Seed ecology of *Bromus sterilis* L.

Samenökologie von Bromus sterilis L.

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Summary

Bromus sterilis L. (barren brome) has become a troublesome weed of winter cereals in reduced tillage systems, mainly in South and North America, middle and Western Europe. In the Czech Republic, its importance has increased dramatically over the past 10 years. Barren brome is reported as a problem weed in other winter crops such as oil seed rape, in vineyards and in other cultivated places. In this study, the dormancy and germination under different temperatures, water and light regimes were investigated. Emergence from different depths and persistence in the soil profile were investigated under field conditions. The seeds of *Bromus sterilis* showed broad ecological valence to hydrothermal factors germinating in the wide range of 5 to 35 °C. Similarly, no strong effect on the germination in an environment with low water potential was observed. The response to light at various temperatures showed that seeds germinated better in darkness. The emergence declined significantly with burial depth (under 40 mm). The loss of primary dormancy was rapid in time and only 50% of the seeds germinated within 8 weeks after collecting from maternal plants. The seeds were not able to survive in the soil seed bank for a longer time and fall seeds lost viability 1 year after burial in a soil profile.

Keywords: *Bromus sterilis*, emergence, germination, seed dormancy, viability

Zusammenfassung

Bromus sterilis L. (Taube Trespe) hat sich in den letzten Jahren zu einem problematischen Unkraut im Wintergetreide bei reduzierter Bodenbearbeitung, vor allem in Süd-und Nordamerika sowie in Mittel- und Westeuropa entwickelt. Seine Bedeutung hat auch in der Tschechischen Republik in den vergangenen 10 Jahren stark zugenommen. In dieser Arbeit wurden die Dormanz und Keimung unter verschiedenen Temperatur-, Wasser- und Licht-Regimen untersucht. Auch der Auflauf aus unterschiedlichen Bodentiefen und die Lebensfähigkeit im Boden wurden unter Feldbedingungen untersucht. Die Samen der Tauben Trespe zeigten breite ökologische Valenz in Bezug auf hydrothermale Faktoren und keimten in einem breiten Temperaturbereich von 5 – 35 °C. Ebenso wurde kein starker Einfluss des niedrigen Wasserpotentials auf die Keimung festgestellt. Die Samen keimen unabhängig von der Temperatur besser im Dunkeln als im Licht. Der Auflauf nahm signifikant mit der Bodentiefe (unter 40 mm) ab. Ein relativ rascher Verlust der primären Dormanz wurde beobachtet und die Samen keimten 8 Wochen nach dem Absammeln von den Mutterpflanzen nur noch zu 50 %. Die Samen waren nicht imstande in der Samenbank für längere Zeit zu überleben. Nach einem Jahr im Boden waren die Samen nicht mehr lebensfähig.

Stichwörter: Auflauf, *Bromus sterilis*, Dormanz, Keimung, Lebensfähigkeit

Introduction

Bromus sterilis L. (*Anisantha sterilis,* barren brome) has become a troublesome annual weed of winter cereals in reduced tillage systems, mainly in South and North America, Middle and West Europe (Budd, 1981; Häfliger and Scholz, 1981; Fround–Williams, 1983; Eggers, 1990; Allen and Meyer, 2002; Andersson *et al.*, 2002; Mikulka *et al.*, 2005). This weed is very difficult to control especially in cereals, because of its fast population dynamics and the lack of efficient herbicides available. In the Czech Republic, its importance has increased dramatically over the past 10 years. Barren brome is reported as a problem weed in other winter crops such as oil seed rape, in vineyards and in other cultivated plants.

Primary dormancy of *B. sterilis* is very short (Hilton, 1984). Typically, *B. sterilis* emerges in early autumn, together with winter cereals and overwinters in the cereals stands (Koubková, 2001). The temperature optimum for germination ranges between 5 and 23 °C (Hilton, 1984). Mature dry seeds germinate best at a temperature of 15 °C without light as a trigger (BUHLER and HOFFMAN, 2000). Germination of freshly harvested seeds can be inhibited by red light (HILTON, 1987). Light induced dormancy was observed by POLLARD (1982) and PETERS *et al.* (2000). The seeds of *B. sterilis* are able to germinate from at 0 to 7 cm soil depths. Their persistence in soil is short (ROBERTS, 1986). KOUBKOVÁ (2001) reported that the seeds did not emerge after burial at 7 to 10 cm.

