Seed Size and Dormancy in *Rumex obtusifolius**

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Abstract

MARTINKOVÁ Z., HONĚK A., PUDIL F. (1999): **Seed size and dormancy in** *Rumex obtusifolius*. Pl. Protect. Sci., **35:** 103–107.

We tested the hypothesis, suggested by literature data, that in *Rumex obtusifolius* L. the germination of matured seeds harvested from dry standing shoots and achene morphology are correlated. In these seed materials the level of germination is determined by the incidence of primary seed dormancy. The regression of the percentage of germinating seeds on achene, perianth and seed size and mass were calculated for seed materials of 30 plants. The materials in which achene morphology was investigated were selected *ex post* from a set of seed materials of 241 plants to cover the range of variation of germinability of individual plants which was between 0–66%. There was no relationship between any characteristic of achene quality and germination except for a positive correlation between germination percentage and achene mass calculated only for seed materials of plants which produced germinable seeds (i.e. when plants with 0% germination were excluded from the analysis). The second part of the study investigated the effects of size variation on germinability among seeds harvested from one plant and after removal from the perianth. This variation was tested using sets of 20 size-assorted groups of 50 seeds, each originating from a particular plant; materials from six plants were tested. There were significant differences in the average germination between plants. However, in the material from the same plant there was no consistent relationship between seed mass and percentage of germination. We conclude that there exists no direct relationship between achene, perianth or seed size or mass and incidence of primary seed dormancy.

Key words: *Rumex obtusifolius*; broad leaved dock; germination; dormancy; seed; achene; size

The total amount of dry mass which a plant allocates to propagules depends on plant size and proportion of mass allocated to seed production (WEAVER & CAVERS 1980; WEINER 1988). These traits vary between species and with environmental conditions prevailing at the time of seed maturation. Besides inherited or induced variation between mother plants the variation in propagule size may be influenced by several epigenetic factors including size and position of the inflorescence, position of the seed in the inflorescence, and timing of maturation during the season (BIERE 1991; SCHMITT *et al.* 1992; WINN & GRESS 1992). As a consequence, the average size of propagules may vary largely and this variation affects several properties of the offspring, before as well as after germination: proportion of dormant seeds, speed of germination and size of young plants (POMMEL 1990; LIMBACH & CALL 1996; MCKEE & RICHARDS 1996; MOJONNIER 1998). The variation in the proportion of primary dormant seeds affects the capability of germination immediately after dispersal.

In *Rumex obtusifolius* L. there exists a large variation in achene size as well as incidence of primary dormancy. The incidence of primary seed dormancy varies between individual plants and localities (CAVERS & HARPER 1966). After maturation, only a fraction of seeds (frequently zero) is able to germinate. The proportion of germinable seeds varies little during the period when achenes persist on standing shoots (HUMPHREYS *et al.* 1997). Achene size varies with the position in the inflorescence (CAVERS & HARPER 1964). There exists also an enormous morphological variability between plants, which is partly important for sub-specific taxonomy (KUBÁT 1990). This inherited variation includes also the relative size of seed and perianth. Achene size and proportions of perianth and seed thus vary between localities but also between plants at the same locality (CAVERS & HARPER 1966). The size and morphology of the achenes is probably determined not only by genetic and maternal factors. Environmental conditions, including the timing of maturation, soil and nutrition quality, and herbivore grazing also affect achene

*The work was funded by Grant No. 521/99/1116 of the Grant Agency of the Czech Republic and Grant No. EP 0960006441 of the Ministry of Agriculture.

variation and proportion of dormancy (COTTAM *et al.* 1986).

The biology of dispersal of *Rumex* species in the Czech Republic has been studied by KOHOUT (1974). In this work we investigate further details of this process, the possible covariation between morphology and size of achenes (mass and volume of seed and perianth) and percentage of primary seed dormancy in seed materials of particular plants. The occurrence of primary dormancy was established on seed materials freshly harvested from standing shoots of mature plants by testing their germination under constant temperature and light conditions. We investigated both the variation between plants as well as consequences of within-plant variation of seed size.

MATERIAL AND METHODS

The work included two experiments which studied the relationship of the incidence of primary dormancy to (A) between-plant and (B) within-plant variation of achene, perianth and seed mass and size.

