Dependence of Drooping Birch (Betula pendula) and Lime Tree (Tilia Cordata) Relative Seed Production as a New Seed Production Index on the Intensity of Motor Traffic Pollution

Elena A. Erofeeva

Lobachevsky State University of Nizhni Novgorod, Russia, 603950, Nizhni Novgorod, Gagarina Avenue, 23

ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form 8 July 2014
Accepted 10 August May 2014
Available online 30 August 2014

Keywords:
Betula pendula; Tilia cordata; relative seed production; motor traffic pollution; bioindication.

ABSTRACT

Dependence of drooping birch (Betula pendula Roth) and lime tree (Tilia cordata Mill.) relative seed production as a new index of seed production on the intensity of motor traffic pollution was studied. In 2010-2011, a dependence of this plant parameter on pollution intensity was found for B. pendula and T. cordata. An increase in traffic caused a significant reduction in relative seed production in comparison with the control. The dependence of B. pendula relative seed production on traffic intensity was clearer in comparison with the same T. cordata dependence. In different years of observation, a similarity in the studied dependencies was found. Therefore, the relative seed production of studied plant species can be used for bioindication.

© 2014 AENSI Publisher All rights reserved.

To Cite This Article: Elena A. Erofeeva, Dependence of Drooping Birch (Betula pendula) and Lime Tree (Tilia Cordata) Relative Seed Production as a New Seed Production Index on the Intensity of Motor Traffic Pollution. Adv. Environ. Biol., 8(13), 282-286, 2014

INTRODUCTION

It is known that environmental pollution causes a decrease in the seed production of different plant species [1-5]. At the same time, some of authors have shown that chemical pollutants can increase this parameter in woody [3,6] and herbaceous plants [7-9]. In spite of these contradictions, some of authors suggest using seed production to assess the level of environmental pollution (for bioindication) and for biomonitoring [7,10]. Therefore, it is necessary to study the reproductive capacity of different plant species under the action of anthropogenic stress in a wide range of values to determine the pattern of this dependence. Determination of the pattern of dependence of bioindicator species’ seed production on contamination levels, will allow a proper evaluation of environmental pollution using seed production as a parameter. Drooping birch (Betula pendula Roth) and lime tree (Tilia cordata Mill.) often grow in roadside forest strips of the cities in Russia. These species also have a different resistance to some of the pollutants contained in the exhaust of motor transport, such as nitrogen and sulfur oxides [11]. Therefore, these species of woody plants were selected for this study.

There are a lot of different methods for assessing tree seed production. However, these methods are based on estimating of the average seed number per plant and, therefore, they require a large sample of trees (n > 30) [12-13]. At the same time, the urbanized territory researcher usually has to deal with small samples of trees. We have developed a technique that allows us to study seed production for small samples of trees. The technique allows the determination of the relative seed production of the coenopopulation (i.e., a group of plants of this species). The relative seed production is a term that was proposed by this study. The relative seed production of a coenopopulation is the percentage of plant organs (or parts of organs) with seeds in coenopopulation from a total number of such organs (both with seeds and without them). The percentage of plant organs with seeds is calculated for a pooled sample of all tree data in a coenopopulation, therefore, this method is amenable to small samples of trees. The relative seed production of a coenopopulation is calculated as a percentage from the maximum seed production of a coenopopulation when there are seeds on all plant organs, which can have generative buds. Therefore, such seed production is called relative. B. pendula has long and short shoots. Only short shoots can have one or two generative buds that will give rise to collective fruits with seeds. Such generative buds are called mixed generative buds because they generate leaves and collective fruits [14]. Therefore, we calculated a percentage of short shoots with seeds in B. pendula to evaluate their relative seed production. T. cordata only has long shoots predominantly containing mixed generative buds generating
collective fruits with seeds and leaves. Therefore we calculated a percentage of the long shoot nodes with seeds in *T. cordata* to evaluate their relative seed production.

The aim of this study was to determine the dependence of the relative seed production for different species of woody plants (*T. cordata* and *B. pendula*) on the intensity of motor traffic pollution in a wide range of values over two years of observation.

**MATERIALS AND METHODS**

**Study area and study sites:**

Our research was carried out in 2010–2011. We studied relative seed production in middle-aged generative trees of *B. pendula* and *T. cordata*. The trees grew in 9–10 model areas (plots) of tree stands planted along roadsides in the upland part of the city of Nizhni Novgorod (Russia) (Tables 1–2). Motor traffic is a major source of pollution in this part of the city.

All plots were characterised by similar soil conditions (light gray forest soils with anthropogenically mixed upper horizons) and a normal moistening regime. Their location was chosen so that traffic intensity varied within a wide range, with the minimum and maximum values differing by a factor of several tens. A conditionally clean area near the village of Kiselikha, 20 km north of Nizhni Novgorod, was chosen as the control plot for *B. pendula*. Forest Park Shchelkovsky Farm was chosen as the control plot for *T. cordata*. Control plots were located far from highways and other pollution sources.

