Seed dormancy and germination of Shaggy soldier (*Galinsoga ciliata* Blake.) and Common lambsquarter (*Chenopodium album* L.)

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ABSTRACT

Laboratory experiments were carried out with seeds of *Galinsoga ciliata* and *Chenopodium album* in 1998, 2000 and 2001. The study involved germination of non-dormant seeds in the light and the dark at 5–30°C, the germination energy at 15, 24, and 33°C, and the primary dormancy of seeds matured during the period from July to October. Both weeds germinated better in the light compared to the dark. Seeds of *G. ciliata* germinated at 10–33°C. Germination exceeding 85% was recorded at 12–28°C. *Ch. album* germinated in a wider temperature interval (5–33°C). Maximum germination (75%) was obtained at 18°C. A very high germination energy of *G. ciliata* seeds was found at 24°C. At this temperature, 89% of seeds germinated during the second and third day of the germination test. Seeds of *Ch. album* had a low germination energy at 15 and 24°C. The germination energy was high only at 33°C, however, the total germination reached at this temperature was only 26.5%. Both *G. ciliata* and *Ch. album* formed primary dormant seeds during all three testing years. The length of primary dormancy varied from 10 to 100 days depending on the date of ripening and on the year. The longest primary dormancy was found with early ripened seeds (July and August).

Keywords: weed biology; seeds; dormancy; germination; Shaggy soldier; *Galinsoga ciliata*; Common lambsquarter; *Chenopodium album*

Late emerging weeds, including *G. ciliata* and *Ch. album,* propagate only generatively. *G. ciliata* and *Ch. album* have a great generative potential. Individual plant may create from a few score up to hundreds of thousands of seeds (Holm et al. 1977). The seeds can persist in the soil for a long time (Tyšer 1998).

Weed seeds germination is strongly influenced by temperature (Ramirez Santa Pau and Diaz de Gueren 1995). There are three cardinal temperature points (minimum, optimum and maximum). The temperature points of the late spring weeds are higher in comparison with other weeds. The respective values can vary in the dependence on the origin of seeds and their age. Minimum temperature influences the time of emergence and the possible occurrence in field crops. Optimum and maximum germination temperatures are generally lower than optimum and maximum temperatures for growth (Procházka et al. 1998).

The light is not always necessary to generate germination (Mikulka and Chodová 2003). However, some weeds germinate better in the light than in the dark and conversely (Pons 1992, Jensen 1995, Ku et al. 1996). Seeds can be positively or negatively photoblastic. In particular, germination is affected by far red radiation (FR, wave length cca 660 nm). FR radiation affects the phytochrome present in seeds. Germination depends on the presence of the active phytochrome form (P_{fr}). Its level implicating germination shows significant differences between plant species. In positively photoblastic seeds, phytochrome is inactive (P_r) or the P_{fr} level is low and FR is essential to induce generation of the appropriate amount of P_{fr}. Negative photoblastic seeds possess the P_{fr} level high enough and FR radiation may lower this level (Borthwick et al. 1969). Photoblastic seeds properties are of an adaptable importance. The positive photoblastic seeds have little stock stuff and therefore the germinating plants have to reach the proper conditions for their autotrophic existence as soon as possible. A negative reaction to the light becomes effective under conditions that are not suitable for germination (appropriate soil moisture), deep under the soil surface in arid areas in particular (Procházka et al. 1998). The dormancy level often affects seeds photoblasticity (Baskin and Baskin 1994). Seeds of some weeds germinate only in the dark in a particular period of the year (Milberg 1994).