Achene Materials

(A) In 1997, achenes of *R. obtusifolius* were collected from 241 plants at 64 localities of the western Czech Republic (Bohemia). The localities were meadows, abandoned fields, ridges or roadside margins of agricultural land and forests with natural stands of R. *obtusifolius*. The minimum distance between localities was 500 m. At each locality the achene materials were collected from dry standing shoots, separately from 1–10 (typically 5) randomly selected plants growing within a 30 × 30 m area. Fallen shoots were not sampled to avoid the effect of moistening on dormancy termination (cf. TOTTERDELL & ROBERTS 1979). On each plant the achenes were harvested from all shoots, mixed and divided into two parts. One was stored dry at room conditions until germination experiments, the other was preserved for analysis of achene morphology. Of the total material, 30 plants were selected *ex post*, according to the percentage of germination established in the previous tests: 10 plants with no germination, 10 plants with low (4.7–17.3%) and 10 plants with high (24.7–66.0%) percentage of seed germination. The plants included in this study were collected between March 2 and May 31, 1997, at 21 localities situated between 49°32'–50°47' N and 13°55'–15°28' E, and at altitudes of 160–630 m.

(B) Achenes were collected from six randomly selected plants of a stand at Prague-Ruzyně (50°06' N, 14°16' E) naturally established on a meadow, on March 3, 1999. The achenes of all shoots of each plant were mixed and stored dry at room conditions until germination experiments.

Achene Morphology

(A) Achenes were oven dried and divided into two parts. In the first part 100 achenes were weighed. In the other part the perianths were removed by hand rubbing and 100 seeds were weighed. The size of achenes and seeds was then measured using the system LUCIA image analysis (LABORATORY IMAGING 1997). For particular samples this system enabled to calculate average volumes of achenes (including perianths) and seeds. The average volume of each of achene and seed samples was expressed as mean "equisphere". The equisphere was calculated as a hemisphere constructed above the circle whose area is equal to the mean area of the two-dimensional images of the achenes or seeds present in the sample.

(B) From a large sample of achenes of each plant (ca. 10 thousand) the perianths were removed by hand rubbing. The seeds were roughly assorted into a small and a large fraction by a sieve of 0.9 mm mesh size. From each fraction, groups of 50 small, medium and large seeds were selected. Each such group of similar size was manually selected, and always by one of the authors (AH). Previously it was ascertained that this procedure enables to select groups of objects whose variation in size was less than 5% of the average (HONĚK *et al.* 1998). Since the germination tests followed the seeds were not oven dried.

Germination Experiments

The germination experiments were done on seeds after removal of the perianths by hand rubbing within one week before the start of germination tests.

(A) The germination tests were performed within 30 days after collection of the achenes. The perianths were removed from the achenes of each plant, and three samples of 100 seeds were established. Each of the samples was then spread on filter paper moistened by 5 ml tap water in a Petri dish of 10 cm diameter. The tests were done at constant 25°C and light conditions (4 h light : 20 h darkness photoperiod). Germinated seeds were counted and removed in 2-day intervals until no further germination occurred within 4 days.

(B) Germination tests with size-assorted groups of 50 seeds (see above) started on March 25, 1999, and were performed as in (A).

Statistical Evaluation

(A) For material of each plant nine characteristics of achene morphology were established using mass and volumetric data (Table 1). These should characterize the mass and size of achene, perianth and seed. Germination percentages were transformed to 2 arcsin $P^{1/2}$ where P is proportion of germinating seeds (angular transformation). The regression of the percentage of germination on each of these characteristics of achene morphology were then calculated. The regressions were calculated separately for (i) seed materials of all 30 plants and (ii) for seed materials of 20 plants in which a fraction of seeds germinated.

(B) Regressions of germination percentages (angular transformation) of the size-assorted samples on average seed mass of the samples were calculated. The calcula-

Table 1. The characteristics of mass and size of achene, perianth and seed

Trait	Calculation	Unit
Achene mass	100 achene weight	g
Achene volume	1 achene volume (equisphere)	mm^3
Relative seed mass	seed mass/achene mass	
Seed mass	100 seed weight	g
Seed volume	1 seed volume (equisphere)	mm^3
Specific seed mass	(seed mass/seed volume)*10	g/cm^3
Perianth mass	achene mass-seed mass	g
Perianth volume	achene volume – seed volume	mm^3
Specific perianth mass	(perianth mass/perianth volume)*10	g/cm^3

tions were done separately for 20 samples of each plant and for the pooled data. The differences between plants were tested by analysis of covariance ANCOVA using germination percentage (angular transformation) as factor and seed mass as covariate. In (A) and (B) the calculations used STATISTICA for Windows (STATSOFT 1994).

