Seed production and germination in *Agrostemma githago*

Produkce a klíčivost semen u druhu *Agrostemma githago*

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Selected reproductive characteristics of *Agrostemma githago* (capsule number per plant, seed number per capsule, seed weight) are presented. Plants were grown in three different situations, i.e. (1) garden bed, (2) rye field and (3) winter wheat field in central Bohemia. Among-site differences were found in all the characteristics studied. Plants grown under garden conditions exhibited significantly higher values than those from both fields. The plants grown with rye produced fewer capsules with more and heavier seeds than those growing in the wheat field. Germination rate of seeds from the wheat field was significantly lower (about 10 %). Most of the freshly harvested seeds (74–87 %) germinated within 4 days. The germination was slower in older seeds, especially those stored for more than 30 weeks, but the total numbers of germinated seeds were similar in all age groups (85–95 %). The seed viability was high even 3 years after the harvest and reached 85 %.

Keywords: *Agrostemma githago*, seed production, germination, dry storage, seed age, seed viability

Introduction

In recent years, human impact caused obvious impoverishment of biological diversity. *Agrostemma githago* L. is one of the species endangered by agricultural procedures in many European countries (Thompson 1973). In the Czech Republic, this species was an abundant weed of cereals in lowlands and hills in the past (Dostál 1950). Its performance was reduced and the species became rare with improved seed cleaning and with crop rotations used in the last decades (Kropáč et Nejedlá 1956, Kohout 1985). Svensson et Wigren (1983) noted that, amongst other reasons, the decrease of *A. githago* is enhanced by its short dormancy and the absence of mechanism inhibiting germination in the soil; the species therefore does not form a seed bank.

Considering all the localities reported up to now, *A. githago* has been known from more than 250 fields of the Central European grid mapping (using the grid of 10×6 geographical minutes), which represents more than one third of the area of the Czech Republic (Slavík 1986). In spite of this, at present it occurs only rarely and ephemerally. Single plants are usually found, and larger populations are very rare (Šourková 1990). *A. githago* has been also seldom reported from secondary stands like dump hills, stack edges, etc. The dramatic decrease of *A. githago* has led to the species being included into the Red List among critically threatened taxa (Holub et al. 1979). Its agronomic classification in the category of the most dangerous weeds (Kohout 1985) is therefore surprising.

The conservation of weedy species is problematic, because the efforts are being made to eradicate them from the fields in order to protect crops. Hence the gene pool of such species should be artificially maintained in special stands (Skalický 1981), in fields of biologically grown crops or in field margins cultivated without agrochemicals (Helfrich 1988). Furthermore, the seeds of *A. githago* are believed to lose their viability very quickly (Kropáč et Nejedlá 1956, but see Firbank 1988).

The aim of the present study is to (1) investigate the seed production of *A. githago* in three different stands, (2) compare the germination of seeds freshly harvested from these stands, and (3) test the viability and germination dynamics of differently aged seeds.

Material and methods

Seeds were collected in the field of wheat at the "Větrov" estate close to Dobronice near Bechyně in August 1988. To obtain enough seed for the purpose of the present study, the seeds collected in the field were sown and seeds of resulting plants were harvested in two successive years in the garden at Beztahov near Votice, district of Benešov, central Bohemia.

In 1990, the sowing was carried out in three stands at Beztahov near Votice, i.e. (a) a garden bed – 0.25 m^2 plot, pure stand (sown on 29 September, further termed as locality no. 1); (b) field of rye (cv. Breno), 0.5 km NW of the village (sown on 5 October, locality no. 2); (c) field of winter wheat (cv. Regina) at the northern edge of the village (sown on 30 September, locality no. 3).

Both cereals were sown at commonly used sowing rates of 400–500 seeds/m^2 (wheat) and 300–400 seeds/m^2 (rye) (Petr 1983). *Agrostemma* seeds were placed randomly within the 10 m^2 plot in each crop to simulate the "weed" density of approx. 10 plants/m^2. Unfortunately, the stand at locality no. 3 was partly cut in July, and only a patch approx. 1 m^2 in size was left.

The *Agrostemma* plants were harvested in August 1991 (on 4th, 17th and 14th at the particular localities) before the harvest of the cereals. In each plant, the number of capsules per plant, number of seeds per capsule, and plant height (only at the locality no. 2) were recorded. Seeds were dried at room temperature to the constant weight and weighed in groups of 100. Their moisture content was then set at 10.45 % by drying a sample of 300 seeds at 105° C. These seeds were thereafter excluded. Then the seeds were stored in paper bags at room temperature.

