

ECOPHYSIOLOGICAL CONDITIONS OF GERMINATION OF BARNYARD GRASS [*ECHINOCHLOA CRUS-GALLI* (L.) P. BEAUV.] DIASPORES

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Abstract: The aim of the study was to investigate the effect of some different environmental conditions prevailing during the development and ripening of *Echinochloa crus-galli* diaspores on their germination. Some seeds were tested in the autumn the same year, whereas others were divided into two groups: dispersed seeds and seeds within the inflorescence. Then the seeds of both groups were buried. After eight-month stratification in the soil, the diaspores were tested under the same conditions as the samples examined in the autumn. The seeds tested in the spring germinated faster than those tested in the autumn. Also the germination capacity of barnyard grass caryopses examined in the summer was almost twofold higher than the germination capacity of those examined in the autumn. Both autumn and spring tests revealed that the harvest time affected germination. The seeds obtained in the second half of August and at the beginning of September (in the middle of the growing season) were characterized by a higher germination capacity than the caryopses collected at the beginning and the end of the reproduction period. The results show that the germination capacity and rate were not influenced by the place of origin, habitat conditions and accompanying plants. It was found in spring tests that germination depended on the kind of dissemination unit stored in the soil. After eight-month soil stratification, dispersed caryopses germinated by approx. 20% better than those stored with a part of the inflorescence.

Key words: barnyard grass *Echinochloa crus-galli*, diaspores, germination response, date of collection, place of collection

INTRODUCTION

One of the key characteristics of annual plants is their generative reproduction ability. During their short life-cycle annual plants are subjected to a variety

of phytocenotic and agricultural conditions, so they form diaspores in order to survive the unfavorable period.

Seeds of many wild plant species do not germinate at the same time. Almost all species are equipped with dormancy mechanisms, permitting their escape in time (germination at the time most favorable to growth and development, some seeds stored in the soil seed bank, periodicity of growth continuation) (Baskin and Baskin 1995, 1998; Bochenek 1998; Egley 1995; Falińska et al. 1994; Karssen et al. 1998; Roberts and Neilson 1980, 1983; Symonides 1989, 1997; Vleeshouwers and Bouwmeester 2001). Even seeds from one population do not form a homogenous groups in terms of germination capacity. This is caused by a variety of factors accompanying the process of seed formation and ripening, as well as the possible interactions between them. Developing seeds accumulate all environmental experiences that in the future may modify the genetically determined dormancy of diaspores (Trewavas 1986; Aldrich 1997; Kolk 1979). Although seed dormancy is a genetic feature, it can be influenced by environmental and biological conditions such as temperature, light intensity and quality, photoperiod, nutrition and seed position during seed development on the mother plant (Egley 1995). Seed dispersal studies often focus on spatial patterning, but the timing of dispersal is also important (Erwin and Wetzel 2001).

The aim of the study was to investigate the effects of different environmental conditions prevailing during the development and ripening of *Echinochloa crus-galli* diaspores on their germination in the autumn, when diaspores were placed in the soil seed bank, and in the spring, when they were dug up at the time considered optimum for growth continuation. The effects of the time of ripening and dissemination of various populations (place of collection), and the kind of dissemination unit placed in the soil, were taken into consideration.

MATERIALS AND METHODS

The experimental materials comprised husked caryopses of *Echinochloa crus-galli*, obtained from populations found in production fields in North-Eastern Poland (Table 1). The seeds used to determine the effects of ripening time on germination were collected in a potato population at Tomaszkowo (population 1). The caryopses were collected at seven dates, from the moment of seed dispersal from the inflorescence (1.08.2000) to the harvest of the crop (20.09.2000). Germination tests were performed on barnyard grass seeds from nine populations found in various crops (Table 1) in the Warmia and Mazury Province (populations 2–7) and in the Pomeranian Province (populations 8–10). The places of collection were situated along the W-E gradient in North-Eastern Poland. Harvest took place at the beginning of September, i.e. in the middle of the growing season of barnyard grass, and concerned only seeds that were easily dispersed from the inflorescence. Barnyard grass diaspores got into the soil seed bank via dispersal or at the moment of crop destruction by ploughing in the whole plant or its part. To determine whether the dissemination unit that got into the soil in the autumn affected germination, the germination responses of diaspores obtained by dispersal (dispersed seeds) and diaspores buried with the inflorescence (seeds with

the inflorescence) were compared. The diaspores for this test were collected from population 7 (maize).

