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# Effect of polluted environment on the female and male strobili bearing of European Scots pine provenances

**Abstract:** Studies on female and male strobili production as well as on pollen production and viability were performed at a polluted (Luboń) and a control (Kórnik) sites. Female strobili bearing per tree and total length of male strobili produced per tree were significantly higher in Luboń than in Kórnik and the stand density and tree crown exposition to sunlight were likely responsible for that result. Percentage of pollen germination was not affected by any variables studied. Neither provenance nor provenance x site interactions were found.

**Additional key words:** *Pinus sylvestris*, female cone, male flowers, pollen, provenances

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## Introduction

Site conditions affect the abundance of pollen and seed production in Scots pine stands in nature. Mean annual production of pollen on the poor *Calluna*-type site in Finland was about 9 kg per ha, while on the more fertile *Myrtillus*-type site pollen production yielded about 35 kg per ha. Also the proportion of seed crop produced on poor, medium and fertile sites was as 1: 2 : 3 respectively (Sarvas 1962). Artificial improving of forest soil fertility with mineral fertilisers frequently resulted in an increased seed and pollen crop too (Nanson 1965, Hattemer et al. 1977, Chałupka and Fober 1977, Danusevičius 1987, Wesoły et al. 1987).

Air and soil pollution is also a factor which influences site conditions affecting many physiological and growth traits as well as different stages of the generative reproduction process of forest trees, among them also of Scots pine (Karolewski 1989). It was clearly demonstrated that environmental pollutants reduce the size and germination capacity of Scots pine pollen grains as well as the pollen tube elongation *in vitro* (Mejnartowicz and Lewandowski 1985, Smith 1990, Cox 1992). As regards female generative structures a reduction of cone dimensions and decrease of seed quality were noticed (Smith 1990, Cox 1992).

No detailed data was found on the influence of environmental pollution on quantitative aspects of Scots pine generative reproduction *in vivo* conditions. Thus the aim of the study performed was to analyse several quantitative characters of female and male strobili crop as well as of pollen production and viability in Scots pines of different geographic origin growing under pollution and in a relatively free of pollution area.

## Materials and methods

Same provenances (Table 1) from three blocs were selected from two experimental sites. One of them is located in a very polluted area about 2 km east of a phosphate fertiliser factory in Luboń near Poznań. After dramatic diminishing of gaseous pollutants from

the factory in late 80s a soil pollution still remains strong and affects significantly physiological status of Scots pine trees (Oleksyn et al. 1999). The control site is located about 12 km south-east of a polluted one near Kórnik in an area relatively free of pollution. More detailed data about both sites as regards the experimental lay-out, level of pollution and chemical soil properties were published earlier (Oleksyn and Białobok 1986, Reich et al. 1994).

All mature female cones were collected and counted on trees of 14 provenances (Table 1) at the end of August 1994 in Kórnik and in March 1995 in Luboń. Cones were maturing during the summer of 1994 and in spite of the difference in counting time the collection concerned the same cone crop year. Additionally, in 1997 trees with mature 2-year old cones were counted and the percentage of female cone bearing trees was estimated for the same provenances on both sites.

Male strobili were collected in Luboń and Kórnik in May 1996 from all flowering trees of 5 selected provenances (Table 1). The weight of male strobili and pollen was calculated after drying and pollen extraction. After 6 months of storage in standard conditions (dessicator with $CaCl_2$ in a refrigerator), the germination capacity of pollen was tested. Female and male strobili, as well as pollen characters, are presented on a per tree basis for each provenance, and the percentage values were subjected to the arcsine transformation for analysis of variance according to the model presented in Table 2. Expected mean squares were calculated according to Hicks (1973) and the following symbols were used:

$p$ – number of provenances;
$l$ – number of localities;
$b$ – number of blocs in localities;
$\sigma^2_P$ – variance of provenances;
$\sigma^2_L$ – variance of localities;
$\sigma^2_{PL}$ – variance of provenance and localities interaction;
$\sigma^2_B$ – variance of blocs in localities;
$\sigma^2_{PB}$ – variance of provenance and blocs in localities interaction.

# Results and discussion

## A. Female cone bearing

Statistically significant differences (Table 3) were found between 14 provenances in the percentage of cone-bearing trees which ranged from 0.5% for provenance Miłomłyn (Poland) to 25.1% for provenance

Table 1. Origin of *Pinus sylvestris* populations analysed in the female flowering studies listed according to their latitude
* – provenances which also male flowering was observed on

| Population no. | Provenance | Country | Lat. N | Long. E |
|---|---|---|---|---|
| 15 | Sumpberget | Sweden | 60°11’ | 15°52’ |
| 2 | Kondezhskoe | Russia | 59°58’ | 33°30’ |
| 3* | Serebryanskoe | Russia | 58°50’ | 29°07’ |
| 4 | Silene | Latvia | 55°45’ | 26°40’ |
| 5 | Miłomłyn | Poland | 53°34’ | 20°00’ |
| 6 | Supraśl | Poland | 53°12 | 23°22’ |
| 11 | Betzhorn | Germany | 52°30’ | 10°30’ |
| 7* | Spała | Poland | 51°37’ | 20°12’ |
| 8* | Rychtal | Poland | 51°08’ | 17°55’ |
| 12* | Lampertheim | Germany | 50°00’ | 10°00’ |
| 14 | Haguenau | France | 48°49’ | 7°47’ |
| 16* | Zahorie | Slovakia | 48°46’ | 17°03’ |
| 17 | Pornoapati | Hungary | 47°20’ | 16°28’ |
| 18 | Maocnica | Montenegro | 43°10’ | 19°30’ |