This research is focused on the influence of hydrothermal and light conditions on viability, germination and emergence of a selected Czech population of *Bromus sterilis*.

Material and Methods

Seeds of *B. sterilis* for experiments were collected in July 2011 and 2012 in one locality close to Dřemčice (50° 28′ 28″N, 13° 54′ 47″E) in the Czech Republic. Seeds were air dried after collection and stored dry in darkness at 20 °C in the lab until use.

Dormancy and germination laboratory tests

Seed germination was tested in 12-cm-diam Petri dishes. Into these dishes, smaller Petri dishes of 7-cm-diam were inserted upside-down and covered by cellulose filter paper. The cellulose filter paper was moistened with 20 ml of distilled water or polyethylene-glycole 6000 (PEG) solution. 25 seeds were placed per Petri dish in four replicates for each treatment. Two different light regimes (12 hour light / 12 hour darkness and permanent darkness) were used. Germination tests were carried out under fluorescent light (growth chamber Sanyo MLR-350H), providing a photo flux density of approximately 160 µE m^{-2} s^{-1} and R/ FR ratio of 15. For germination in complete darkness, the Petri dishes were wrapped in one layer of aluminium foil. Seeds were inspected for germination in Petri dishes for 21 days; germinated seeds were counted daily. The dishes in the darkness regime were inspected under green light of a wavelength of 532 nm, which does not affect the seed dormancy.

Each remaining not germinating seed was tested for viability by the tetrazolium chloride test. Seeds were placed in a Petri dish containing 10 ml of freshly prepared 0.2% solution of 2, 3, 5-triphenyl tetrazolium chloride and incubate for half an hour. The seeds coloured pink or red were considered viable.

A. Dormancy was tested at temperatures of 20 °C, 10 °C and 20/10 °C in one week intervals (first 2 months) and one month intervals until 12 months after harvest.

B. Germination was tested in a wide range of temperatures. Seeds were incubated at 0 °C, 5 °C, 10 °C, 20 °C, 25 °C, 30 °C, 35 °C, 40 °C, and 45 °C. The experiment was carried out with fully matured non-dormant seeds.

C. Effect of water stress on germination was simulated by usage of the PEG 6000 solution. Temperatures in climatic chambers were set to 20 °C and 10 °C. The concentrations of PEG 6000 solutions were calculated according to Michel and Kaufmann (1973): Ψ= -0.25, -0.5, -0.75, -1, -1.25, and -1.5 MPa for 20 °C and Ψ=-0.075, -0.1, -0.25, -0.5, -0.75, -1 for 10 °C. As the control variant, a germination in distilled water (Ψ= 0) was used. The experiment was carried out with fully matured non-dormant seeds.

The outputs of the B and C experiments were the seed germination values (%) and time, which is necessary for germination of 50% of all germinated seeds during an observation period for each treatment (T_{50}, days). T_{50} values were calculated using non-linear regression (Log-logistic four parameters model).

Dynamics of *Bromus sterilis* emergence under field conditions

B. sterilis seeds were sown in the autumn of 2012 on an experimental field of CULS (50°7'39.803"N, 14°22'28.136"E) at different depths (0, 2, 4, 8, and 12 cm) with four replications each. This experiment started at the 12th of September 2012. For each treatment and replication, 500 seeds per 1m² were sown. Emergence was counted every week on 1m². Soil moisture and temperature were recorded using automatic sensors (2 x Pt1000+MinikinTT and Gypsum block GB3+MicroLog SP3).

Persistence of *Bromus sterilis* seeds in a soil profile

A field trial on annual dynamics within a soil seed bank was established in 2012 starting on the 12th of September. 50 seeds were packed in plastic net bags together with 100 ml of soil. The seed bags were buried in different depths of a soil profile (4, 12, and 24 cm) in four replications. The bags were excavated monthly and viable seeds were recorded.

Analysis of variance was used for data evaluation in the Statistica program (version 10) and non-linear regression in R-Project (version 2.15.2).

