Seasonal Change of Germination of *Poa crassinervis* Honda

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Abstract : Seasonal change in germination of *P. crassinervis* was compared to that of *P. annua* collected from the same habitat. Germination tests were made at 10, 15, 20, 25 and 30°C. To analyze the three phases of the germination process: the final cumulative germination percentage, the weighted mean germination ratio and the onset of germination, the cumulative seed germination curve was fitted to Richards' function model. *P. crassinervis* seeds germinated from late summer to early winter, while *P. annua* germinated throughout the year at 10°C. In both species, high cumulative germination percentage was found from August to December except for *P. crassinervis* seeds at 30°C. Cumulative germination curves of both species were very well fitted to Richards' function model. The time to reach maximum germination percentage in *P. crassinervis* was always shorter than that of *P. annua* when seeds were incubated at 10, 15, 20 and 25°C. An apparent seasonal dormant and non-dormant cycle and immediate germination were found in *P. crassinervis*. The germination characteristics of *P. crassinervis*

seemed to be disadvantageous for seedling establishment in a severely disturbed habitat.

Key words : *Poa crassinervis*, *P. annua*, Richards' function model, seasonal change of germination

Introduction

Poa crassinervis Honda is an annual winter weed distributed in drained paddy fields, upland fields, roadsides and gardens in western Japan. *P. annua* L., a closely related species of *P. crassinervis*, is a cosmopolitan weed and very adaptable. Many reports are found on the ecological and phenological characters of *P. annua*^{12,16)}, but no studies have been attempted on *P. crassinervis*.

The germination and dormancy mechanisms of seeds are of great adaptive importance in ensuring that seedling emergence occurs at the most advantageous time and place⁸⁾. Seed germination is one of the most critical developmental phases in the life cycle of a plant¹⁰⁾. Studies on the life cycles of many annual winter species such as *Viola arvensis* Murr.⁷⁾, *Capsella bursa-pastoris* L.⁵⁾, *Veronica federifolia* L.¹⁴⁾, *Lamium purpureum* L.³⁾ and *Lesquerella stonensis* Rollins⁶⁾ show that the seeds do not germinate during summer but begin germination in autumn. Weed seeds in soil go through annual dormant and non-dormant cycles and these responses are important life cycle adaptations to the habitat⁴⁾. Therefore, determining the seasonal

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change of germination is important to know the life history characteristics of the weed.

The functional approach to plant growth analysis has been applied to cumulative germination data¹⁵⁾. The Richards' function model which is one of the most expanded logistic functions is useful for fitting the cumulative seed germination curve^{9,11,13)}. Parameters of the final percentage of cumulative germination, the weighted mean germination ratio and the onset of germination may be pertinent to the analysis of ecological characteristics including the seedling establishment in the habitat. We use this model to analyze the germination characteristics of *P. crassinervis*.

The purpose of this study was to clarify the seasonal change of seed germination of *P. crassinervis*. Germination of this species was compared to that of *P. annua* which was collected from the same habitat.

Materials and Methods

Seed collection and burial in soil

Mature seeds of *P. crassinervis* and *P. annua* were collected from a winter cabbage (*Brassica oleracea* L. var. *capitata* L.) field at Takanabe, Miyazaki Prefecture (32°08'N, 131°31'E) on March 17, 1994. Both weeds were dominant in this field. Two variants of *P. annua*, an annual and a perennial, were reported¹⁶⁾, the *P. annua* we collected was the annual. After collection, the seeds of both species were dried in the laboratory. On May 6, 1994, about 10,000 seeds of each species divided into 12 lots were packed in 0.5 mm mesh cloths. Packed seeds were buried at a depth of 5–10 cm in the upland field of the Research Institute for Bioresources, Okayama University in Kurashiki. All buried seeds remained under that natural condition until the germination test was started.

Seasonal change of germination

Before burial treatment, seed germination of the two species was tested on May 1, 1994. The germination test was conducted under five different temperatures, 10, 15, 20, 25 and 30°C (12 h dark/12 h light, 6,200 lux) for 20 days. Seeds were placed on moist filter paper in 9 cm glass petri dishes, germination was recorded daily and germinated seeds were removed. Radicle emergence was the criterion for germination¹⁾. The test was conducted with three replications of fifty seeds for each species. The seeds buried in soil were dug up at about one month intervals from June, 1994 to May, 1995 and another germination test was made as above.