Dormancy is one of the important biological seeds properties that enables the weeds reproduced generatively to survive (Mikulka et al. 1999). Harper (1977) describes primary and secondary dormancy according to the time of origin. Primary dormancy is generated during the seed development. The length of primary dormancy is influenced by the endogenous effects of the mother plant genotype (Martinková and Honěk 1995, 1997), the degree of seeds maturity, the content of stock stuff, seed anatomy, enzyme activity, etc. (Hron and Vodák 1959). The most frequent source of the primary dormancy is a high content of inhibitory compounds in the seed, in the first place of abscisic acid, derivates of benzoic, jasmon, cinnamon acids, as well as coumarin (Procházka et al. 1998). Bedding of the seeds in soil or their stratification (placing the seeds in moist sand at a low tempera-

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Table 1. Time of seed harvest

Year	*Galinsoga ciliata*			*Chenopodium album*	
	July	August	November (October)	August	October
1998	3.7.	1.8.	3.10.	–	–
2000	20.7.	20.8.	20.9.	25.8.	1.10.
2001	25.7.	25.8.	25.10.	15.8.	1.10.

ture) cause the removal of these compounds (Matsuo and Kubota 1993, Kohout and Hamouz 2000). The breaking of primary dormancy is therefore influenced by the soil moisture (Yamasue et al. 1992), temperature and its fluctuation (Martinez Ghersa et al. 1997). The length of primary dormancy of many species depends to a high degree on the wheather conditions in the respective year (Kohout 1981, Barralis et al. 1988).

MATERIAL AND METHODS

Seeds of *G. ciliata* and *Ch. album* from maternal plants collected in East Bohemia (320 m above sea level, average year temperature 8.5°C, average total year precipitation 600 mm) were investigated. Soil type in this area is distric cambisol.

Germination

Matured seeds of *G. ciliata* and *Ch. album* collected in 2000 in the middle of September and at the beginning of October 2001 were placed in a dark and dry place at 20°C. The tests were carried out after the loss of primary dormancy (3 months after the harvest). Germination proceeded in Petri dishes on 3 water-soaked filter papers sheets. Seeds of *Ch. album* were separated from tunics which may cause the inhibition of germination (Holm et al. 1977). Germination (in climatic chambers) was evaluated after 14 days. Germination was observed at constant temperatures of 5, 8, 10, 12, 14, 16, 18, 20, 22, 24, 26, 28, and at 30°C, in the fluctuating light (14/10 h, 1000 lx) and in the dark. Germination in the dark proceeded in Petri dishes wrapped in 2 aluminium foils. Further, the germination energy was studied at constant temperatures of 15, 24, 33°C (14/10 h light period, 1000 lx). In this experiment, the germination was evaluated daily. The germinated seeds were taken off during the test. Each treatment involved 50 seeds in 4 replications. The results of both years were evaluated.

Table 2. Photoblastic effect on germination of *G. ciliata* and *Ch. album*

	Germination (%)	
	G. ciliata	*Ch. album*
Darkness	16.00	12.00
Light	98.00	67.00
D_{min} ($\alpha = 0.01$)	23.84	16.44

Dormancy

Matured seeds of *G. ciliata* and *Ch. album* were collected from July to October in 1998, 2000, and 2001. The dates of the individual collections are presented in Table 1. Seeds were kept in a dark, dry place at 20°C. Their germination was evaluated at 20 °C and at 14/10 light interval (1000 lx). Seeds of *Ch. album* were separated from their tunics. Seeds germinated on 3 water-soaked filter papers sheets in Petri dishes. The evaluation was done 7 days after placing the samples in climatic chambers. Each treatment involved 4 replications with 50 seeds each.

Statistics

Statistical data of all testing years were processed by analysis of variance according to Tukey *HSD* ($\alpha = 0.05$ and $\alpha = 0.01$) in the program Statgraphic Plus 4.0.

RESULTS

Germination

Germination in the light of *G. ciliata* was 98% and that of *Ch. album* was 67%, whereas in the dark it was only 16% and 12%, respectively (Figure 1). The differences found are significant (Table 2).

The temperature dependence of *G. ciliata* and *Ch. album* seeds germination is given in Figure 2. The seeds of *G. ciliata* started to germinate at 10°C in both years. Maximum germination degree (above 85%) was obtained at 12–28°C. Germination significantly decreased at 30°C ($\alpha = 0.01$).