Table 1. Place of collection, habitat and date of collection of diaspores used in the experiments. All sites were located in the Warmia and Mazury Province (A*) except Stare Pole and Krzyżanowo (the Pomeranian Province) (B**)

Population No.	Place of collection (Province A*, B**)	Longitude	Latitude	Habitat type	Date of collection (2000)
1	Tomaszkowo (A)	20°25'	53°33'	potatoes	Aug. 1, Aug. 8, Aug. 18, Aug. 30, Sept. 5, Sept. 13, Sept. 20
2	Tomaszkowo (A)	20°25'	53°33'	sugar beet	Sept. 7
3	Tomaszkowo (A)	20°25'	53°33'	maize	Sept. 7
4	Łęczany (A)	21°09'	53°48'	sugar beet	Sept. 6
5	Łęczany (A)	21°09'	53°48'	maize	Sept. 6
6	Popielno (A)	21°38'	53°35'	sugar beet	Sept. 6
7	Popielno (A)	21°38'	53°35'	maize	Sept. 6
8	Stare Pole (B)	19°12'	53°53'	sugar beet	Sept. 8
9	Stare Pole (B)	19°12'	53°53'	potatoes	Sept. 8
10	Krzyżanowo (B)	19°12'	53°52'	maize	Sept. 8

After harvest the seeds were stored dry at 22°C and 30% RH. The first germination tests were conducted in the autumn, of the year of harvest. The other lot of seeds and whole inflorescences with seeds was buried in the soil at a depth of 20 cm for eight months starting from October of the year of harvest. The seeds were put into nylon bags and protected against rodents with wire netting. Another germination test was carried out in May.

The seeds were germinated in an incubator at the constant temperature of 26°C. Before germinations the seeds were sterilized for one hour in a 1% sodium hypochlorite solution, and then rinsed with water three times. The seeds were sown in Petri dishes lined with filter paper moistened with deionized water, 25 diaspores in five replications. In order to estimate the germination dynamics of *Echinochloa crus-galli* diaspores, readings were taken on the third and tenth day of the experiment. Due to the fact that a similar method was applied to field crops (Grzesiuk and Kulka 1981), and for practical reasons, in the text they were referred to as germination rate (test after three days) and germination capacity (test after nine days).

The results presented are means of the germination percentages obtained in five replicates \pm SE of the mean.

RESULTS AND DISCUSSION

Germination of barnyard grass diaspores as dependent upon the time of ripening and dispersal

The germination test performed in the autumn showed that the seeds obtained in the second half of August and at the beginning of September had the highest germination capacity (60–64%) (Fig. 1). The seeds collected at the beginning and at the end of dissemination had the lowest germination rates (beginning of August – 25%, end of September – 29%). The germination rate was very low in caryopses collected in the first half of August, then increased to 57% (seeds collected at the beginning of September), to decrease again to approx 20%.

In the germination test conducted in the spring the seeds achieved full germination capacity already on the third day of the experiment. Compared with the test performed in the fall, the germination capacity and rate of *Echinochloa crus-galli* seeds increased on average by about 60% and 40% respectively. The majority of seeds germinated at the level of 80 to 100%. Only the germination rate of those collected at the beginning of August was 67% (Fig. 1).

The results of spring and autumn tests indicated that the time of ripening and dispersal of barnyard grass seeds affected their germination response (Fig. 1). In both experiments the highest germination capacity was recorded for seeds that ripened and were dispersed in the middle of the growing season, i.e. from mid-August to mid-September. The test carried out in the fall suggested that barnyard grass seeds ripening and collected within the same population but at different dates differed in the depth of primary dormancy (innate to seeds after maturation on the mother plant; tests after harvest). This was most probably related to the duration of after-harvest ripening before the first test was made, although the impact of environmental factors on seed formation cannot be excluded as well. Just like many other grass species, barnyard grass caryopses required after-harvest ripening (Grzesiuk and Kulka 1981; Zimdahl 1993). According to Li Sun Žun (1962), after-ripening of barnyard grass seeds lasted under our conditions two to three months. It followed that in the presented experiment the seeds collected at the end of the growing season had a shorter after-ripening period. The poor germination of the seeds collected at the earliest suggested that although dispersed, they were still unripe and needed a longer dormancy period. Grzesiuk and Kulka (1981) demonstrated that the rate of after-harvest ripening was significantly affected by the moisture content in seeds, and that water loss usually enhances germination capacity.