Results

Dormancy and germination

A. The primary dormancy of *B. sterilis* seeds was very short, only one month (Fig. 1-3). The seeds did not germinate well in July. Just one week after the harvest of seeds from maternal plants, the germination was only 10% under 12/12 light/darkness and 30% in darkness at 20 °C. In following the 5 weeks, the germination increased to 60% under light and to 92% in darkness. In the following months, the differences in germination at 20 °C were not statistically significant between all light regimes at the probability level $\alpha = 0.05$ (Fig.1). Below 10 °C temperature, the germination one week after harvest was only 20% under light and 90% in darkness. Germination of seeds at 10 °C was lower, increased during the season but reached a maximum only 80% under the light regime. In general, the lower temperature inhibited the germination in July and caused the highest differences between the light and darkness regimes for a whole testing period ($F = 10.958$, $p>0.001$) (Fig. 2). At changing temperature regimes of 20 °C with light and 10 °C in darkness, the germination was 60% and 100% one week after harvest. Five weeks after the harvest, 93% of the seeds germinated under light and 100% in the darkness regime with changing temperatures. Germination in the months between August and June of the following year did not differ significantly ($F = 3.9064$, $p = 0.00019$) at 20/10 °C.

The seeds of *B. sterilis* germinated better in darkness than under a light regime at all tested temperatures.

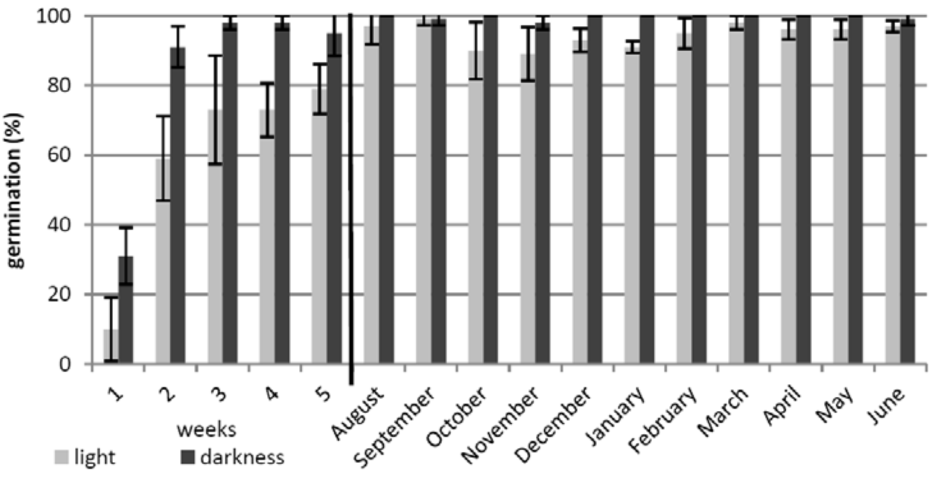

Fig. 1 Germination of *B. sterilis* at 20 °C.

Abb. 1 *Keimung von* B. sterilis *bei 20 °C.*

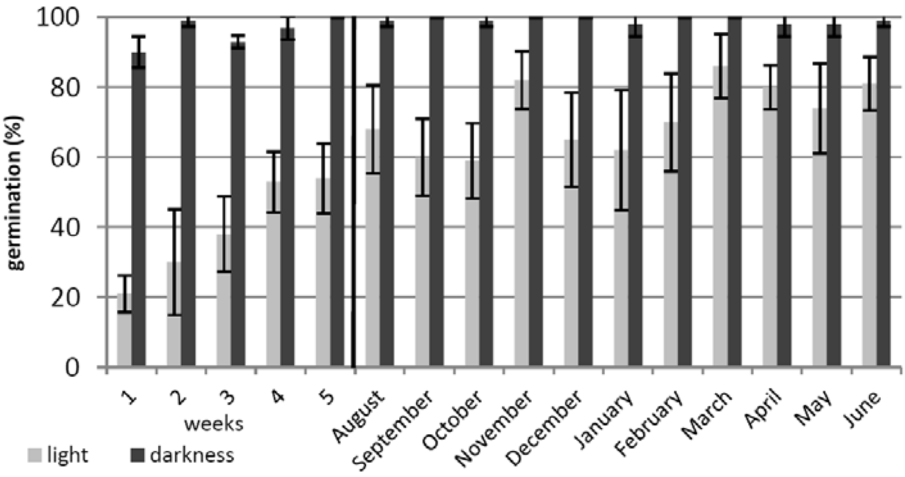

Fig. 2 Germination of *B. sterilis* at 10 °C.