Ch. album germinated in a wide temperature range (5–33°C). At 5°C, 4% germination was found but the increase of germination with increasing temperature was only slow. Significantly higher germination ($\alpha = 0.05$) was registered at about 14°C (39%). The highest germination

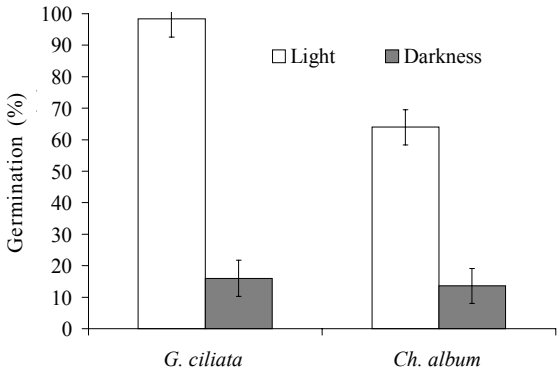

Figure 1. Photoblastic effect on germination of *G. ciliata* and *Ch. album*

value (75%) was achieved at 18°C. An additional temperature increase caused a decrease of germination (with α = 0.05) at 24°C. Only 13% germination was recorded at 30°C. The statistical data of both testing years for both weed species are shown in Table 3.

The seeds of *G. cilata* showed a high germination energy, in particular at 24°C (Figure 3). 89% seeds started to germinate during the second and third days. No significant increase was observed on the following days. At 15°C, the seeds started to germinate during the fourth day (4.5%). 96% seeds germinated within 7 days and no further statistical increase occurred (α = 0.05). At 33°C, the seeds started to germinate on the second day (0.5%). A conclusive germination increase was recorded only on the fourth day (48%). Further increase of germination was not significant (α = 0.05). The statistical data of both years are shown in Table 4.

The seeds of *Ch. album* showed a low germination energy at 15 and 24°C. Only at 33°C, the germination energy was high but the total germination was only 26.5%. The first seeds germinated within 24 hours at 24°C and

Table 3. Temperature effect on germination of *G. ciliata* and *Ch. album*

Temperature	Germination (%)	
	G. ciliata	*Ch. album*
5°C	0.00	4.00
8°C	0.00	9.00
10°C	39.00	9.00
12°C	87.00	24.00
14°C	94.00	39.00
16°C	95.00	45.00
18°C	97.00	75.00
20°C	99.00	62.00
22°C	97.00	63.00
24°C	98.00	51.00
26°C	97.00	38.00
28°C	90.00	27.00
30°C	67.00	13.00
D_{min} (α = 0.05)	14.54	22.62
D_{min} (α = 0.01)	16.96	26.39

33°C (3.5% and 6.5%, respectively). At 24°C, 66.25% of seeds germinated within six days. The following increase of germination was not significant (α = 0.05). A very low germination energy was recorded at 15°C. The first seeds (3%) started to germinate on the third day. The increase of germination was very low and a higher increase occurred only after 7 days. 58.5% of seeds germinated after 11 days and further increase was insignificant (α = 0.05). The statistical data on both years are given in Table 4.