The tendency towards better germination of seeds that achieved maturity in the middle of the growing season was also confirmed in the spring test. The germination capacity of seeds produced over that time ranged between 89 and 100%, compared with 67 to 85% in the other periods (Fig. 1). It should be noted that different dormancy-breaking mechanisms were observed during seed germination in the autumn and spring. Based on own observations, it was found that in all experiments May was the optimum month for spring tests (Figs. 1, 2, 3). This was confirmed by four-year studies on the seasonal changes in germination of barnyard grass seeds conducted in the Czech Republic (Honěk et al. 1999), which showed that seeds exhumed from the field at monthly intervals reached their maximum germination capacity in May and June.

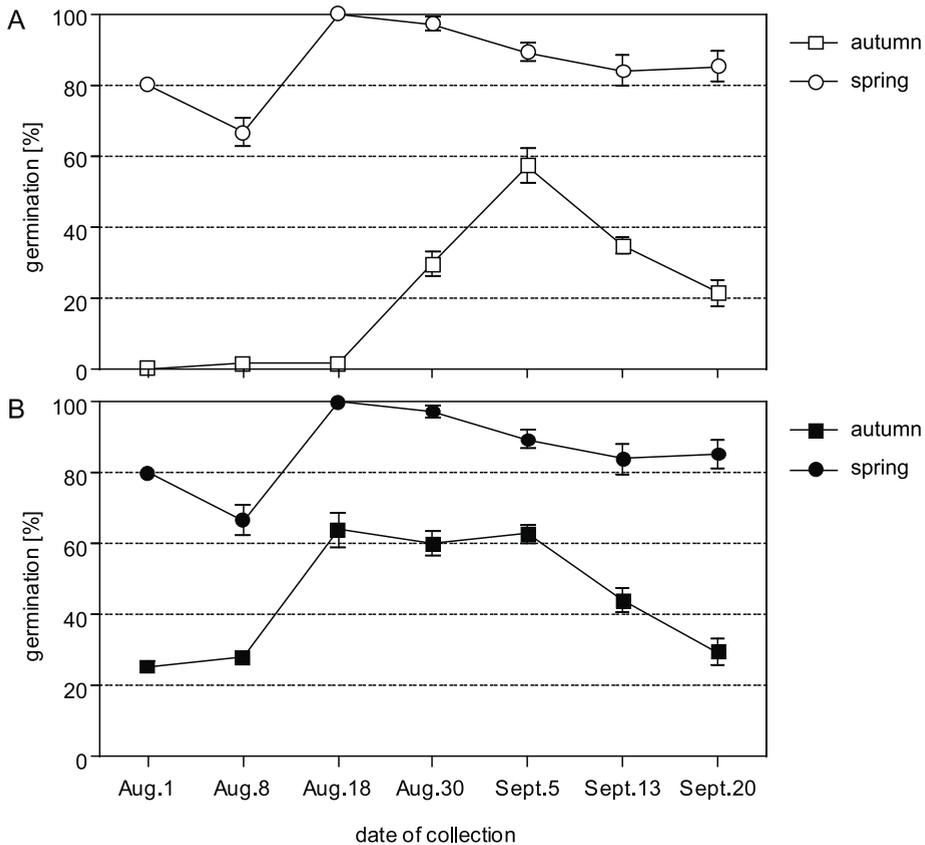


Fig. 1. Effect of date of collection on the germination of *Echinochloa crus-galli* seeds collected from the same population (pop.1, potatoes). A – germination measured after 3 days, B – germination measured after 10 days. Error bars are means \pm SE

Differences in the germination of seeds collected at different dates throughout one year of growing were also recorded in other species of annual, biennial and perennial plants (Baskin and Baskin 1995; Gutterman 1992a; Gutterman 1994; Falińska 1981; Joley et al. 2003; Jursík et al. 2003; Klips and Peñalosa 2003; Loster 1981; Rice 1987; Roach 1986). These observations confirmed that the time of seed autumn had a significant effect on germination capacity. The timing of seed autumn is a function of both the time it takes for fruits to mature and the length of time that seeds are retained on the mother plant (Klips and Peñalosa 2003).