Abb. 2 *Keimung von* B. sterilis *bei 10 °C.*

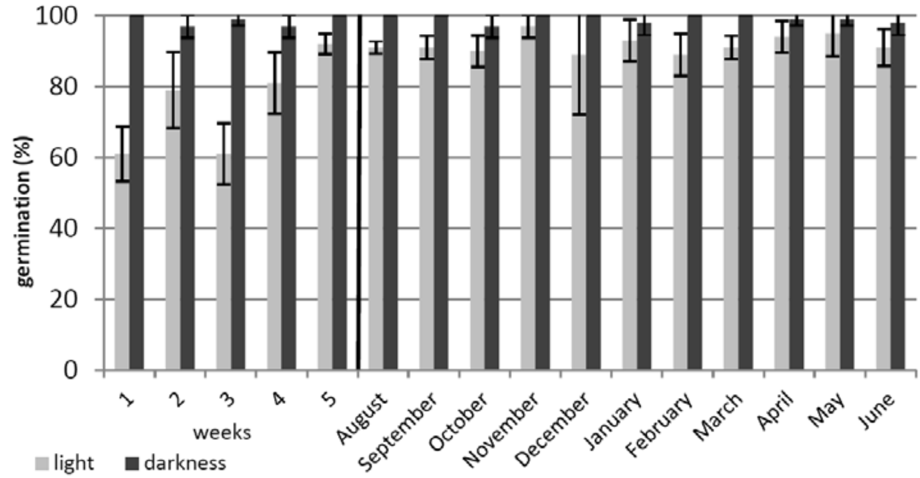

Fig. 3 Germination of *B. sterilis* at 20/10 °C.

Abb. 3 *Keimung von* B. sterilis *bei 20/10 °C.*

B. The seeds did not germinate at either very low or very high temperatures such as 0 °C, 40 °C, and 45 °C. The optimum temperature for germination ranged between 20 and 30 °C, when the germination reached 95 to 100%. The seeds of *B. sterilis* germinated usually better in darkness than in light. Only at 30 °C, the 12/12 light regime gave better germination than in darkness (Fig. 4).

The time which is necessary for germination of 50% of seeds under different temperatures is presented in Table 1. The seeds germinated most quickly at the temperatures 20 °C and 25 °C in both light regimes where 50% germination was achieved earlier than within one day. On the contrary, at 5 °C under both light regimes, the T_{50} value ranged between 5 and 6 days.

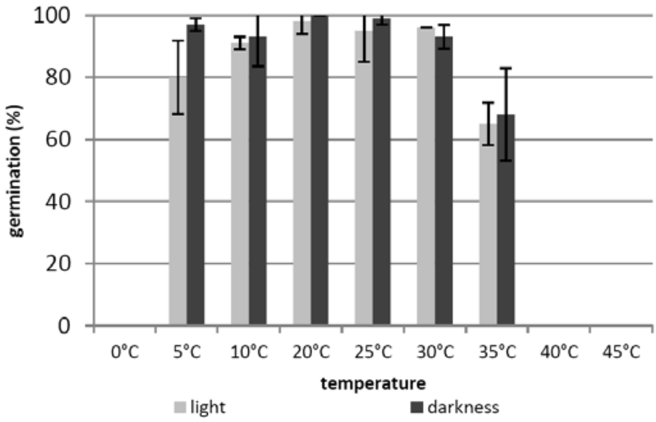

Fig. 4 Germination of *B. sterilis* seeds at different temperatures.
Abb. 4 *Keimung von* B. sterilis *bei verschiedenen Temperaturen.*

Tab. 1 T_{50} values (days) of *B. sterilis* at different temperatures.
Tab. 1 *T_{50}-Werte (Tage) für B. sterilis bei verschiedenen Temperaturen.*

	light		darkness	
temperature	T_{50}	SE	T_{50}	SE
5 °C	5.95	0.15	5.41	0.13
10 °C	3.93	0.096	2.09	0
20 °C	0.53	0	0.53	0
25 °C	0.41	0	0.63	0
30 °C	1.49	0.25	2.15	0.14
35 °C	1.64	0.006	0.21	0

T_{50}- number of days for germination of 50% seeds, SE- standard error

C. Germination tests under conditions of water stress showed big differences between two light regimes. Substantially higher germination rates were found in darkness, especially for lower water potentials. At 20 °C and darkness, the germination was up to -1.0 MPa similar to control (more than 80%). More intensive water stress caused a decrease of germination rate to 50% for the two lowest potentials. This is still a rather high germination rate showing that *B. sterilis* is able to germinate quite well under conditions of water shortage. Different results were obtained for germination in 12/12 light the regime where already the water potential of -0.25 substantially reduces the germination rate. A water potential of -0.5 MPa decreased the germination to a rate below 20%. At -1.0 MPa and lower, no germination was observed. As presented in Table 2, a decreasing water potential prolonged also the time needed for germination of 50% of the seeds.