In all germination tests, 100 seeds were placed in 9 cm Petri dishes with 1 layer of filter paper (FILTRAK, no. 390) and moistened with tap water. Germination was tested at room temperature (between 18° and 20° C) in daylight. Seeds were examined every 2 days. A seed was considered as germinated when the radicle emerged. Germinated seeds were removed, those that have gone mouldy or had soft and brownish content were considered dead and eliminated. Germination was examined until the last seed of each set germinated or died.

To compare the germination of freshly harvested seeds, 8 replicates from each of the three localities were incubated on October 30, 1991.

To study the effect of age on seed viability, seed sets from the locality no. 2 were sown in 5-week intervals (30 October and 6 December 1991, 9 January, 13 February, 20 March,

23 April, and 26 May 1992), and one (23 September 1992) three years (26 September 1994) after the harvest. Five replicates were used, except of four in the last two cases.

Results

Seed production

The data obtained are presented in Table 1. The results were tested using ANOVA and the among-site differences in all the characteristics studied were significant. Multiple range analysis (Scheffe test) showed that plants from the 3 localities differed significantly in the seed number per capsule and in the weight of 100 seeds. In the capsule number per plant, the production of those cultivated under garden conditions (locality no. 1) was more than doubled compared to those grown in both fields.

Sufficient number of plants harvested from the locality no. 2 made it possible to test for the correlation between plant height and the number of capsules per plant which was highly significant ($r = 0.65$, $p \leq 0.001$, $n = 119$).

Germination of freshly harvested seeds

Most seeds (74–87 %) germinated rapidly within 4 days; after then the germination was slower. In total, 75–91 % of the seeds germinated (Table 2).

ANOVA revealed significant among-site differences. The number of germinated seeds from locality no. 3 (which gave lower number of seeds per capsule and lower mean seed weight) was significantly lower (by more than 10 %, Table 2).

Germination of seeds of different age

Significant differences in germination of particular age groups were found (Table 3). The seeds up to 30 weeks after harvest germinated rapidly, most of them within 4 days. The germination was slower in older seeds. Especially the 3-year-old seeds germinated over a longer period. The final number of germinated seeds was, however, the same (Fig. 1).

Table 1. – Reproductive characteristics of *Agrostemma githago* from three different stands: 1 – garden, pure stand, 2 – rye field, 3 – wheat field. Means bearing the same letter column-wise were not significantly different in multiple range analysis (Scheffe test), $p \leq 0.001$.

	Loc. no.	Mean	S.d.	n
Capsules per plant	1	8.17[a]	5.46	12
	2	2.64[b]	2.10	119
	3	3.89[b]	2.20	9
Seeds per capsule	1	30.57[a]	6.97	89
	2	26.19[b]	6.62	154
	3	22.23[c]	8.63	42
Weight of 100 seeds [g]	1	1.40[a]	0.03	10
	2	1.28[b]	0.02	18
	3	1.07[c]	0.11	8

Table 2. – Germination rates of freshly harvested seeds collected at three different stands: 1 – garden, pure stand, 2 – rye field, 3 – wheat field. Means bearing the same letter column-wise were not significantly different in multiple range analysis (Scheffe test), $p \leq 0.001$, $n = 8$.

Loc. no.	Germinated seeds (in %)					
	Within 4 days		Within 7 days		Total	
	Mean	S.d.	Mean	S.d.	Mean	S.d.
1	86.50[a]	3.46	86.75[a]	3.37	90.75[a]	3.20
2	85.00[a]	3.96	85.00[a]	3.96	86.38[b]	4.14
3	73.63[b]	6.65	73.63[b]	6.65	75.50[c]	8.14

Table 3. – Mean germination of seeds of different ages. Seeds from the rye field (locality no. 2) were used. Means bearing the same letter column-wise were not significantly different in multiple range analysis (Scheffe test), $p \leq 0.001$.