Baskin and Baskin (1998), Fenner (1992), and Gutterman (1992b) suggested that factors like temperature, precipitation, day length, spectral composition of light or aging of the mother plant during seed formation and ripening considerably influence the dormancy patterns of seeds produced over one growing season. Gutterman (1992b) reported higher germination for *Amaranthus retroflexus* L. and *Aegilops geniculata* Roth seeds from plants maturing at higher temperatures, and for *Chenopodium album* L. seeds from plants maturing at lower temperatures. Seeds ripening under various conditions (day length) may differ in anatomy and chemical composition, e.g. "long day" *Chenopodium polyspermum* L. diaspores

have thicker coats and poorer germination capacity that “short day” ones (Pourrat, Jacques 1975). Seeds of some representatives of *Fabaceae* differ in coat development, structure, water permeability and resistance to fungal infections depending on day length (Guterman 1992b). Studies on the effects of day length on many annual crops showed that in most cases dormancy was more easily broken by “short day” seeds than by “long day” seeds (Guterman 1992b; Jursík et al. 2003). The opposite tendency was observed in a few species only, including *Carrichtera annua* (L.) DC. – a member of the family *Brassicaceae* – whose seeds produced during the “long day” (20 hours) germinated better than those produced during the “short day” (8 hours) (Guterman 1992b). According to Westoby (1981), the reason for differentiated germination capacity was seed coat modification resulting from specific environmental conditions during growth and development.

Germination of barnyard grass seeds collected from various populations in the same year

Barnyard grass seeds were collected from local populations (Table 1) that differed in habitat conditions, climate conditions and accompanying field crops. The longest distance between the sites was about 140 km. Barnyard grass seeds collected at particular sites differed in germination capacity which ranged from 12 to 62%. The parameters of seed germination equalized following natural stratification in the soil. The majority of seeds germinated as soon as on the first days of incubation, and germination reached 71 to 79% (Fig. 2). A differentiated level

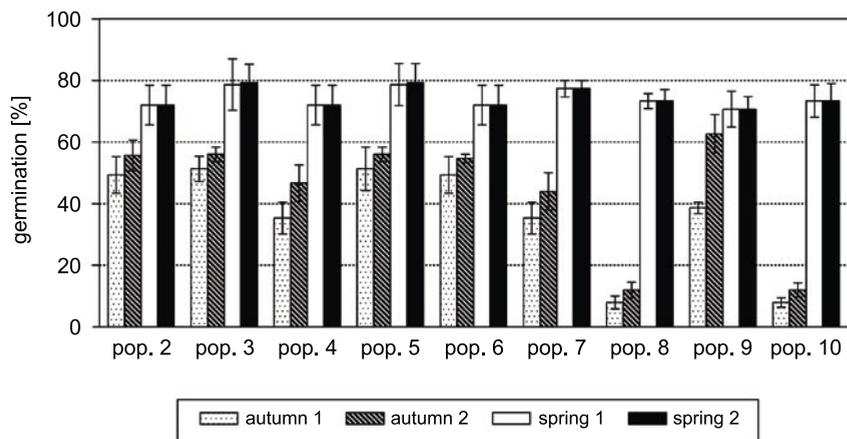


Fig. 2. Germination of *Echinochloa crus-galli* seeds collected from different populations. 1 – observations after 3 days, 2 – observations after 10 days. Error bars are means \pm SE

of primary dormancy of barnyard grass seeds from various populations was also observed during studies conducted in West Bohemia (Honěk and Martinková 1996) and in the Philippines (Namuco et al. 2000). These authors found that barnyard grass seeds from local populations may differ in the depth of primary dormancy and rate of its breaking under cold climate conditions. Various levels of primary dormancy of seeds from various populations were also recorded in