RESULTS

Between-Plant Variation of Achene, Perianth and Seed Size

The percentage of germination in seed samples of plants was regressed on values of nine traits of achene morphology. No significant relationship was found in the total sample of 30 plants (Table 2). However, a significant ($p < 0.05$) positive relationship between germination percentage and total achene mass was established for plants in which a fraction of seeds germinated (Fig. 1). The relationships between germination and other traits, perianth and seed size and mass, were not statistically significant (Table 2).

Within-Plant Variation of Seed Size

The above results indicated that germination rate might correlate with seed size. This assumption was tested by establishing germination percentage in seed materials of six plants, each of which consisted of 20 size-assorted samples of 50 seeds. No coherent relationship was found between germination percentage and seed size (Fig. 2). The average germination for materials of particular plants varied between 0.1 (SE: 0.05–0.25) and 47.9 (SE: 41.7–54.1) percent (standard errors SE are asymmetrical due to angular transformation). In four plants the regressions of germination on seed mass were not significant ($r = -0.105 \pm 0.192$). In two plants the regressions were significant at $p < 0.05$, however both positive ($r = +0.458$) and nega-

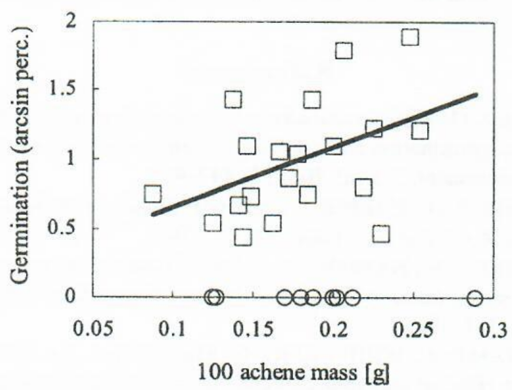

Fig. 1. The regression of the percentage of germination (angular transformation) on achene mass (100 achene mass). The regression is calculated for plants in which a part of seeds germinated (□), data for plants with zero germination is indicated (O)

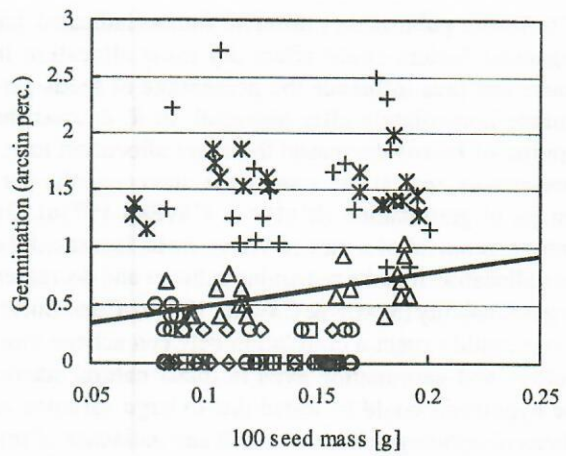

Fig. 2. The regression of the percentage of germination (angular transformation) on average seed mass (100 seed mass) in size-assorted seed samples. The six series of samples are indicated by different symbols. Each series consists of 20 size-assorted samples of 50 seeds originating from seed material provided by a particular plant. The line indicates regression for pooled data: [germination] = 3.656*[100 seed mass] + 0.169

Table 2. The range of variation (minimum, maximum) of achene traits in 30 selected plants, parameters of regression (percent germination = a*seed mass + b), coefficient of determination (R^2), degrees of freedom (df) and F-value. The regression was calculated for all 30 plants (All data) and 20 plants whose seed materials germinated (Germinating materials)

	All data							Germinating materials				
	min	max	a	b	R^2	df	F	a	b	R^2	df	F
Achene mass	0.087	0.289	1.366	0.412	0.011	28	0.301	4.297	0.227	0.200[a]	18	4.507[a]
Achene volume	5.02	14.99	–0.046	1.068	0.047	28	1.382	–0.019	1.150	0.016	18	0.292
Relative seed mass	0.444	0.817	–0.905	1.242	0.019	28	0.538	–0.500	1.309	0.012	18	0.227
Seed mass	0.069	0.195	–0.149	0.678	0.000	28	0.001	6.868	0.229	0.151	18	3.204
Seed volume	0.81	1.63	0.344	0.213	0.016	27[b]	0.428	0.287	0.604	0.023	17[b]	0.409
Specific seed mass	0.664	1.200	–46.33	10.72	0.014	27b	0.410	–71.78	16.13	0.095	17[b]	1.780
Perianth mass	0.016	0.137	3.835	0.404	0.031	28	0.893	5.266	0.639	0.130	18	2.680
Perianth volume	4.21	13.42	–0.034	0.884	0.028	27[b]	0.769	–0.004	0.976	0.001	17b	0.017
Specific perianth mass	0.038	0.126	287.4	3.78	0.016	27[b]	0.447	112.3	8.48	0.005	17b	0.084