Analysis of cumulative germination curve

We used the Richards' function model to analyze the cumulative seed germination curve. The Richards' function defines a family of asymptotic curves including special cases of the monomolecular, autocatalytic (logistic) and Gompertz functions and is effective and flexible in fitting the plant growth curve¹¹⁾. It has been used by several authors to fit cumulative growth or germination data^{9,13)}. Estimated parameters were calculated to use the nonlinear optimum program of Simplex which utilized Fujii's method⁹⁾. Following Lehle and Putnam¹¹⁾, the forms of the functions were defined as:

$$W = A\{1 + b \exp(-kt)\}^{1/1-m} \quad \text{for } m > 1$$

$$W = A\{1 - b \exp(-kt)\}^{1/1-m} \quad \text{for } m < 1$$

where W is cumulative germination percentage at time t . The parameters of b , k and m were calculated by Simplex method to use the empirical initial values. The practically used range was as follows: $2 < b < 10$, $0.3 < k < 4$ and $1.0001 < m < 2.2$. A is the practical data of final cumulative germination percentage. According to Richards¹³⁾, the area under the curve is calculated as $A^2 k(2m +$

$2)^{-1}$. Hence the mean height is $A^2K(2m+2)^{-1}/A$. An alternative interpretation of this parameter is the weighted mean cumulative germination ratio (R). R indicates germination percentage per day throughout the whole period of germination and was defined as:

$$R = Ak(2m+2)^{-1}$$

According to Fujii *et al.*⁹⁾, the onset of germination (T_s) indicating the time required to germinate one seed when germination percentage is 100% was defined as:

$$T_s = \ln[\{1/n\}^{(1-m)} - 1]/b/(-k) \quad \text{for } m > 1$$

$$T_s = \ln[\{1 - (1/n)^{(1-m)}\}/b]/(-k) \quad \text{for } m < 1$$

where n is the number of seeds used in the germination test.

Results and Discussion

Seasonal change of germination

Seasonal change of cumulative seed germination percentage of the two species is shown in Fig. 1. No seeds of either species germinated at any temperature before burial treatment in May, 1994; all were in the primary dormant state. In *P. crassinervis*, 26% of the seeds germinated at 10°C and 5% at 15°C after one month burial but none at the other temperatures. In July after two months burial, more than 95% of the *P. crassinervis* seeds germinated at 10 and 15°C and 71% at 20°C. *P. crassinervis* seeds buried for one or two months germinated at lower temperatures, and the maximum temperature for germination gradually increased with the duration of burial. From August to November, 94–100% of the *P. crassinervis* seeds germinated at 10–25°C, but few of them germinated at 30°C in any season. From November to January, their cumulative germination percentage drastically dropped at all temperatures and from January to March, the seeds hardly germinated at any tempera-

Fig. 1. Seasonal change of cumulative germination percentage in *P. crassinervis* and *P. annua* seeds following 0 to 372 days of burial.

Seeds of both species were buried on May 6, 1994 and dug up at one month intervals. Germination tests were conducted at 10, 15, 20, 25 and 30°C for 20 days.

ture. In May, 1995, about 60% of the *P. crassinervis* seeds germinated at 10 and 15°C. Thus, seasonal change of dormant and non-dormant cycle was clearly recognized in this species.

In *P. annua*, 90, 16 and 5% of the seeds germinated at 10, 15 and 20°C after one month burial, respectively. After two months burial, 86% germinated at 10 and 15°C, and 83% at 20°C. These seeds also germinated at lower temperatures after one or two months burial and germinated well from August to October. At 30°C in which temperature the *P. crassinervis* seeds germinated little, 20–66% of the *P. annua* seeds germinated. In November, cumulative germination percentages at each temperature temporarily decreased although the reason for this is not clear. From January to February, cumulative germination percentage dropped at all

temperatures. At 10°C, 19–42% of the *P. annua* seeds germinated from January to March: they hardly germinated at the other temperatures in March. In May, 1995, 86–95% of the *P. annua* seeds germinated at 10, 15 and 20°C; thus these seeds germinated throughout the year at 10°C.

In June after one month burial, higher cumulative germination percentages were found in *P. annua* than in *P. crassinervis*, indicating that the primary dormancy of it may be deeper than that of *P. annua*. The same result was found in a previous study on the effect of storage temperature and period on the germination of freshly harvested seeds of *P. crassinervis*¹⁷⁾.