Seed age	n	Germinated seeds (in %)					
		Within 4 days		Within 7 days		Total	
		Mean	S.d.	Mean	S.d.	Mean	S.d.
10 weeks	8	85.00[a]	3.96	85.00	3.96[ab]	86.38[a]	4.14
15 weeks	5	95.00[a]	1.41	96.40	1.14[a]	96.40[a]	1.14
20 weeks	5	90.80[a]	4.92	93.60	3.58[a]	95.00[a]	3.39
25 weeks	5	91.80[a]	3.03	95.40	1.14[a]	95.80[a]	1.30
30 weeks	5	86.20[a]	4.32	92.60	4.10[a]	93.20[a]	4.15
35 weeks	5	81.00[ab]	9.35	91.20	4.09[a]	94.80[a]	2.95
40 weeks	5	72.80[ab]	9.03	90.80	5.85[a]	91.00[a]	5.70
1 year	4	80.50[ab]	10.66	91.25	6.40[ab]	93.50[a]	5.32
3 years	4	55.00 [b]	25.23	70.00	21.91[b]	84.50[a]	9.81
P		≤ 0.00001		≤ 0.0002		≤ 0.0009	

Table 4. – Available data on seed production in *Agrostemma githago*.

Source	seeds/plant	seeds/capsule	capsules/plant	* Note
Firbank 1988 (sec. Firbank 1984)	0–3000		2–8*	herb. material of plants growing among cereals
Watkinson 1981	up to 3685*			isolated plants
Svensson et Wigren 1983		max. 66*	up to 8	maximum found in early-opening flowers
Harper et Gajic 1961			40–50*	isolated plants of Yugoslavian origin planted in England

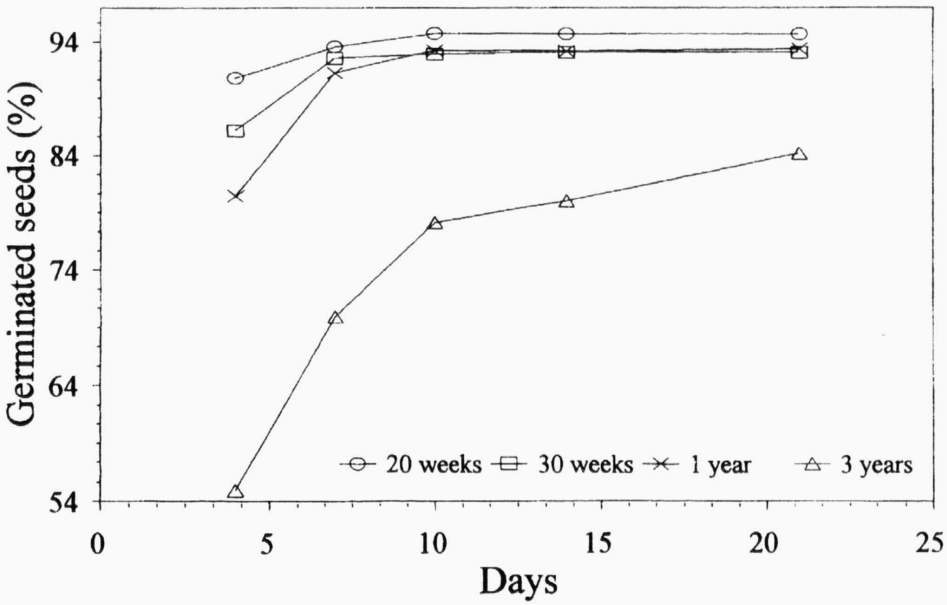

Fig. 1 – Germination dynamics in *Agrostemma* seeds of four different ages (20 weeks, 30 weeks, 1 year, and 3 years after harvest).

Discussion

Seed production

Seed weight of approximately 8 mg was found in *Agrostemma* plants in England (Thompson 1973 in Firbank 1988), 7–9 mg were reported from Sweden (Svensson and Wigren 1983). Heavier seeds were reported from Southern Europe, i.e. 17 mg from Yugoslavia (Thompson 1973 in Firbank 1988), and 25 mg from Bulgaria (Hammer in Firbank 1988). The results obtained by the present study are intermediate; the mean weight of seeds was 11 to 14 mg depending on the stand.

Available data on the seed production of *A. githago* are summarized in Table 4. Multiplying the numbers of capsules per plant and numbers of seeds per capsule (Table 1) gives the mean number of 250 seeds per plant in the pure garden stand, corresponding values being 69 in rye, and 86 in wheat. These results correspond to those reported in the literature, being in the lower part of the published intervals. The highest fecundity found in plants from the pure garden stand indicates the influence of available resources.

Both the seed number per capsule and the capsule number per plant were reported to decline with increasing plant density in various species by many authors (in *Agrostemma* by Harper et Gajic 1961, Watkinson 1981, Svensson et Wigren 1983). *A. githago* responds to increasing density both by mortality (self-thinning) and plasticity (reduced production) (Harper et Gajic 1961, Watkinson 1981). Watkinson (1981) and Firbank et Watkinson (1985, 1986) pointed out that seed production of *A. githago* was influenced by wheat more at low densities of *Agrostemma* than at higher densities.