other annual plants (Gutterman 2000). Some researchers (Andersson and Milberg 1998) suggested that germination tests performed on newly-collected seeds were of minor importance as regarded the determination of ecological conditions of germination. They believed that under natural conditions seeds remained buried in the soil for at least several months and reveal their full potentials only after natural cold stratification. This hypothesis was positively verified in our experiment. Barnyard grass diaspores subjected to cold stratification, stored in the soil for eight months, started to germinate within a very short time. Their germination parameters increased and equalized (Fig. 1). The low variation in secondary dormancy patterns (induced in buried seeds; spring test) between particular barnyard grass populations collected along the W-E gradient in North-Eastern Poland may suggest their low genetic variation. Professional literature provides much information on differences in dormancy patterns between seeds collected from various populations (Gutterman 2000; Keller and Kollmann 1999; Milberg et al. 1996; Paterson et al. 1976; Naylor and Abdalla 1982; Schutz and Milberg 1997). These differences were often explained on the grounds of genetic adaptation to local environmental conditions. Other important factors were primarily environmental impacts that accompany seed ripening, age of the mother plant and seed position on the plant (Andersson and Milberg 1998; Fenner 1991; Gutterman 1992). In addition, different conditions during natural stratification caused a more or less constant change in dormancy levels (Vleeshouwer 1995).

Most species of wild plants produce seeds in various populations, which after stratification in the soil differ in the duration of secondary dormancy and the length of time needed to break it. That is why seeds that germinate non-simultaneously form more than one cohort. Under changing environmental conditions germination increases the chance for successive germination and subsequent plant development (effective reproduction). If germination of all seeds occurs in a time considered inappropriate for seedling growth, then unfavorable weather conditions may kill the young plants. It seems that in the case of barnyard grass the varying levels of secondary dormancy, responsible for the continuity of the existence of the species, results from the time of seed shedding rather than from the place of origin (date of collection *versus* place of collection). The different dormancy levels, resulting from the place of seed collection, probably constitute the basis of the survival strategy of *Echinochloa crus-galli* in North-Eastern Poland. Examples of other plant species that seeds collected from various populations did not differ in the dormancy level after cold stratification in the soil were *Silene noctiflora* L. (Andersson and Milberg 1998) and *Centaurea cyanus* L. (Keller and Kollmann 1999). Seeds of *S. noctiflora* were collected from nearby populations, whereas seeds of *C. cyanus* were collected in Switzerland, Germany and Great Britain. According to Keller and Kollmann (1999), the low variation in dormancy patterns between seeds from particular populations might be caused by adaptation to agricultural factors rather than climate conditions.

Effect of the dissemination unit stored in the soil seed bank on germination

In order to determine whether the dissemination unit that got into the soil in the autumn affects germination, the germination of diaspores obtained by dispersal (dispersed seeds) and diaspores buried within the inflorescence (seeds

with the inflorescence) were compared. The seeds were stored in the soil over winter and then germination tests were conducted. After eight-month stratification in the soil it was found that the germination capacity of seeds depended on the kind of dissemination unit that got into the soil seed bank (Fig. 3).

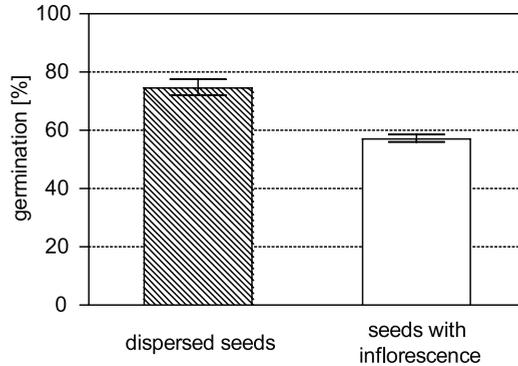


Fig. 3. Effect of the dissemination unit (dispersed seeds, seeds within the inflorescence) stored in the soil seed bank on germination capacity (%) – the test was performed in the spring, when the seeds were dug up (seeds collected from pop. 7, maize). Error bars are means \pm SE