From August to December, high cumulative seed germination percentages were found at the wide ranging temperatures except for 30°C of *P. crassinervis*. The primary dormancy of seeds in both species seemed to be broken in this period, and the maximum and range of temperature for germination increased as shown in *Arabidopsis thaliana* (L.) Heynh.²⁾ and *L. stonensis*⁶⁾. Dormant seeds of some annual winter weeds afterripen at high temperature and their primary dormancy is broken^{1–3)}. High summer temperature is required for completion of the life cycle³⁾ and for *P. crassinervis*, 30°C was required to break primary seed dormancy¹⁷⁾.

When the seeds of winter annuals such as *Lamium amplexicaule* L.³⁾, *V. federifolia*¹⁴⁾, *C. bursa-pastoris*⁵⁾ and *L. stonensis*⁶⁾ which fully afterripen were exposed to low temperature, these seeds went into a secondary dormant state. From January to April, *P. crassinervis* and *P. annua* seeds might be in a secondary dormant state (Fig. 1). In December, final germination percentage of *P. crassinervis* at 20 and 25°C dropped drastically, but that of *P. annua* seeds did not, germinating

throughout the year at 10°C (Fig. 1). The degree of secondary dormancy seemed to be stronger in *P. crassinervis* than in *P. annua*.

Analysis of cumulative germination curve

In Fig. 2, cumulative seed germination curves at 10, 15, 20 and 25°C fitted to Richards' function model are shown from September to December. All curves were simulated for $m > 1$ and were very well fitted to this model. The time to reach the maximum germination percentage of *P. crassinervis* seeds was always shorter than that of *P. annua* at any temperature (Fig. 2). The weighted mean germination ratio (R) and the onset of germination (Ts) calculated by Richards' function are shown in Fig. 3; both were affected by the test temperature. *P. crassinervis* seeds tested at 20 and 25°C initiated germination within five days and the highest weighted mean germination ratios (59–69%) were found in October and November. In *P. annua*, the seeds tested at 20 and 25°C initiated germination within five days, and those tested at 30°C within four days. R of *P. annua* showed 35–61% at 20 and 25°C from September to December except for November. From September to November, R of the *P. crassinervis* was higher than that of *P. annua* at 10–25°C except for the September test at 25°C. The optimum temperature for germination of *P. crassinervis* seemed to be 20 and 25°C during the autumn.

P. crassinervis seeds had a clear seasonal dormant and non-dormant cycle. According to Baskin and Baskin⁶⁾, *L. stonensis* the narrowly endemic weed native to the Central Basin of Tennessee germinated only in autumn in the field. They referred to this species as an obligate winter annual. When the seeds are exposed to low temperature in winter, they enter secondary dormancy and do not germinate. Other narrowly endemic winter annuals such as *Leavenworthia* spp.

Fig. 2. Comparison of cumulative germination curves of *P. crassinervis* and *P. annua* seeds tested at 10, 15, 20 and 25°C from September to December, 1994.

These curves were fitted to the Richards' function model.

Fig. 3. Effect of temperature on the weighted mean germination ratio (R) and the onset of germination (Ts) culculated by Richards' function model resulting from fitting to cumulative germination curves of *P. crassinervis* and *P. annua*.

Curve fitting was conducted from September to December, 1994.

and *Phacelia dubia* (L.) Trel. var. *interior* Fern. are also obligate winter annuals⁶⁾; *P. crassinervis* can be referred to as an obligate winter annual weed based on the results of this study. In contrast, geographically widespread winter annual weeds are of obligate and facultative types; a facultative type does not show secondary dormancy. *P. annua* tested in this study is thus referred to as a facultative winter annual weed.

P. crassinervis seeds germinated more quickly and immediately than *P. annua* seeds under an adequate germination temperature. *P. crassinervis* seldom occurs in a severely trampled or disturbed site, and its germination characteristics seem disadvantageous for seedling establishment in a severely disturbed habitats.

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References

- 1) Baskin, J.M. and C.C. Baskin 1976. High temperature requirement for afterripening in seed of winter annuals. *New Phytol.* **77**, 619-624.
- 2) Baskin, J.M. and C.C. Baskin 1983. Seasonal change in the germination responses of buried seeds of *Arabidopsis thaliana* and ecological interpretation. *Bot. Gaz.* **144**, 540-543.
- 3) Baskin, J.M. and C.C. Baskin 1984. Role of temperature in regulating timing of germination in soil seed reserves of *Lamium purpureum* L. *Weed Res.* **24**, 341-349.
- 4) Baskin, J.M. and C.C. Baskin 1985. The annual dormancy cycle in buried weed seeds: A Continuum. *BioScience* **35**(8), 492-498.
- 5) Baskin, J.M. and C.C. Baskin 1989. Germination responses of buried seeds of *Capsella bursa-pastoris* exposed to seasonal temperature changes. *Weed Res.* **29**, 205-212.
- 6) Baskin, J.M. and C.C. Baskin 1990. Seed germination biology of the narrowly endemic