Dormancy

G. ciliata created primary dormant seeds. Duration of primary dormancy varied from 10 to 100 days, depend-

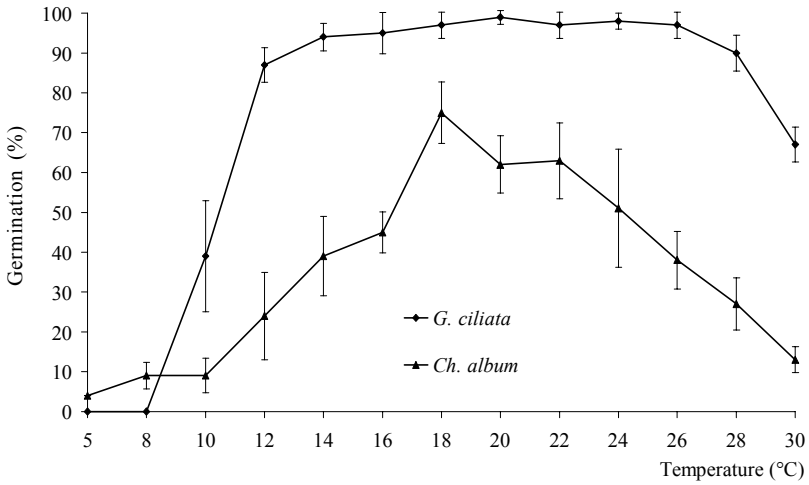

Figure 2. Temperature effect on germination of *G. ciliata* and *Ch. album*

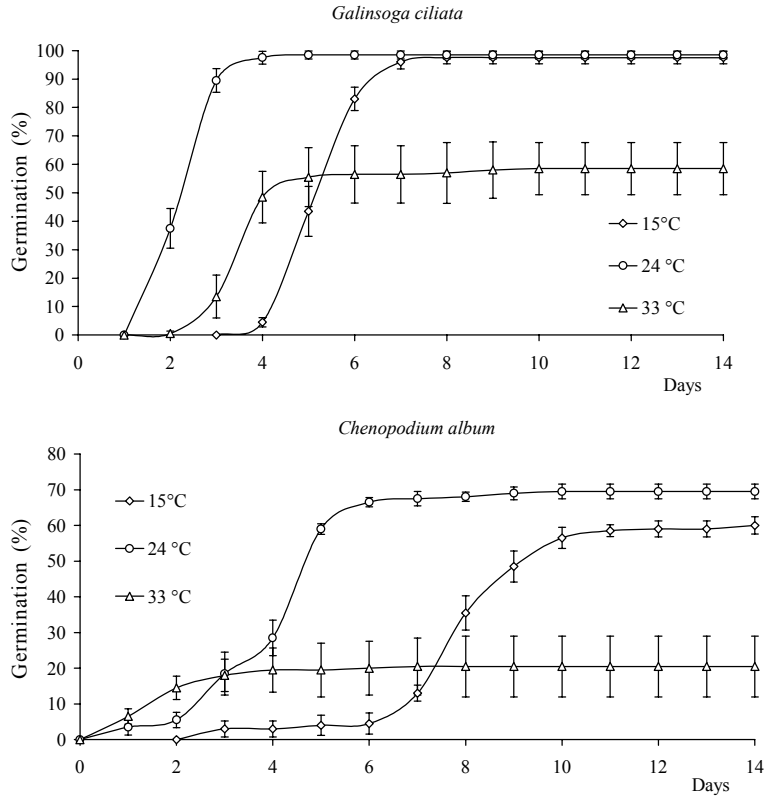

Figure 3. Germination energy of *G. ciliata* and *Ch. album* at different temperatures

ing on the maturity time and the year (Figure 4). The strongest primary dormancy was found with the seeds ripened in July and August. In the given years, the seeds of *G. ciliata* achieved the maximum of germination at an approximate time. After breaking the dormancy, the seeds kept their high germination (75–90%) till the end of the test. The statistical data from 3 years are given in Table 5.

Table 4. Temperature effect on germination energy (germination, %)

Days	*G. ciliata*			*Ch. album*		
	15°C	24°C	33°C	15°C	24°C	33°C
1	0.00	0.00	0.00	0.00	3.50	6.50
2	0.00	38.00	0.50	0.00	5.50	20.50
3	0.00	89.00	13.50	3.00	18.00	24.00
4	4.50	97.00	48.00	3.00	28.25	24.00
5	43.50	98.00	55.00	3.50	58.75	25.50
6	83.00	98.00	56.00	4.50	66.25	25.50
7	96.00	98.00	56.00	13.50	67.25	26.00
8	97.50	98.00	57.00	35.50	67.25	26.50
9	97.50	98.00	57.50	48.50	67.75	26.50
10	97.50	98.00	57.50	56.50	68.75	26.50
11	97.50	98.00	57.50	58.50	69.25	26.50
12	97.50	98.00	57.50	59.00	69.25	26.50
13	97.50	98.00	57.50	59.00	69.25	26.50
14	97.50	98.00	57.50	60.00	69.25	26.50
D_{min} ($\alpha = 0.05$)	10.97	9.47	24.11	8.04	8.23	17.93
D_{min} ($\alpha = 0.01$)	13.57	11.91	28.55	9.38	9.85	20.56