The relationship between the capsule number per plant and the seed number per capsule seems to be constant. Kelly (1984, after the data of Watkinson 1981) reported that plants bearing more fruits produced more seeds per fruit. The same trend was apparent in the stands of various density in Sweden (Svensson et Wigren 1983) and in the present study as well.

Positive correlation between the plant height and the number of capsules per plant found in the present study corresponds to the positive relationship between the biomass production (shoot dry weight) and fecundity (seed number per plant) reported by Watkinson (1981) and Firbank et Watkinson (1986).

Germination

Some authors declared that seeds of *A. githago* loose quickly their viability (e.g. Kropáč et Nejedlá 1956). However, seed longevity depends mainly on the seed moisture content and the temperature during storage (Harrington 1973, Bewley et Black 1985). The recommended convenient water content of the seeds for storage is between 5 and 14 % (Harrington 1959 in Harrington 1972), between 9 and 15 % (Hübel 1966) and between 8 and 9 % (Bewley et Black 1985). Moisture content of the seeds in the treatment used in the present study agreed with these intervals, being 10.45 %. High germination rate (85 %) was therefore found after 3 years of dry storage. Similarly, Flood et Reynolds (in Firbank 1988) found the germination exceeding 60 % after 6 years of storage. Hammer (in Firbank 1988) noted that the seeds retained their viability even for more than 20 years. On the other hand, the results of the Beal's experiment showed that the seeds of *A. githago* were not viable after 5 years when buried in the moist sand (Darlington 1931).

Svensson and Wigren (1983) observed 100 % germination in fresh seeds both in Petri dishes and in the field; after 2.5 years of storage, the germination in Petri dishes was still 92 %, but only 22 % of seeds stored for 3 years germinated in the field. Lower germination under field conditions may be caused by the fact that the seeds are unable to absorb sufficient water to germinate, as seed area of contact with the substrate is small due to its rugged surface (Harper and Benton 1966).

Seed quality apparently tends to affect germination. The population which produced the lightest seeds and the lowest number of seeds per capsule (locality no. 3) showed the lowest germination rates. The same effect was recorded by Wulff (1973) in *Hyptis suaveolens*. She found great variability in seed size, which was correlated with differences in the germination response. Thompson (1973) found inequality in germination responses of *A. githago* populations collected from different parts of Europe. Bewley et Black (1985) mentioned only environmental conditions during seed ripening to affect viability.

Short after-ripening in *A. githago* was reported by Krippelová et Krippel (1955), Firbank et Watkinson (1986) and Firbank (1988). After-ripening is hastened by an increase in temperature during seed storage (Hübel 1966). In this treatment, the germination of the youngest seeds (10 weeks after harvest) was lowest in comparison with the seeds up to 1 year old. An after-ripening period, during which the germination success increased to the maximum, was observed by Thompson (1973, in Firbank 1988) and Svensson et Wigren (1983).

Svensson et Wigren (1983) described that the seeds stored for 1 year at room temperature started to germinate faster and that the germination rate was as high as 90 % compared to

85 % in fresh seeds. In the present study, most of the fresh seeds germinated within 4 days and the germination was slower in older seeds. Similarly, rapid germination was identified under the laboratory and/or field conditions (Harper et Gajic 1961, Firbank et Watkinson 1986, Thompson 1973). The last author, however, reports the need of higher temperature for 50 % germination in older seeds. Germination responses depended on the duration of period for which the seeds were stored (Thompson 1973).

The role of the length of sunlight per day during germination does not seem to be important, as no differences were found in the total numbers of germinated seeds sown in particular terms over the first year after harvest. Similarly, Firbank et Watkinson (1986) observed that *A. githago* can germinate at any time of the year, given sufficient moisture.

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Souhrn

U rostlin *Agrostemma githago* pěstovaných v zahradní monokultuře a na pšeničném a žitném poli na Voticku byl zjišťován počet tobolek na rostlinách, počet semen v tobolkách a hmotnost semen. Hodnoty těchto charakteristik se lišily v závislosti na typu stanoviště. U rostlin pěstovaných v zahradní monokultuře byly zjištěné průměrné hodnoty, především počet tobolek na rostlině, průkazně vyšší. Rostliny z žitného pole měly méně tobolek, avšak více a těžších semen v tobolce ve srovnání s rostlinami pěstovanými na pšeničném poli.

