The Seeds Quality of Betula pendula Roth and Betula obscura Kotula from Semi-Natural and Anthropogenic Habitats

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Abstract: This research presents the results of the study of seeds quality of two Polish native species of the genus Betula L. (Betula pendula Roth and Betula obscura Kotula), growing on the semi-natural (low human activities) and anthropogenic (high human activities) habitats. In this study the generative phase has been investigated to find differences between studied taxa and try to find out why population of B. obscura is very rare. In this research we have checked the quality of the seeds from B. obscura and B. pendula and test the survival of seedlings sowed into the ground researched in laboratory conditions. Results of germination capacity shown significant difference between trees from the anthropogenic and semi-natural sites; the energy capacity indicated significant difference between trees: B. pendula and B. obscura from all study areas. Mixed-model ANOVA/MANOVA for seedlings growth showed statistically important effects of factors (species, area, months). The results show that B. obscura grows better on the anthropogenic habitats than B. pendula, but the latter had more of the fully developed seeds and higher germination and seeds energy capacity.

Key words: Aggregation index, seeds germination capacity, seeds energy capacity, survival of seedlings

INTRODUCTION

One of the most important processes which defines the rapid growth, competition and ability to adapt, is the reproduction factor. The reproduction is decided mostly by fecundity of specimen and also survival rate of the progeny, until it becomes able to reproduce itself (Galloway, 2005; Tang and Tiderstedt, 2001). This variability is conditioned by both genetic and environmental factors. It is so because the number of offspring produced in different conditions is not so important as its ability to survive and reproduce (Sultan, 1995; Callaway et al., 2003; Alpert and Simms, 2002).

Betula obscura Kotula is endemic species in Central Europe covering the Czech Republic, Slovakia, Poland and Ukraine (Lesiński, 1999). Stecki et al. (1928) made detailed research morphology and anatomy of these taxa and after checking such qualities as bark, leaves, generative organs and shoots recognized B. obscura as a species. Affirmations of this thesis were studies made by Jentys-Szaferowa (1959), where perceived differences between the same traits both for B. obscura and for B. pendula. B. obscura was acknowledged as a species by Szafer et al. (1986), Seneta (1973) and Gostyńska-Jakuszewska (1992 cit. Mirek et al., 2002). A different point of view had been taken by Seneta and Dolatowski (1991, 2003), Zając and Zając (2003) and Mirek et al. (2002) those have acknowledged this taxon as a new form. Rutkowski (2004) recognized B. obscura as subspecies.

There is no difference between seeds production by B. pendula and B. obscura (Jentys-Szaferowa, 1959). However, according to our observations, the nuts sizes of B. pendula are bigger. It is assumed that large seed sprout faster than the small ones. The number of sprouts from larger seeds is also bigger, because are better nutritionally supplied (Falińska, 1996, 1998; Rees and Verable, 2007; Moles and Westoby, 2006; Burley et al., 2007). Size and seeds progression has huge influence on their sprouting and further development. The bigger they are the better-developed sprouts will be. Further seedling development depends on the environmental factors, that can be qualified into two classes like natural environment factors (water, temperature, light, moisture, minerals and pH of the soil) and factors caused by human interference-anthropogenic factors (salinity of soil, organic and non-organic chemicals, pesticides, fertilizers) (Franiel and Więska, 2005; Gratani and Bombelli, 2000; Grzesiuk and Kulka, 1981; Loveitt-Doust, 1989; Wei et al., 2007; O’Reilly and De Atrio, 2007). These factors decide how the process of ripening and sprouting will develop.

In this research the generative phase of B. pendula and B. obscura has been researched to find the
differences between them and try to find out why B. obscura as a taxon, has a few representatives. We checked the seeds quality of B. obscura and B. pendula and tested the mortality of seedlings sowed into the ground in laboratory conditions.

**MATERIALS AND METHODS**

**Study sites:** The study population of Betula pendula and Betula obscura were located in four study plots covering the area of 500 m² on the Silesian Upland in southern part of Poland, in the moderate climate zone (extreme mean temperatures of 7-8°C and 700-800 mm of average annual rainfall). Two contrasting types of Betula L. woodlands can be found in this area: semi-natural represent by two nature reserves Las Murckowski in Katowice (50°21' N, 19°10' E) and Sasanka in Jaworzno (50°27' N, 19°40' E) and region under anthropogenic pressure represent by the Ponds Paciorkowie in Bierny Nowy (50°32' N, 19°24' E) and Mine Sand Szczakowa in Jaworzno (50°32' N, 19°40' E). The soil type in all sites is podsol and rusty with pH 7.0-7.3 (Tokarska-Guzik, 1996; Tokarska-Guzik and Chmura, 1996; Górecka et al., 1997).

**Data sampling:** During vegetative seasons 1999-2001, at each study plots 23 mature specimens of B. pendula and 15 specimens of B. obscura (20-25-years-old) were selected. Ten female fructifications were taken from the mid-crown of each birch tree, situated in a paper bag and transported to the laboratory.