Table 2. Model for the analysis of variance

| Source of variation | Degrees of freedom | Expected Mean Square |
|---|---|---|
| Total | plb-1 | |
| Provenances ($P$) | p-1 | $A=\sigma^2_{PB} + b\sigma^2_{PL} + lb\sigma^2_P$ |
| Localities ($L$) | l–1 | $B=\sigma^2_{PB} + p\sigma^2_B + b\sigma^2_{PL} + pb\sigma^2_L$ |
| $P \times L$ | (p–1)(l–1) | $C=\sigma^2_{PB} + b\sigma^2_{PL}$ |
| Blocs in localities ($B$) | (b–1) | $D=\sigma^2_{PB} + p\sigma^2_B$ |
| $P \times B$ (error) | l(p–1)(b–1) | $E=\sigma^2_{PB}$ |

Sumpberget (Sweden) (Fig. 1). No differences were noticed between two locations, i.e. polluted in Luboń and relatively free of pollution in Kórnik ones (18.5% and 18.3% respectively), and no interaction was found between provenances and locations.

Mean number of 2-year-old female cones per tree was significantly higher (Table 3) in the polluted area in Luboń where one tree produced 4.71 of cones on average compared to 0.11 cone per tree on the control site in Kórnik. There were no statistically significant differences between provenances for that trait (Table 3).

More abundant cone bearing on individual trees grown at the polluted site in Luboń was rather unexpected compared to the data from literature where a decrease in abundance of female strobili production in different coniferous tree species has been noticed (Smith 1990). However both locations differed significantly in the mean available plot area for one tree (1.99 $m^2$ in Luboń versus 1.08 $m^2$ in Kórnik) (Tab. 3) and the number of cones per tree was significantly correlated ($r = 0.395$; $p = 0.05$) with this trait. Thus it could be assumed that the more abundant cone bearing on the individual trees at the polluted site resulted probably

Table. 3. Results of analysis of variance. F – test values

| Source of variation | Percentage of cone bearing trees | Mean number of female strobili per tree | Total average length of male strobili per tree, cm | Mean dry weight of male strobili per tree, g | Mean dry weight of pollen produced per tree, g | Mean dry weight of pollen by running cm of male strobili, g | Pollen germination, % | Mean area per tree in the plot, $m^2$ |
|---|---|---|---|---|---|---|---|---|
| Provenances (P) | 3.795*** | 0.663 | 0.831 | 0.626 | 0.647 | 0.644 | 1.342 | 1.136 |
| Localities (L) | 0.011 | 21.516*** | 10.237** | 2.693 | 1.517 | 1.611 | 0.777 | 19.498*** |
| P × L | 1.232 | 0.711 | 0.499 | 0.361 | 0.292 | 1.624 | 0.454 | 0.126 |
| Blocs in localities | 0.530 | 1.016 | 1.105 | 0.711 | 2.325 | 3.504* | 0.025 | 0.403 |