**Table 1:** Traffic intensity in studied areas of the city of Nizhni Novgorod here *B. pendula* grew.

<table>
<thead>
<tr>
<th>#</th>
<th>Studied areas</th>
<th>Traffic intensity in 2010, vehicles per hour</th>
<th>Traffic intensity in 2011, vehicles per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Melnikova Street</td>
<td>48</td>
<td>–</td>
</tr>
<tr>
<td>2</td>
<td>Nizhni Novgorod Kremlin</td>
<td>64.5</td>
<td>81</td>
</tr>
<tr>
<td>3</td>
<td>Lomonosova Street</td>
<td>141</td>
<td>141</td>
</tr>
<tr>
<td>4</td>
<td>Nevzorovitch Street</td>
<td>313.5</td>
<td>312</td>
</tr>
<tr>
<td>5</td>
<td>Nartova Street</td>
<td>684</td>
<td>822</td>
</tr>
<tr>
<td>6</td>
<td>Meditsinskaya Street</td>
<td>763.5</td>
<td>945</td>
</tr>
<tr>
<td>7</td>
<td>Timiryazeva Street</td>
<td>1,254</td>
<td>1,383</td>
</tr>
<tr>
<td>8</td>
<td>Belinskogo Street</td>
<td>2,662.5</td>
<td>2,850</td>
</tr>
<tr>
<td>9</td>
<td>Gagarina Prospect (Lebedeva Street bus stop)</td>
<td>3,499.5</td>
<td>3,792</td>
</tr>
<tr>
<td>10</td>
<td>Gagarina Prospect (University bus stop)</td>
<td>4,257</td>
<td>4,731</td>
</tr>
</tbody>
</table>

**Table 2:** Traffic intensity in studied areas of the city of Nizhni Novgorod where *T. cordata* grew.

<table>
<thead>
<tr>
<th>#</th>
<th>Studied areas</th>
<th>Traffic intensity in 2010, vehicles per hour</th>
<th>Traffic intensity in 2011, vehicles per hour</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Nizhni Novgorod Kremlin</td>
<td>70.5</td>
<td>90</td>
</tr>
<tr>
<td>2</td>
<td>Nevzorovitch Street</td>
<td>414</td>
<td>300</td>
</tr>
<tr>
<td>3</td>
<td>Meditsinskaya Street</td>
<td>805.5</td>
<td>774</td>
</tr>
<tr>
<td>4</td>
<td>Timiryazeva Street</td>
<td>1,254</td>
<td>1,275</td>
</tr>
<tr>
<td>5</td>
<td>Genkinoy Street</td>
<td>1,395</td>
<td>1,128</td>
</tr>
<tr>
<td>6</td>
<td>Belinskogo Street</td>
<td>2,662.5</td>
<td>2,477</td>
</tr>
<tr>
<td>7</td>
<td>Gagarina Prospect (Lebedeva Street bus stop)</td>
<td>3,738</td>
<td>3,672</td>
</tr>
<tr>
<td>8</td>
<td>Gagarina Prospect (University bus stop)</td>
<td>4,257</td>
<td>4,593</td>
</tr>
<tr>
<td>9</td>
<td>Lyadov Square</td>
<td>5,697</td>
<td>5,321</td>
</tr>
</tbody>
</table>

**Estimation of motor traffic pollution:**

Motor traffic pollution was estimated by the traffic intensity (vehicles per hour) (Tables 1–2). The traffic intensity was a median of vehicles per hour counting three times a weekday: in the morning (from 8 until 10), in the afternoon (from 12 until 15) and in the evening (from 17 until 19) [15]. We have previously demonstrated that the traffic intensity was correlated with the content of the main pollutants (oxides of sulfur, nitrogen, carbon, benzine, kerosene, benzopyrene and formaldehyde) in the air along highways in Russian (*r* = 0.8–0.9; *p* < 0.05).

**Estimation of relative seed reproduction:**

We estimated seed production in 10 trees of each plot when seeds started to mature but still did not fall (the third decade of June for *B. pendula* and the first decade of September for *T. cordata*). *Betula pendula* has seeds only on short shoots, therefore, the number of shoots with and without seeds was estimated. We studied 100 short shoots in the middle and lower part of the crown of each tree from the motorway (20 short shoots in five different parts of the crown of the tree). Then, the percentage of short shoots with seeds in the pooled sample of short shoots for all 10 trees of the plot was calculated (10 trees x 100 short shoots; *n* = 1,000).

*Tilia cordata* has only long shoots. Seeds of *T. cordata* develop on the long shoots of the current growing season. Therefore, we studied 100 long shoot nodes with and without seeds in the middle and lower part of the crown of each tree from the motorway (20 shoot nodes in five different parts of the crown of the tree). Then, the
percentage of shoot nodes with seeds in the pooled sample of nodes for all 10 trees of the plot was calculated (10 trees x 100 shoot nodes; n = 1,000).