Klíčení semen v laboratorních podmínkách probíhalo rychle především u čerstvých semen – 74 až 86 % vyklíčilo během 4 dní. Starší semena (zejména skladovaná déle než 30 týdnů) klíčila postupně, avšak výsledná klíčivost se u různě starých semen prakticky vyrovnala (85–96 %). I klíčivost semen uskladněných po dobu 3 let za pokojové teploty dosáhla v laboratorních podmínkách 85 %. Rovněž byly zjištěny rozdíly v klíčivosti čerstvých semen ze 3 lokalit.

References

Bewley J. D. et Black M. (1985): Seeds. Physiology of development and germination. – Plenum Press, New York and London.

Darlington A. T. (1931): The fifty year period of Dr. Beal's experiment. – Amer. J. Bot., New York, 18:262–265.

Dostál J. (1950): Flora of the Czech Socialistic Republic. – Praha. [In Czech]

Firbank L. G. (1988): Biological flora of the British Isles: *Agrostemma githago* L. – J. Ecol., Oxford, 76:1232–1246.

Firbank L. G. et Watkinson A. R. (1985): On the analysis of competition within two-species mixtures of plants. – J. Appl. Ecol., Oxford, 22:503–517.

Firbank L. G. et Watkinson A. R. (1986): Modelling the population dynamics of an arable weed and its effects upon crop yield. – J. Appl. Ecol., Oxford, 23:147–159.

Harper J. L. et Benton R. A. (1966): The behaviour of seeds in soil. II. The germination of seeds on the surface of a water supplying substrate. – J. Ecol., Oxford, 54:151–166.

Harper J. L. et Gajic D. (1961): Experimental studies of the mortality and plasticity of a weed. – Weed Res., Oxford, 1:91–104.

Harrington J. F. (1972): Seed storage and longevity. – In: Kozlowski T. T. [red.], Seed biology, Vol. 3, p. 145–245, Academic Press, New York.

Harrington J. F. (1973): Packaging seed for storage and shipment. – Seed Sci. Technol., Zürich, 1:701–709.

Helfrich R. (1988): Das "Acker- und Wiesenrandstreifenprogramm" in Bayern – ein Programm zur Verbesserung der gesamtökologischen Situation in der Feldflur. – Schriftenreihe Bayer. Landesamt f. Umweltschutz 84:233–244.

Holub J., Procházka F. et Čeřovský J. (1979): List of extinct, endemic and threatened taxa of vascular plants of the flora of the Czech Socialistic Republic (first draft). – Preslia, Praha, 51:213–237. [In Czech]

Hübel M. (1966): Untersuchungen über die Beeinflussung der Nachreifung von *Agrostemma*-Samen durch Temperatur und Wassergehalt. – Flora, Jena, 157:109–130.

Kelly D. (1984): Seeds per fruit as a function of fruits per plant in 'depauperate' annuals and biennials. – New Phytol., London, 96:103–114.

Kohout V. (1985): Weed diagnostics. – MZVŽ, Praha. [In Czech]

Krippelová T. et Krippel E. (1955): Weed seeds. – Vydavatelstvo SAV, Bratislava. [In Slovak]

Kropáč Z. et Nejedlá M. (1956): Sprouting plants of our common weeds. – SZN, Praha. [In Czech]

Petr J. (1983): Intensive grain-growing. – SZN, Praha. [In Czech]

Skalický V. (1981): Questions of weed retreat and extinction. – In: Holub J. [red.], Vanishing flora and gene pool conservation in the Czechoslovak Socialistic Republic, Studie ČSAV, 1981/20:83–88. [In Czech]

Slavík B. (1986): Phytocartographical syntheses of the ČSR. – BÚ ČSAV, Průhonice. [In Czech]

Svensson R. et Wigren M. (1983): History and biology of *Agrostemma githago* in Sweden. – Svensk Bot. Tidskr., Lund, 77:165–190. [In Swedish]

Šourková M. (1990): 16. *Agrostemma* L. – koukol. – In: Hejný S. et Slavík B. [red.], Flora of the Czech Republic 2:159–160, Academia, Praha. [In Czech]

Thompson P. A. (1973): Effects of cultivation on the germination character of the Corn Cockle (*Agrostemma githago* L.). – Ann. Bot., London, 37:133–154.

Watkinson A. R. (1981): Interference in pure and mixed populations of *Agrostemma githago*. – J. Appl. Ecol., Oxford, 18:967–976.

Wulff R. (1973): Intrapopulational variation in the germination of seeds in *Hyptis suaveolens*. – Ecology, Tempe, 54:646–649.

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