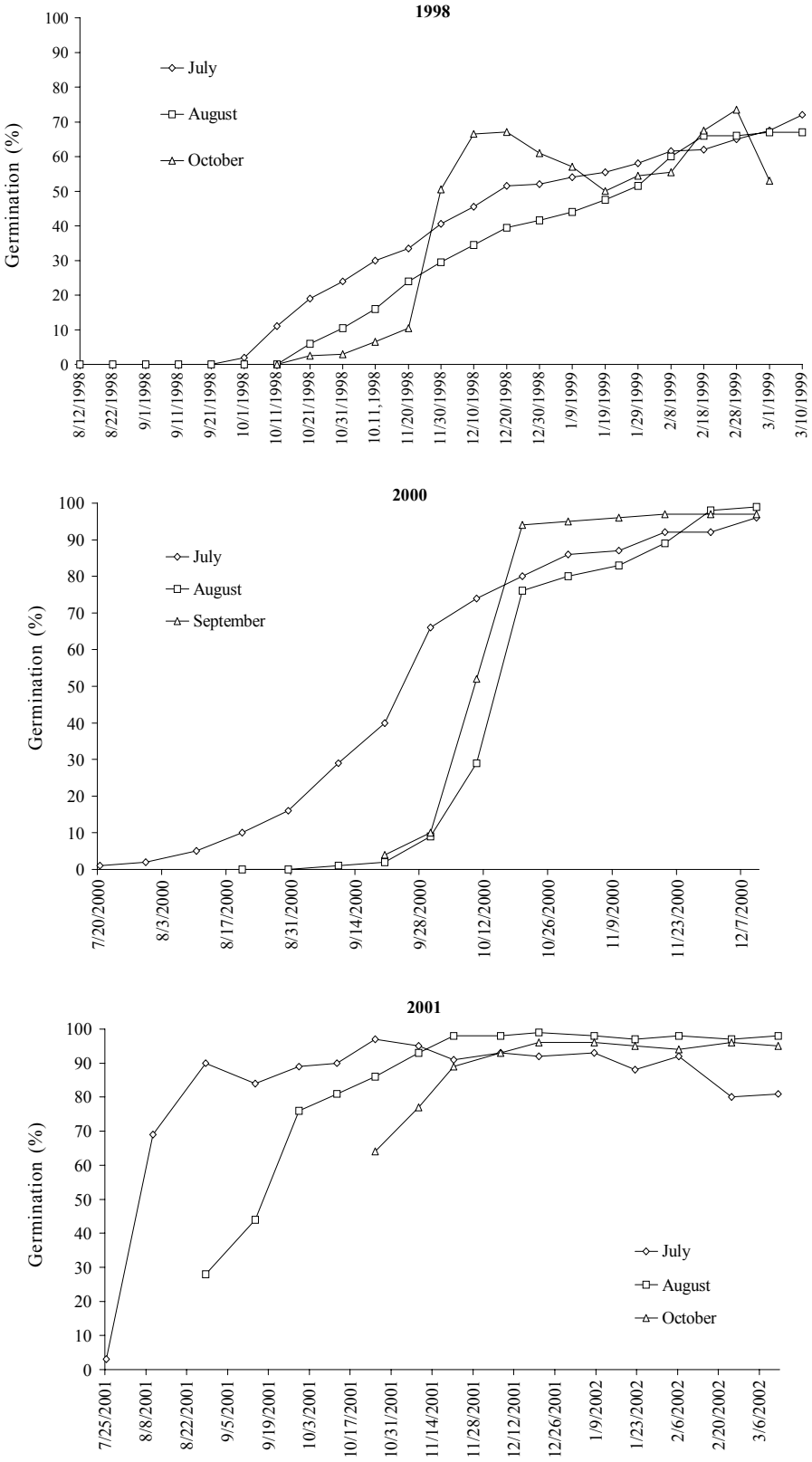

Figure 4. Dormancy in seeds of *G. ciliata* from different collections

The seeds of *Ch. album* matured in August and October showed a significant differentiation in the duration and strength of dormancy (Figure 5). The earliest ripened seeds (August) revealed a strong primary dormancy (50–100 days). The following increase of germination was slow with an average germination of 27% 150 days after ripening. The seeds of *Ch. album* ripened in October were partially dormant after the harvest (germination