Barnyard grass diaspores stored with a part of the inflorescence showed lower germination (Fig. 3). Dispersed caryopses germinated by approx. 20% better than those stored with a part of the inflorescence. Studies on seeds of field crops indicated that the date of threshing, i.e. seed separation from the mother plant affected the biological quality of seeds because after harvest the plant was still supplied with various compounds indispensable for the completion of growth and development (Lityński 1982). Plants that developed from seeds stored in the inflorescence were more drought-resistant (Grzesiuk 1961). Mierzwińska and Sójka (1963) demonstrated that faba bean seeds stored in pods achieved higher germination capacity. A similar phenomenon was observed in wild plants whose mature seeds did not undergo dispersion. Attached to the mother plant, they germinated better and better as the temperature range widens (Baskin and Baskin 1977). However, these examples of the positive effect of the prolonged contact between the mother plant and mature and fully formed seeds concerned only diaspores stored in a store-room or in the open air, whereas in the present experiment barnyard grass seeds were buried in the soil. Poor germination of barnyard grass seeds attached for a long time to a part of the mother plant was related primarily to the autoallelopathic properties of the species. When seeds were stored in the soil with a part of the inflorescence, certain chemical compounds were liberated that toxic properties resulted probably from chemical changes taking place during organic matter decomposition. This mechanism is called functional allelopathy or environmental substance release (Wójcik-Wojtkowiak 1987). However, true allelopathy cannot be excluded either. Grodziński (1965) reported that extracts from the remains of barnyard grass had a very strong inhibitory effect on germination. According to Aldrich (1997 as cited in Gressel and Holm 1964), water extracts from barnyard grass

seeds contained true allelopathins which were inhibitors of seed germination in field crops, although their activity manifested itself by germination delay rather than prevention.

CONCLUSIONS

1. The germination of *Echinochloa crus-galli* caryopses is affected by environmental conditions. Diaspores that ripened in the middle of the growing season (from mid-August to the beginning of September) germinated better both in the spring and in the autumn than those produced later.
2. It was found that barnyard grass seeds from various populations located in North-Eastern Poland differed in their germination in the autumn, but the parameters of germination equalized following cold stratification in the soil.
3. Barnyard grass diaspores get into the soil seed bank via dispersal or at the moment of crop destruction by ploughing in the whole plant or its part. Diaspores with a part of the inflorescence stored in the soil over winter showed lower germination than those isolated from the panicle. This was most probably related to the autoallelopathic properties of the species.
4. Cold stratification in the soil made barnyard grass seeds germinate on the first days of the test, and their germination capacity was almost twofold higher than that recorded in the autumn test.

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POLISH SUMMARY

EKOFIZJOLOGICZNE UWARUNKOWANIA KIEŁKOWANIA DIASPOR CHWASTNICY JEDNOSTRONNEJ [*ECHINOCHLOA CRUS-GALLI* (L.) P. BEAUV.]

Celem opracowania była ocena kiełkowania diaspor *Echinochloa crus-galli* w zależności od różnych czynników, w których następowało ich formowanie i dojrzewanie. Ziarniaki poddawano testom kiełkowania w dwóch terminach: jesienią w roku zbioru oraz wiosną, po półrocznym przechowaniu w glebie. Jesienią najwyższą zdolność kiełkowania posiadały ziarniaki pozyskiwane po pierwszej połowie sierpnia do początku września. Najślabiej kiełkowały ziarniaki zebrane na początku i pod koniec okresu reprodukcji. Badania wiosenne potwierdziły tendencję do najlepszego kiełkowania tych nasion, które dojrzewały w pełni okresu wegetacyjnego. Wykazano też, że miejsce pochodzenia, warunki siedliskowe i towarzysząca roślina uprawna nie modyfikowały energii i zdolności kiełkowania. Przechowanie diaspor w glebie przez okres zimy wpływało korzystnie na ich kiełkowanie. Wiosną większość ziarniaków rozpoczynała kiełkowanie już w pierwszych dniach testu. Zdolność kiełkowania ziarniaków chwastnicy jednostronnej w porównaniu z testami jesiennymi wzrosła prawie

dwukrotnie. Wykazano ponadto, że w okresie wiosennym kiełkowanie zależy od jednostki disseminacyjnej, jaka dostała się do gleby. Po półrocznej stratyfikacji glebowej ziarniaki wolne kiełkowały o około 20% lepiej od tych, które były przechowywane z częścią kwiatostanu.