**Seeds germination capacity:** At the Ecology Department 300 seeds (100 seeds per one repetition) from each investigated tree were placed on tissue paper in 12 Petri dishes. Seeds were kept in growth chamber at a temperature of 24°C for 14 days. They were also irradiated in 24 h cycle: 16/8 h, by light of 880 µEm^-2 sec^-1. The dishes were hydrated with distilled water and the numbers of sprouted seedlings were counted every day. For each study area there were made 3 repetitions, which tested ability of the seeds to sprout after a month.

**Seeds energy capacity:** The seeds energy was calculated after 14 days. We used formula recommended by Lityński (1977):

\[ W = \Sigma(d \times pd)k^{-1} \]

Where:
- \( W \) = Pieper factor
- \( d \) = Next day of sprouting
- \( pd \) = Percent ratio of seeds sprouted in the following day
- \( k \) = Percent ratio of all sprouted seeds

**Degree of seeds development:** One thousand seeds, picked randomly, were taken from each area from B. pendula and B. obscura pure seeds sample. The observations were made to check degree of seeds development using optical microscope MB 30. Test was supposed to tell, whether seeds were full, partly-fill embryo, full seed not fertilized or empty (Noland et al., 2006).

**Seedlings survival:** The surface layer of soil from all study areas was carried into Ecology Department Growth Room and put into 80 (2 species × 4 study area soil × 10 plastic pots: 8×7×7 cm) pots. Seeds from both species germinated in growth chamber and after 14 days, 800 seedlings were planted out to the pots. Seedlings were hydrated distilled water and every week their number was checked. After 150 days the experiment was terminated.

**Statistical analyses:** Simple statistical parameters (mean, standard deviation) for all vegetative period were estimated by using the Descriptive Statistics procedure of the Statistica 5.1 PL, StatSoft, Poland. The variation of germination and seeds energy capacity between the study areas was evaluated by the Kruskal-Wallis test with the non-parametric procedure, because result of Shapiro-Wilk test did not show a normal layout. Mixed-model ANOVA/MANOVA was using to detected significant differences and effect interaction in percentage of seedling survival between study area taxaons and months. Seedlings survival comparison between two taxaons and two types of habitats were determined by chi square test (Zar, 1999; Stanisz-Wallis, 2005).

The aggregate measurement was used to define, which study areas displays the best habitat conditions to develop of birch seedling. It was done by calculating average arithmetic from each variable(stimulants: seed germination capacity, energy, percent of fulfilled seeds, percent of surviving seedlings and distimulants: percent of empty seeds, percent of seedlings not survive), which were made comparable thanks to unifying them and expressing this average on point scale in the range from 0 to 100 (Thiele, 1993). The formula then takes the form:

\[ W_i = 100 \left( m \cdot \Sigma a_i x_i \right) \]

Where:
- \( W_i \) = Aggregation index
\[ m \quad \text{No. of traits} \]
\[ a_i \quad \text{Weight of j-variable} \]
\[ x' \quad \text{Stimulants or distinulants} \]

The sum was made by unifying with the use of these formulas:

\[ \text{Stimulants: } x' = (x_i - \min \{x_i\})(\max \{x_i\} - \min \{x_i\}) \]
\[ \text{Distinulants: } x' = (\max \{x_i\} - x_i)(\max \{x_i\} - \min \{x_i\}) \]

**RESULTS AND DISCUSSION**

Analysis of the results of germination capacity shown significant difference between trees from the anthropogenic and semi-natural sites (\( df = 8, H = 18.67, p = 0.016 \)). Results of the energy capacity indicated significant difference between trees: B. pendula and B. obscura from all study areas (\( df = 8, H = 16.68, p = 0.04 \)) (Fig. 1). Seeds of B. pendula characterized a high degree of development, because more than half of them were fully developed and this vegetative season we can define as a highly productive (Fig. 2). Mixed-model ANOVA/MANOVA for seedlings growth showed statistically important effects of factors (species, area, months) (Table 1).

The aggregate index showed that the best conditions for B. pendula can be found on the Ponds Paciorkowce, where Wi index amount 35.7, while the worst was on the Mine Sand Szczakowa (Wi = 16.5) and creates the best conditions for B. obscura (Wi = 41.9) (Fig. 3). In both reserves the habitat conditions was very similar. The habitat conditions were not good enough for the seeds quality of B. obscura in Las Murkowski (Wi = 27.7) and Saska (Wi = 22.6).

After taking into consideration two populations: B. pendula and B. obscura, generally the percentage of seedlings survival in the end of the study (150 days) was 62.5% for B. pendula, while for population of B. obscura 88.5%. The results Chi-square test separately for semi-natural and anthropogenic areas, the acquired result was very highly statistically important, if considered as the data about survival of seedlings (Chi-square = 8.42, \( df = 1 \), \( p = 0.0037 \)).