At 10 °C, the impact of water stress on germination was higher compared to 20 °C. In permanent darkness, the water potential of -1.0 MPa decreased the germination to 50%. In the 12/12 light regime, the germination rate amounted only to 20% under a potential of -0.075 MPa. No germination was observed at the potentials -0.75 MPa and lower. The influence of water stress on the T_{50} value at 10 °C is presented in Table 3.

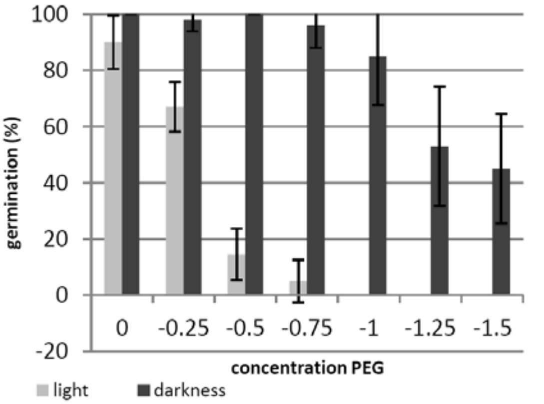

Fig. 5 Germination of *B. sterilis* at decreasing water potential at 20 °C.

Abb. 5 *Keimung von* B. sterilis *bei sinkendem Wasserpotential bei 20 ° C.*

Tab. 2 T_{50}-values (days) at decreasing water potential (Ψ).

Tab. 2 *T_{50}-Werte (Tage) bei sinkendem Wasserpotential* (Ψ).

temperature 20°C	light		darkness	
Ψ	T_{50}	SE	T_{50}	SE
0	0.53	0	0.53	0
-0.25	1.44	0.057	1.11	0.03
-0.5	2.37	0.075	1.64	0.09
-0.75	5.24	0.38	1.67	0.04
-1	4.69	0.11	2.72	0.03
-1.25	6.18	0.23	4.14	0.07
-1.5	14.49	0.015	4.63	0.045

T_{50}- number of days for germination of 50% seeds Ψ (MPa)- values of water potential, SE- Standard error

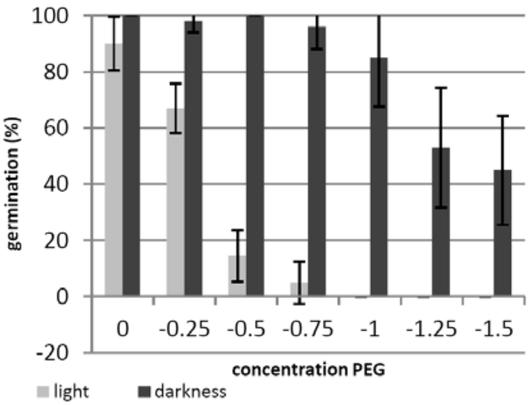

Fig. 6 Germination of *B. sterilis* at decreasing water potential at 10 °C.

Abb. 6 *Die Keimung der* B. sterilis *bei sinkendem Wasserpotential bei 10 °C.*

Tab. 3 T_{50}-values (days) at decreasing water potential.

Tab. 3 *T_{50}-Werte (Tage) bei sinkendem Wasserpotential.*

temperature 10°C	light		darkness	
Ψ	D_{50}	SE	D_{50}	SE
-0	3.93	0.096	2.09	0
-0,075	4.68	0.14	2.96	0.006
-0,1	4.84	0.09	3.33	0.018
-0,25	5.91	0.19	3.94	0.005
-0,5	5.99	0.24	4.48	0.017
-0,75	9.8	0.004	5.21	0.054
-1	0	0	5.64	0.13

T_{50}- number of days for germination of 50% seeds Ψ (MPa)- values of water potential, SE- standard error

Emergence under field conditions

Seed emergence decreased significantly with seed depth but also seeds placed on the soil surface emerged with lower rates than those at 2 cm depth (Fig. 7). This can be explained by a seed-soil contact and a lack of moisture necessary for seed imbibitions (BRUCKLER, 1983). Seeds were not able to emerge from 12 cm.