**Statistical analysis:**

Statistical analyses were carried out using the programs Statistica 6.0. and Primer of Biostatistics 4.03. Chi-squared test with the Bonferroni correction was used for multiple comparisons of the studied parameters in trees of different plots. Regression analysis was used to evaluate the dependence of the studied parameters on traffic intensity. Sampling percentages with standard errors were used for graphical data presentation.

**Results:**

*Betula pendula* relative seed production upon exposure to motor traffic pollution:

The results of regression analysis showed that the dependence of short shoot seed percentages on traffic intensity was most adequately described by a quadratic polynomial equation and had a distinct monotone pattern in 2010–2011 (Fig. 1a,b). The high traffic intensity caused a significant decrease in the studied parameter of *B. pendula* in comparison with the control. There was a positive correlation between the percentage of short shoots with seeds in 2010–2011 (Pearson correlation: $r = 0.83; p = 0.014$). This confirms the similarity of the identified dependencies in different years of observation.

*Fig. 1:* Dependence of drooping birch (*Betula pendula*) relative seed production on the motor traffic intensity in 2010 (a) and in 2011 (b).

* indicates significant differences between seed production of trees growing in contaminated and control (0 vehicles per hour) areas at p < 0.05.

*Tilia cordata* relative seed production upon exposure to motor traffic pollution:

Regression analysis showed that the percentage of shoot nodes with seeds in *T. cordata* also depended on traffic intensity in 2010–2011 and was most adequately described by a monotone quadratic polynomial function (Fig. 2a,b). An increase in traffic intensity caused a significant decrease in the studied parameter (relative seed production). At the same time, this dependence was significantly more difficult to detect. Two points of dependence were outside the 95% confidence interval of values; therefore, they were excluded from regression analysis in 2010–2011 (in 2010 – Gagarin pr., University bus stop; Lyadov Square; in 2011 – Nevzorovih St.; Genkinoy St.). Exclusion of such points from regression analysis is an accepted procedure in statistics [16]. A correlation between the percentage of shoot nodes with seeds in 2010–2011 was found (Pearson correlation: $r = 0.65; p = 0.040$). This confirms the similarity of the identified dependencies in different years of observation.

**Discussion:**

Relative seed production of the studied plant species depended on the intensity of motor traffic pollution in 2010–2011. An increase of motor traffic caused a significant reduction in this plant parameter in comparison with the control. Our data are consistent with the results of other authors who have shown a decrease in seed production upon exposure to environmental pollution [1-4]. Apparently, this effect was caused by drying of the tree crown under an increased traffic load. We observed an increase in the percentage of crown drying with increasing motor traffic pollution. Crown drying of the tree induces the intensive growth of shoots for crown regeneration, which results in a shortage of resources for seed reproduction. We showed that the dependence of *B. pendula* relative seed production on traffic intensity was clearer than that of *T. cordata*. It is known that *T.*
cordata is a more resistant species to exposure to sulfur and nitrogen oxides in the exhaust of motor vehicles [11].

Fig. 2: Dependence of lime tree (Tilia cordata) relative seed production on the motor traffic intensity in 2010 (a) and in 2011 (b).

* indicates significant differences between the seed production of trees growing in contaminated and control (0 vehicles per hour) areas at p < 0.05.

The identified dependencies were similar in the different years of observation. This indicates that the studied species save on seed reproduction under adverse environmental conditions because they are perennial, and seed reproduction can be carried out later under more favourable environmental conditions.

Conclusion:
Thus, we found monotone dependences of B. pendula and T. cordata relative seed production on the intensity of motor traffic pollution in a wide range of values over two years of observation. Therefore, this index can be used for bioindication. At the same time, the use of B. pendula and T. cordata relative seed production to assess the level of contamination is limited. Studied seed production index occur only once a year, thus it would only allow an estimation of pollution on a yearly basis.

At present, the causes of delay of seed production in plants upon exposure to environmental pollution are insufficiently explored. This phenomenon needs further analysis.

We can draw the following conclusions based on this study:
1. Relative seed production of B. pendula and T. cordata depends on the intensity of motor traffic pollution. An increase in motor traffic causes a significant reduction of this plant parameter in comparison with the control.
2. The relative seed production of B. pendula was more dependent on traffic intensity than that of T. cordata.
3. The studied dependencies did not vary significantly between the different years of observation (in 2010–2011). Therefore, the relative seed production of the studied plant species can be used for evaluating motor traffic pollution intensity for bioindication and biomonitoring.

ACKNOWLEDGMENTS

The anonymous reviewers gave valuable comments on earlier versions of the manuscript.

REFERENCES