The evaluation of seeds vitally and condition are very important research and practical problem. In case of the investigation of seed germination capacity, germination tests used these days are accurate, lengthy procedures. A statistically significant in the dynamic of sprouting seeds each site was received. It would seem that the biggest amount of sprouted seeds was on the semi-natural habitats (reserve Las Murkowski and reserve Saska). This sites have nearly background levels of pollution and studied taxons in these sites look healthy. The anthropogenic habitats represent heavily polluted industrial barrens, where B. pendula and also

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**Fig. 1:** Results of Kruskal-Wallis test for testing effect (a) germination capacity and (b) energy capacity between semi-natural habitats (A - reserve Las Murkowski, B - reserve Saska), anthropogenic habitats (C- ponds Paciorkowce, D- mine sand Szczakowa) and species (a-Betula pendula, b- Betula obscura)
B. pendula are quite infrequent. The survivors demonstrate by a void of leaves, discoloration and a low number of fruits. High level of pollution emitted by local industry (coal-mine and power plant) has caused widespread destruction of soils and vegetation (Tokarska-Guzik, 1996; Tokarska-Guzik and Chmura, 1996; Gorcezycya et al., 1997; Kozlov and Niemela, 1999; Valkama and Kozlov, 2001; Zvereva and Kozlov, 2005). This is a main reason decrease of seeds quality. Seeds collected from Szczakowa and Paciorkowoe characterized by a low germination capacity, which probably is an effect of the specimen's bad condition, cause by a vicinity of plants and their intensive activity. It can be assumed that habitat conditions have huge influence on the dynamic of seeds sprouting both for B. pendula and B. obscura. However, without distinction of the study area B. pendula showed better ability to sprout than the B. obscura.

One of the parameters characterizing vitality and seeds condition is their germination energy. High speed of sprouting is a good indicator of seeds vitality, but does not show the seeds ability to sprout into the matured plant (Osumi and Sakurai, 1997). The results of sprouted seeds give only quick information about the sowing material. It becomes important to obtain the knowledge about sprouting energy of the seeds from each probe, counted as a Pieper factor. The higher factor is the lower speed of sprouting (Lityński, 1977). The biggest Pieper factor had the birches growing in Szczakowa, which explains their low dynamic of sprouting. The sprouting energy of other birches was more or less on the same level.

The seeds quality depends on the habitat conditions and maturing of the mother plant. On the process of seeds forming, large effect has environmental conditions (Donohue, 2003; Galloway, 2005; Marchiol et al., 1999). The point of the process was to qualify seeds as full, half-full, empty and partially developed. Seed was acknowledged as full only if they had fully developed germ, which occupied the whole space of the seed and only those seeds were able to sprout (Noland et al., 2006). There was a large disproportion between full and empty seeds, both B. pendula and B. obscura. However, seeds of B. pendula were better develop and concurrently had better germination and energy capacity. The reasons for badly developed germ can be a low temperature during the period of the blossom, pests or sickness of the plant (Grzesiuk, 1965; Osumi and Sakurai, 1997).

The habitat conditions are important for dynamic of seeds sprouting and on the development of the seedlings. B. pendula is characterized by a wide ecological amplitude and high tolerance on the habitat conditions (Franiel and Wieski, 2005; Franiel, 1996). It is the reason of its wide range appearance. Observation of B. obscura, suggest that in her neighbourhood can be found B. pendula which usually exceeds B. obscura in the number of specimen (Sokołowski, 1966; Fiolkowa, 1974; Danielewicz, 1990; Łaszek, 1993). It is then possible that the both trees compete against each other. Competition narrows down
the boarders of the plant tolerance (Chengs et al., 2005; Kreyer and Zerbe, 2006; Lehvaerivtta and Rita, 2002). After getting rid of the concurrent, some species can show wider ecological amplitude then in the presence of the other plants (Falińska, 1998; Tobe and Gao, 2007). It is possible that after getting rid of B. pendula, the range of distribution of B. obscura would be wider. Most probably the selection mechanism acting in anthropogenic habitat allows survival of individuals of both birches different reproductive strategies. Seeds starting to sprout in the first and second season, while the contribution of the last one is smaller, which suggests the dynamics changes in the selection pressure manifested stronger in the environment where changes in biotic and abiotic factors are not gradual but jump wise. It can be noted even within the same vegetation season. Such populations cannot be unambiguously placed in the continuum of life strategies. The set of these features suggests that the selection pressures at the moment of transformation of pioneer habitats into stable ones do not change gradually but jump wise. I certain environments these changes can be characterized by strong dynamics detectable even within the same vegetation season (Alpert and Simms, 2002; Falińska, 1998).

After taking into consideration all studied germination features, it would seem that B. obscura shows lower level of variability on the anthropogenic areas than the B. pendula. It seems that B. obscura is as resilient to pollution as B. pendula. By using the aggregate index studied areas were divided by the means of the best environmental conditions for living on them species of birches. For B. obscura the best condition are on the areas under anthropogenic influence, whereas as for B. pendula these conditions are not very important for its development. This study proves that B. obscura is more resilient to hard environmental conditions, in comparison to the B. pendula. It is possible that if there would not be competition between those species, the amount of specimen of the B. obscura would be as high as silver birch trees.

ACKNOWLEDGMENTS

We would like to thank Professor Stanisław Cabala and Dr hab. Piotr Skubala for their helpful comments on the manuscript. Mrs Paulina Szyfter and Dr. Wiesław Babik are highly appreciated for their valuable suggestions and checking our English.

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