Table 5. Influence of harvest date and seed age on dormancy of seeds

Days after harvest	*G. ciliata*			*Ch. album*	
	date of harvest				
	July	August	October (November)	August	October
	germination (%)				
0	1.33	9.33	22.67	0.50	14.50
50	37.66	36.66	67.66	6.00	72.00
100	64.00	70.66	83.00	18.50	73.50
150	77.00	78.66	90.33	27.00	70.00
D_{min} ($\alpha = 0.05$)			40.67		13.27

14.5%) but 50 days after the harvest, germination of these seeds achieved 72%. Such germination level was preserved till the end of the tests in both years. The statistical data are given in Table 5.

DISCUSSION

Galinsoga ciliata

The seeds of *G. ciliata* germinate at 10 to 33°C. According to Holm et al. (1977), fluctuating temperature has a positive effect on germination. Light is an important factor affecting the germination of seeds. Therefore, *G. ciliata* emerges mainly from the soil surface. That is a certain way of protection both against agricultural technologies and adverse weather conditions. If it comes to overlaying of the upper soil layer only by a few mm due to agricultural technologies or meteorological factors, new plants are able to grow.

In the tropical zone, as the place of origin of G. *ciliata,* the plant does not produce dormant seeds (Holm et al. 1977, Joshi et al. 1992, Sahoo 1998). Nevertheless, after its invasion into the mild zone, the adaptation to the respective conditions had to occur. Plants of *G. ciliata* are not able to survive frosty winter of the mild zone, and therefore a long primary dormancy is put forth. The