- species *Lesquerella stonensis* (Brassicaceae). Plant Species Biology **5**, 205-213.
- 7) Baskin J.M. and C.C. Baskin 1995. Variation in the annual dormancy cycle in buried seeds of the weedy winter annual *Viola arvensis*. Weed Res. **35**, 353-362.
 - 8) Bewley, J.D. and M. Black 1982. Seeds: Physiology of development and Germination. Plenum Press, New York. pp. 175-177.
 - 9) Fujii, Y., T. Shibuya and T. Yasuda 1990. Methods for screening allelopathic activities by using the logistic function (RICHARDS' function) fitted to lettuce seed germination and growth curves. Weed Res, Japan **35**, 353-361. (in Japanese with English summary)
 - 10) Koller, D., M. Sachs and M. Negbi 1964. Germination-regulating mechanisms in some desert seeds. VIII. *Artemisia monosperma*. Plant & Cell Physiol. **5**, 85-100.
 - 11) Lehle, F.R. and A.R. Putnam 1982. Quantification of allelopathic potential of sorghum residues by novel indexing of Richards' function fitted to cumulative cress seed germination curves. Plant Physiol. **69**, 1212-1216.
 - 12) Lush, W.M. 1989. Adaptation and differentiation of golf course population of annual bluegrass (*Poa annua*). Weed Science **37**, 54-59.
 - 13) Richards F.J. 1959. A flexible growth function for empirical use. Journ. of Experimental Botany. **29**, 290-300.
 - 14) Roberts, H.A. and J.E. Neilson 1982. Role of temperature in the seasonal dormancy of seeds of *Veronica hederifolia* L. New Phytol. **90**, 745-749.
 - 15) Thompson, C.R., C.T. Donald and S. Bahman 1994. Germination characteristics of Sulfonylurea-resistant and -susceptible Kochia (*Kochia scoparia*). Weed Science **42**, 50-56.
 - 16) Warwick, S.I. 1979. The biology of Canadian weeds. 37 *Poa annua* L. Can. J. Plant Sci. **59**, 1053-1066.
 - 17) Watanabe, O., T. Enomoto, K. Nishi, T. Matano and T. Tominaga 1996. Effect of storage temperature and period on seed germination of *Poa crassinervis* Honda. Weed Res., Japan **41**(2), 116-119.

ツクシズメノカタビラの発芽の季節変化

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摘 要

ツクシズメノカタビラは西日本に分布に限られ、水田、畑、路傍や街路樹の植え込みなどに生育している。一方、本種に近縁なズメノカタビラは世界的に分布する。本研究ではツクシズメノカタビラの発芽の季節変化をズメノカタビラのそれと比較した。宮崎県の畑地から採集した両種の種子を5月6日に埋土し、翌年の5月まで約1カ月おきに掘り出して10、15、20、25および30°C（12時間明暗）で発芽試験を行った。また、累積発芽曲線に

最も拡張されたロジスティック関数の一つであるRichards関数をあてはめ、最終発芽率、平均発芽速度（1日当たりの発芽率）および発芽開始時間のパラメーターで発芽試験の結果を解析した。

埋土処理を行わなかった両種の種子はまったく発芽せず、一次休眠の状態にあった。ツクシズメノカタビラは8月から12月にかけて10~25°Cで高い発芽率を示したが、30°Cではどの季節でもほとんど発芽しなかった。また、12月から1月にかけてツクシズメノカタビラの発芽率はすべての温度で急激に低下し、2月から3月にかけてほとんど発芽しなかった（Fig. 1）。これは種子が二次休眠に入ったためであると考えられる。ズメノカタビラも8月から12月にかけて10~25°Cで高い発芽率を示し、30°Cでも50%前後発芽した。冬季の発芽率の低下はツクシズメノカタビラよりも鈍く、10°Cでは一年を通して発芽した。

Richards関数から計算した平均発芽速度（R）は両種とも秋から冬にかけて20~25°Cで最も高かつ

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た。ツクシスズメノカタビラの平均発芽速度はスズメノカタビラよりも常に高かった。これはツクシスズメノカタビラの種子が秋に一斉に発芽することを示している。この性質は攪乱程度の高い生育地では実生の定着に関してスズメノカタビラより不利

であるように思われる。

キーワード：ツクシスズメノカタビラ，スズメノカタビラ，Richards 関数，発芽の季節変化