*, ** and *** indicate $p < 0.05$. 0.01 and 0.001 respectively

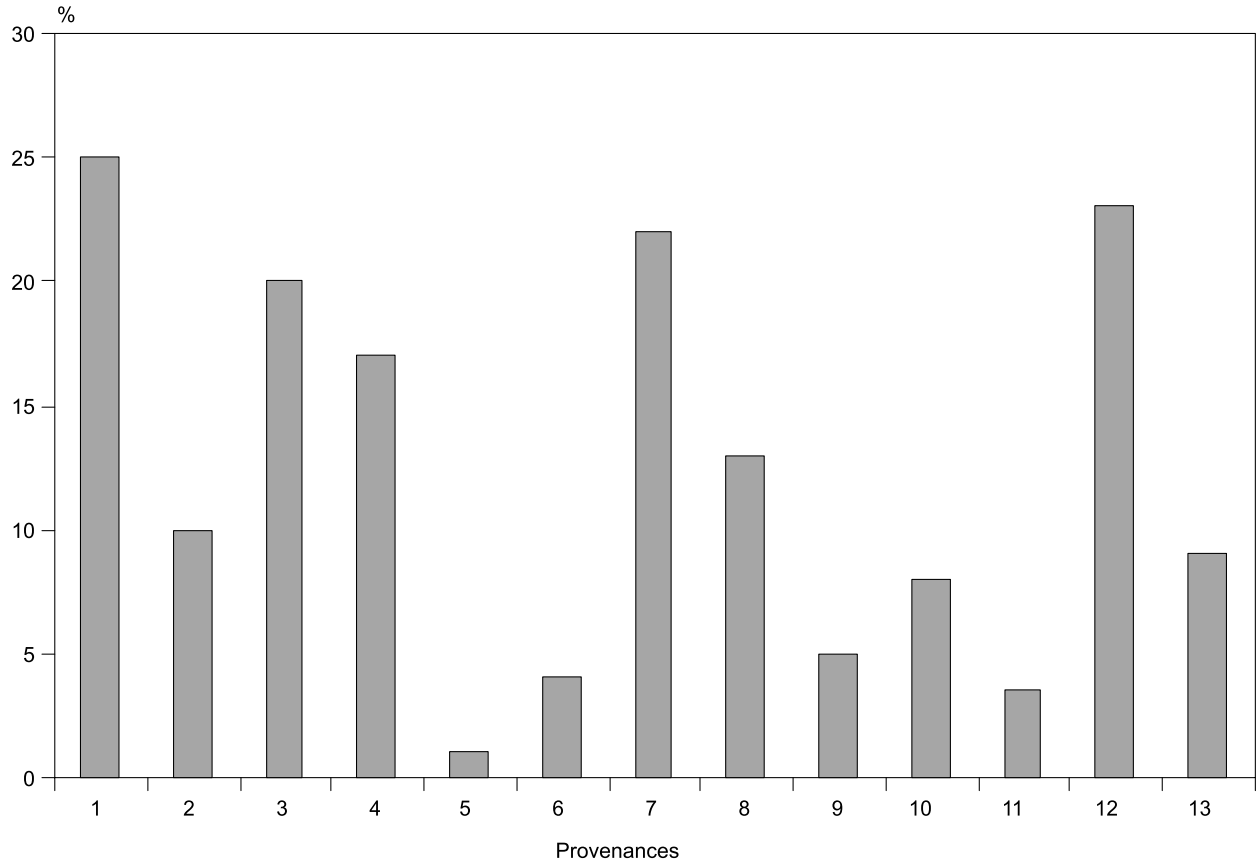


Fig. 1. The differences between European Scots pine provenances in the mean percentage of trees bearing 2-year-old cones (pine provenances listed according to their latitude as in Table 1)

Table 4. Correlation coefficients *r* of male strobili and pollen characters and mean area available per tree in plot

| Characters | Total length of male strobili per tree, cm | Mean weight of male strobili per tree, g | Mean weight of pollen produced per tree, g | Mean weight of pollen by running cm of male strobili, g | Mean area per tree in the plot, $m^2$ |
|---|---|---|---|---|---|
| | 1 | 2 | 3 | 4 | 5 |
| 2 | 0.858 *** | | | | |
| 3 | 0.551 ** | 0.719 *** | | | |
| 4 | -0.034 | 0.250 | 0.718 *** | | |
| 5 | 0.623 *** | 0.429 * | 0.126 | -0.204 | |

*, ** and *** indicate $p < 0.05$, 0.01 and 0.001 respectively

Table 5. Average percentage of germination of *Pinus sylvestris* pollen formed under pollution (Luboń) and on the control site (Kórnik)

| Localities | Provenances | | | | |
|---|---|---|---|---|---|
| | Serebryanskoe (3) | Spała (7) | Rychtal (8) | Lampertheim (12) | Zahorie (16) |
| Kórnik | 29.6 | 50.5 | 9.4 | 35.0 | 72.0 |
| Luboń | 38.5 | 27.0 | 15.1 | 19.6 | 36.5 |

from the better tree crown exposition to sunlight which could overcome the pollution effect.

## B. Male flowering

Among the two male strobili traits analysed only the average total length of male strobili produced per tree was significantly higher in Luboń than in Kórnik (12.09 cm and 3.57 cm respectively) (Table 3). Mean weight of male strobili produced per tree was significantly correlated with the total length of male strobili (Table 4), and differed between Luboń and Kórnik (1.60 g and 0.75 g respectively), but the difference was not statistically significant (Table 3).

Production of pollen, in contrast to male strobili characters, did not differentiate significantly for the polluted and control sites (Table 3). Both pollen production characters (mean weight of pollen produced per tree and pollen production per running cm of male strobili) were significantly correlated with both male strobili characters but it was also interesting that they did not correlate with the stand density (Table 4).

No significant effect of the studied variables was found on the germination of Scots pine pollen (Table 3), and the germination capacity was rather low as indicated in the Table 5. A similar result was earlier observed by Palowski (1994), who also did not find any difference in the percentage of pollen germinated between polluted and unpolluted populations. This character is reported to be very dependent on both between-tree variation and the climatic factors during flowering time (Gozdalik et al. 1998). It is known that pollution diminishes viability of Scots pine pollen (Mejnartowicz and Lewandowski 1985, Wolters and Martens 1987), however it seems that in our studies the effect of polluted site could be hidden by other ecological and/or physiological factors. No significant differences between provenances and no significant interactions between provenances and localities were noticed for all the pollen characters investigated (Table 3).

Our study indicated that relatively heavy soil pollution, even expressed by significantly higher concentration of some heavy metals in pollen grains (Oleksyn at al. 1999), did not decrease the generative effort of Scots pine trees of different provenances and its effect was probably overdominated by other factors such as lower stand density and better access of tree crowns to sunlight.

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