It is evident, therefore, that light is a significant factor in germination of non-dormant seeds only on the occasion of the unfavorable temperature condition.

Seasonal distribution of weed emergence and secondary dormancy in buried seeds

Since it is necessary to know, in planning weed control measures, when buried weed seeds are likely to produce seedlings in quantity, seasonal emergence patterns of buried seeds of many species have been examined. In October 1970, the seeds were uniformly mixed with 15 cm depth of soil confined in pots. Seedling emergence was recorded for 3 years. In addition, number of viable seeds remaining in the soil was measured several times a year during that 3-year period.

It was revealed, as shown by the solid line in Fig. 4, that the potentiality of emergence was clearly characterized by a specific physiological status of individual species. The emergence of *Polygonum lapathifolium* and *Chenopodium album* seeds were found to reach a peak from the beginning of May to the beginning of June, whereas *Echinochloa crus-galli* var. *praticola* showed two major peaks, from the middle of May to the end of June, and in August respectively, though the former was smaller than the latter[4].

The dotted line in Fig. 4 shows the estimated curve of periodicity in germination. It was obtained by plotting the germination percentages which were estimated from Fig. 2 by taking into account the soil temperature observed as shown in Table 2.

Table 2. Soil temperature in the surface layer at the experimental place in 1971

Period	Maximum temperature	Minimum temperature
Apr. 19–Apr. 29	13.7°C	1.2°C
May 1–May 10	10.5	1.9
May 12–May 20	22.9	6.5
May 22–Jun. 1	20.1	9.9
Jun. 3–Jun. 9	22.1	10.7
Jun. 11–Jun. 20	24.1	11.7
Jun. 22–Jul. 9	23.7	15.8
Jul. 11–Jul. 21	21.8	15.3
Jul. 23–Aug. 8	28.9	18.9
Aug. 10–Aug. 24	23.9	16.4
Aug. 26–Sep. 9	22.1	14.0
Sep. 11–Sep. 19	21.0	13.1
Sep. 21–Sep. 30	18.8	9.9
Oct. 2–Oct. 10	17.7	7.6
Oct. 12–Oct. 20	15.8	4.8

Fig. 4 indicates that in *Chenopodium album* and *Echinochloa crus-galli* var. *praticola* the estimated curves of seasonal distribution of germination almost coincided with the actually observed patterns of emergence during the period from May to September. From the results it is evident that the seasonal emergence patterns of these weeds during the time from spring to summer are controlled mainly by the diurnal soil temperature variation in the soil surface layer. However, an apparent discrepancy between the actual pattern of emergence and the estimated curve of germination was recognized with *Polygonum lapathifolium* from June onward, and with *Chenopodium album* in October.

As it is quite probable that such discrepancies might have caused by the secondary dormancy occurring during the period from summer to autumn with *Polygonum lapathifolium* and in autumn for *Chenopodium album*, the ungerminated seeds remaining in various

Table 3. Changes in percentage of ungerminated viable seeds in the course of natural inducing and breaking of the secondary dormancy in the field

Species	Place of seeds in the soil	Time of germination tests in 1971					
		May 20	Jun. 22	Jul. 22	Aug. 25	Sept. 25	Nov. 26
	cm	%	%	%	%	%	%
Chenopodium album	0– 5	0	8.5	28.9	39.6	45.7	7.4
	5–10	0	5.6	23.5	51.0	37.0	8.3
	10–15	0	2.1	16.2	26.4	40.9	1.7
Polygonum	0– 5	0	41.7	90.0	100	100	50.0
lapathifolium	5–10	0.8	2.5	22.6	100	100	9.2
	10–15	0.6	0	3.0	99.5	100	1.5
Echinochloa	0– 5	0	0	0	44.9	86.2	0
crus-galli var.	5–10	0	0	0	35.7	68.4	1.4
praticola	10–15	0	0	0	10.0	63.4	13.9

Note: Ungerminated viable seeds were identified by the TTC test after 3 successive germination tests, namely, the test under the diurnal temperature change (10–25°C) with the sampled soil, the test with 5000 lux fluorescent light after removing soil, and finally the test with KNO_3 solution at 10^{-2}M after drying seeds.

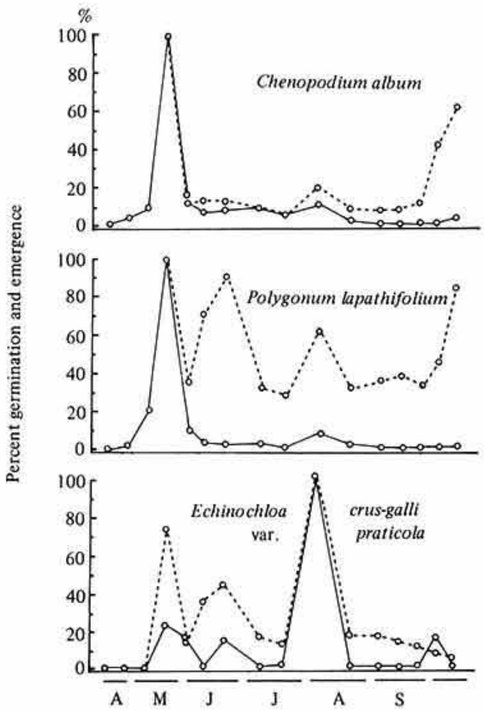

Fig. 4. Seasonal distribution of weed emergence actually observed in 1971 (○—○), and of weed germination experimentally estimated (○---○).

soil layers were taken out and incubated in the laboratory. As shown in Table 3, it seemed that the ungerminated seeds were in the state of thermodormancy; namely, they re-entered into a dormant state due to high temperature in the summer and the dormancy was terminated by the end of November as the temperature lowered. The seeds buried in shallow soil layer were exposed to the secondary dormancy faster than the deeply buried ones. Seeds buried in the soil, therefore, exhibited cyclic changes in dormancy[5].

Thus, the emergence pattern of these weeds can not be explained only by their germination response to soil temperature without considering the occurrence of secondary dormancy. Accordingly, it can be said that the emergence patterns of these weeds are governed by the interaction between soil temperature conditions and physiological state of seeds in the soil, mostly in the upper layer of soil.

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