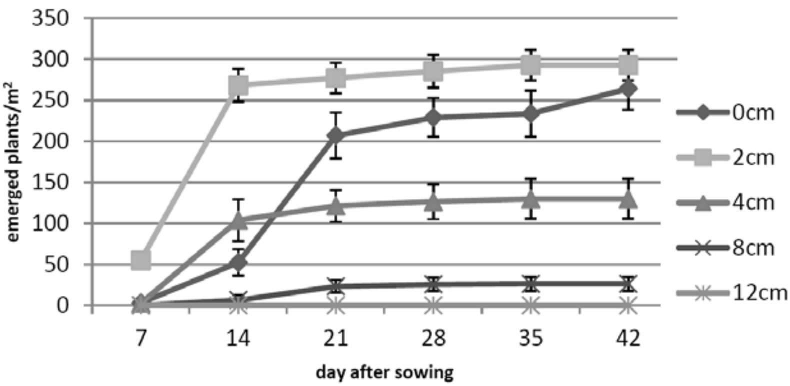

Fig. 7 Emergence of *B. sterilis* seeds from different depths of soil profile.

Abb. 7 *Auflauf von* B. sterilis *Samen aus unterschiedlichen Bodentiefen.*

Viability of seeds in a soil profile

The majority of seeds (95%) germinated within one month in a soil profile. After the winter, no viable seeds were found in bags buried in the soil profile. The average temperature in the soil (8 cm depth) was 1.07 °C during winter (December-February). Minimum temperature was reached at 9^{th} of December 2012 (-1.58 °C) after starting the project.

Discussion

Except for a few species that germinate mostly in a single flush, many grass weeds demonstrate residual dormancy that protracts germination over several waves during the cropping season or several cropping seasons (KON *et al.,* 2007).

Some *Bromus* species such as *Bromus rigidus* and *Bromus dianthus*, important to Southern Australia, start to germinate 8 months after maturity (KLEEMENN and GILL, 2013) to be able to overcome dry periods. On the contrary, *B. sterilis* and *B. tectorum* demonstrate a very short primary dormancy only (FROUND-WILLIAMS, 1981; PETERS, 2000; ANDERSSON, 2002).

Also for the tested population of *B. sterilis* in our study, a short and weak primary dormancy was documented.

Based on the results of all germination tests, our study confirmed that seed viability of *B. sterilis* was very high, ranging between 90-100%, similarly to results of HULBERT (1955), HARRADINE (1986), CHEAM (1987), BURNSIDE *et al.* (1996), LINTELL *et al.* (1999), but germination ability was inhibited by light. The inhibition by light was observed also for other relative species such as *B. rigidus* (KLEEMANN and GILL, 2006) and *Bromus dianthus* (MONTE and DORADO, 2011).

B. sterilis is probably more tolerant to drought during the germination at 20 °C (Fig. 3) than *Bromus tomentelus*, *Bromus inermis* and *B. dianthus* species studied by TAVILI *et al.* (2011), MONTE and DORADO (2011). TAVILI *et al.* (2011) tested the effect of water potential on germination of *Bromus inermis* and *Bromus tomentellus*, but because they used a temperature of 25 °C and different concentrations of PEG other than we did, the results are not fully comparable. Nevertheless, all *Bromus* species germination dropped under high water stress.

The field emergence of *B. sterilis* was very high, especially from upper soil layers. The best emergence was obtained from a depth of 2 cm (58.5%) followed by soil surface (53%). Similarly, MIKULKA and KNEIFELOVÁ (2004) found that seeds of *B. sterilis* emerged best from a depth of 2 cm (95%) and 4 cm (90%). For deeper layers, HOWARD (1991) published that seeds of *B. sterilis* emerged at arate of 5% from 10 cm depth. Also other species such as *B. tectorum* (THILL *et al.*, 1984; UPADHYAYA *et al.*, 1986) and *B. dianthus* (HARRADINE, 1986) did not emerge from soil depths below 15 cm.

The viability of *B. sterilis* seeds in a soil profile was less than one month which is in accordance with data published by FROUD-WILLIAMS (1981), ROBERTS (1986), and LINTELL *et al.* (1999). After one month, the majority of seeds germinates in a soil profile. *Bromus rigidus* and *Bromus dianthus* are more persistent in the soil seedbank (GILL and CARSTAIRS, 1988; KON and BLACKLOW, 1988; KLEEMANN and GILL, 2006; KLEEMANN and GILL, 2009) because of dormancy which prevents the germination for some time.

The study documents that the complex of ecological properties of *Bromus sterilis* (short dormancy, high germination rate especially from upper soil layers, tolerance to light, temperature and water regime) is an adaptation strategy which makes the species successful in current farming systems with a high share of winter crops and reduced soil tillage.

Acknowledgements

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