a significant at $p < 0.05$

b seed volume was not established and the values of Specific seed mass, Perianth volume and Specific perianth mass could not be calculated for one seed sample

tive ($r = -0.558$) (in all cases df = 18). The regression for pooled data was positive, and significant due to high n and generally lower seed weight in plants with low germination than in those with a high one ($r = +0.190$, df = 118). The ANCOVA revealed significant between-plant differences in the average proportion of germinating seeds between the plants ($df_{effect} = 5$, $MS_{effect} = 9.488$, $df_{error} = 113$, $MS_{error} = 0.075$, $F = 126.9$, $p < 0.001$).

DISCUSSION

The results published by different authors indicated that epigenetic factors could affect dry mass allocation in *Rumex* and thus influence the percentage of seeds germinable immediately after dispersal. In *R. crispus* the clipping of leaves decreased the mass allocation to inflorescences and, at the same time, increased the percentage of germination (MAUN & CAVERS 1971a). By contrast, removal of a part of young fruits increased the mass allocation into the remaining achenes and decreased the germinability (MAUN & CAVERS 1971b). Consequently, one could expect a correlation between achene morphology and germination even in intact natural stands. The hypothesis could be tested due to large variation of achene morphology (KUBÁT 1990) and incidence of primary seed dormancy in *R. obtusifolius*.

However, our work could not demonstrate a relationship between achene quality and percentage of primary dormant seeds. The discrepancy between our results and the expected trends in variation of achene morphology and germination may be caused by a complex determination of both traits. Similar factors (genetic and maternal variation between plants, soil and weather conditions, timing of achene maturation) may influence both traits, but each in a different way. The effects on achene morphology and incidence of dormancy are thus only conditionally coherent. This was demonstrated in the experiment using different plants (A) where the results calculated for all plants were not significant while the results for plants whose seed materials contained a fraction of germinable non-dormant seeds were significant. Thus we found no relationship which could predict the percentage of primary seed dormancy from achene morphology.

Acknowledgements

We thank Mrs. L. KRESLOVÁ for excellent technical assistance.

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Received for publication May 5, 1999
Accepted for publication July 8, 1999

Souhrn

MARTINKOVÁ Z., HONĚK A., PUDIL F. (1999): **Velikost nažek a dormance šťovíku tupolistého.** Pl. Protect. Sci., **35**: 103–107.

Na základě literárních údajů bylo možné předpokládat, že procento primární dormance nažek šťovíku tupolistého (*Rumex obtusifolius* L.) sklizených po dozrání ze suchých stojících květenství bude korelovat s jejich morfologií. Tato hypotéza byla testována sledováním závislosti mezi procentem nažek klíčivých za světla při konstantní teplotě 25 °C a hmotností nebo objemem nažek a/nebo okvětí. Klíčivost nažek byla zjišťována u materiálů z 241 rostlin, z nichž bylo vybráno 30 s průměrnou klíčivostí nažek 0–66%. Pro tyto rostliny byl zjištěn průměrný objem a hmotnost nažek s okvětím a bez něho a byla vypočítána regrese procenta klíčivosti na velikosti a hmotnosti těchto částí. V celém vzorku nebyla zjištěna žádná závislost mezi rozměry a hmotností nažek nebo jejich částí a procentem klíčivosti. Významná korelace mezi velikostí a procentem klíčivých nažek však byla zjištěna v případě, když byl výpočet proveden pouze pro rostliny s klíčivými nažkami. Ve druhé části práce byl na vzorcích nažek šesti náhodně vybraných rostlin zkoumán vztah mezi variabilitou hmotnosti nažek bez okvětí a jejich klíčivostí na jedné rostlině. Z jednotlivých vzorků každé rostliny bylo vytvořeno 20 skupin po 50 podobně velkých nažkách, přičemž se skupiny od sebe lišily průměrnou hmotností. Byla vypočtena regrese procenta klíčivosti na průměrné hmotnosti nažek ve skupině. Průměrná klíčivost nažek z jednotlivých rostlin byla odlišná. Uvnitř vzorků z jednotlivých rostlin však nebyl pozorován žádný vztah mezi hmotností a procentem klíčivosti nažek. Z výsledků práce vyplývá, že neexistuje přímý vztah mezi velikostí nebo hmotností nažek a procentem jejich klíčivosti (podílem nažek bez primární dormance).

Klíčová slova: *Rumex obtusifolius*; dormance; nažky; velikost; klíčivost

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