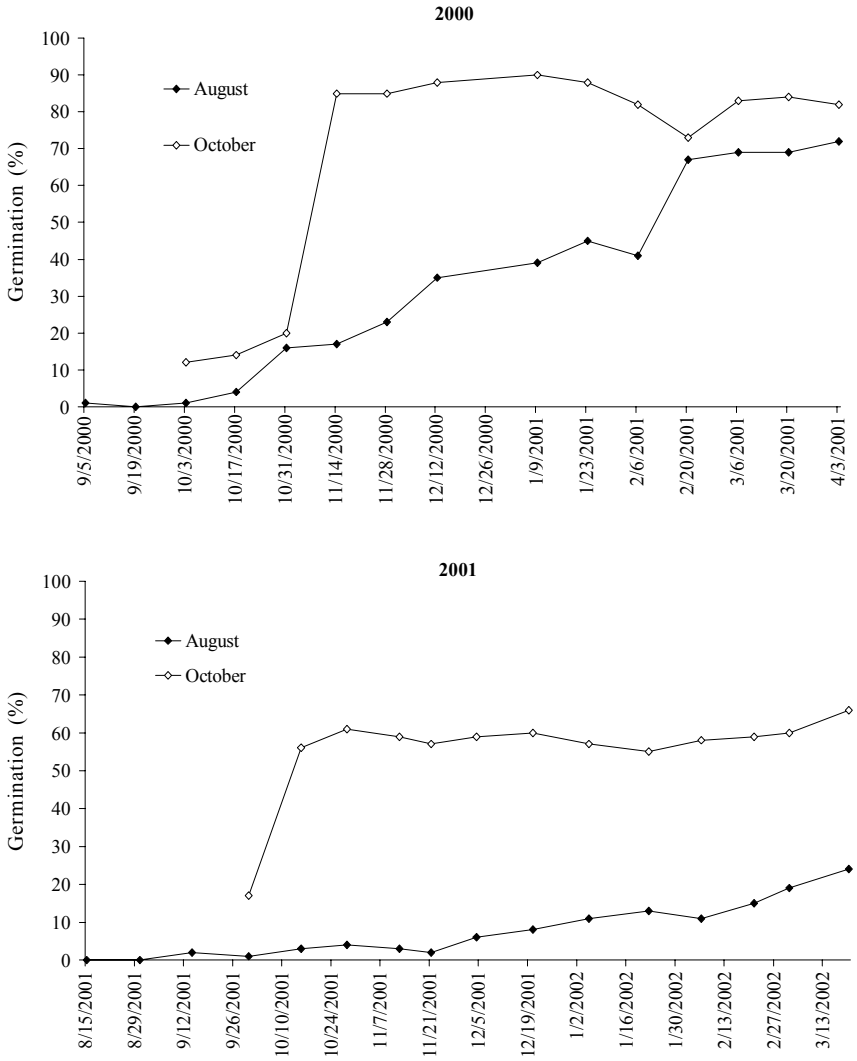

Figure 5. Dormancy in seeds of *Ch. album* from different collections

length of the primary dormancy of *G. ciliata* is affected by the length of the day on which the seeds become matured. A shorter length of the day leads also to a shorter length of primary dormancy of the seeds.

Chenopodium album

Optimum temperature for germination of *Ch. album* seeds depends on their origin and on the year. Optimum temperature for germination lies between 10–25°C (Özer 1996). The seeds ripened at higher altitudes have a wider temperature interval for germination (2–40°C). The seeds which matured in lower altitudes need at least 10°C for their germination. In our tests, the seeds of *Ch. album* started to germinate at 5°C and maximum germination was at 18–22°C. Our results show that the seeds of *Ch. album* are positively photoblastic. Still, some ecotypes were found having a higher germination rate in the dark (Holm et al. 1977). In spite of the fact that the seeds of *Ch. album* are positively photoblastic, they germinate better in the depth of 10 to 20 mm than on the soil surface (Grundy et al. 1996).

The length of primary dormancy of *Ch. album* seeds differs between various populations and can also vary between individuals of the same population (Holm et al. 1977). In general, the duration and strength of primary dormancy are strongly influenced by the length of the day during the seed ripening period. A long day promotes the production of strongly dormant seeds and conversely. Thus, *Ch. album* prevents its early ripened seeds from germination in late summer and at the beginning of autumn. The breaking of primary dormancy of the summer-ripened seeds comes in late autumn when there are no suitable temperature conditions for germination. Thus, the seeds of *Ch. album* can grow in spring in the next year.

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ABSTRAKT

Dormance a klíčivost semen pěťouru srstnatého (*Galinsoga ciliata* Blake.) a merlíku bílého (*Chenopodium album* L.)

V letech 1998, 2000 a 2001 byla sledována primární dormance semen *G. Ciliata* a *Ch. album* dozrálých v průběhu července až října, klíčivost nedormantních semen *G. ciliata* a *Ch. album* za světla a tmy při teplotách 5–30°C a energie klíčení při 15, 24, 33°C. Oba plevele klíčily lépe za světla než ve tmě. Semena *G. ciliata* klíčila při teplotách 10–33°C. Klíčivost přes 85 % byla zaznamenána při 12–28°C. Semena *Ch. album* klíčila při širším teplotním intervalu (5–33°C). Maximální klíčivosti (75 %) bylo dosaženo za teploty 18°C. Semena *G. ciliata* vykázala velmi vysokou energii klíčení zejména při 24°C. Za této teploty vyklíčilo 89 % semen během druhého a třetího dne. Semena *Ch. album* vykázala při 15 a 24°C nízkou energii klíčení. Pouze při 33°C byla energie klíčení vysoká, nicméně při této teplotě byla celková klíčivost pouze 26,5 %. *G. ciliata* i *Ch. album* vytvářely ve všech pokusných letech primárně dormantní semena. Délka primární dormance kolísala od 10 do 100 dní v závislosti na době dozrávání a ročníku. Nejdelší primární dormance byla zaznamenána u nejdříve dozrálých semen (červenec a srpen).

Klíčová slova: biologie plevelů; semena; dormance; klíčivost; pěťour srstnatý; *Galinsoga ciliata*; merlík bílý; *Chenopodium album*

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