BIRCH GROWTH RESPONSES TO THE INSECT INJURY SIMULATIONS

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Abstract

The tree growth compensation followed by insect damage is important for tree survival. Insect damage by making 3 and 6 holes per each leaf, and clipping one third of a leaf were simulated for one-year old silver birch (*Betula pendula* Roth) seedlings once, at the beginning of the vegetation season. The height, aboveground and root biomass, root length, stem diameter and leaf area were measured for all damaged and control seedlings. The aim of the study was to examine the effects of different insect-damage simulations on silver birch growth.

Our study demonstrated that leaf dry mass decreased in response to leaf perforations and clipping one third of leaf. However, at the end of the experiment, the cumulative dry mass reached the level of the control. We found no statistically significant effect on the aboveground and total biomass of damaged seedlings compared to the control. The leaf clipping decreased the leaf area and stem diameter compared both to the treatment with hole-damaged seedlings and the control. The induced birch growth response showed that tree seedlings were able to compensate their growth up to the control level after the insect damage in eight weeks.

Key words: Silver birch, seedling, leaf damage, growth compensation.

Introduction

The current research studies, based on the changing environment with all upcoming consequences, indicate that the increase of the insect herbivores abundance could be expected (Jepsen et al., 2011; Huttunen et al., 2013). Simultaneously, the changes of insect-plant interactions may occur. Among a variety of insect species, approximately two thirds of all known herbivorous insect species are leaf-eating beetles (*Coleoptera*) or caterpillars (*Lepidoptera*) (Schoonhoven et al., 1998). In turn, insects use various feeding strategies to obtain nutrients from aboveground and belowground plant compartments (Howe and Jander, 2008). This biotic stressor may damage plant tissue and disrupt tissue with varying intensities. Generally, insect-caused damage reduces the total leaf area of the plant. As a consequence, the changes in photosynthetic activity could be expected and the decrease in height and diameter increment, also lower mass production, could occur (Schat and Blossey, 2005; Huttunen et al., 2007). Surveys, such as that conducted by Byington et al. (1994) and Stevens et al. (2008), have shown that individual tree response depends both, on the internal features, time required for plant recovery and growth potential and on the type, duration and intensity of insect damage.

During the last three decades, a number of studies have shown different growth responses to insect damage: plant biomass of damaged plants decreased after the damage event or it was to some extent compensated by intensified growth of the remained tissues (Lacery and Poolean, 1981; McNaughton, 1986; Oesterheld, 1992; Anten and Ackerly, 2001; Ferraro and Oesterheld, 2002; Wise and Abrahamson, 2008). The compensation for insect-damaged trees was identified by Osier and Lindroth (2004) and Landhäusser and Lieffers (2012). The studies based especially on the growth response of birch species damaged by insects were conducted by Mutikainen et al. (2000), Anttonen et al. (2002) and Huttunen et al. (2013). The decrease of foliage changes the partitioning between aboveground and root biomass, i.e. decrease in root/shoot ratio could be indicated (Oesterheld, 1992; Markkola et al., 2004).

Despite quite a lot above-mentioned published issues, we have not succeeded to find any significantly sound data of similar research in the Baltic region. With caution, we state that this is the first attempt to simulate such damage types in our climatic conditions and to obtain their effects on tree growth. In the present study, we examine the effects of different intensities and types of insect-damage simulations on the growth of the fast growing successional tree species - silver birch - seedlings. We have raised the hypothesis that the seedlings that are affected by insects grew better than undamaged seedlings, even after damage.

Materials and Methods

This study was designed as a pot-cultivated experiment and it was conducted in the central part of Lithuania at the Dubrava Experimental and Training Forest Enterprise. One-year old visually healthy Silver birch (*Betula pendula* Roth) seedlings were used as plant material. The birch seedlings of approximately equal height were selected and planted into plastic pots of 3 liters filled with the mixed peat and sand soil on April 2, 2014. During the experiment, weed control was carried out; birch seedlings were regularly watered but never received any fertilizer. Three different types of insect damage were simulated: (1) three and (2) six perforations (0.33 cm^2) per each leaf using a steel hole-punch, and (3) clipping one-third of each leaf using scissors, were simulated on June 17, 2014. The clipping treatment was used as largest damage aiming to simulate the completely different damage type, i.e. when insects damage leaf tips. Non-damaged seedlings were also set as control. Totally, 20 birch seedlings were set in each treatment.

At the end of the experiment, eight weeks post-simulation, the following indices of each seedling were assessed: (1) height; (2) total dry mass, including leaf, stem, shoots and roots mass; (3) the diameter of main stems at a 2 cm distance above the stump-base using an electronic digital calliper; the length of main-root and leaf area of three leaves, taken randomly from each seedling per each treatment, using a scanner with leaf area analysis software WinFOLIA 2004a (Regent Instruments Inc., Quebec, Canada). All collected samples were oven-dried at 60 °C and weighted.

The total biomass of each tree was calculated by the summation of the aboveground and root dry mass, in grams. The cumulative leaf, aboveground and total dry mass was calculated by summing the dry mass at harvest and the leaf mass removed during insect damage simulations.

Root dry mass was expressed in relation to the aboveground dry mass (root/shoot ratio), cumulative leaf mass - in relation to root dry mass (cumulative leaf mass/root mass ratio), and leaf dry mass – in relation to the total biomass (leaf weight ratio).

The data was statistically analysed. First, the data normality was checked by Lilliefors and Kolmogorov-Smirnov tests, then the nonparametric Kruskal-Wallis analysis of variance (ANOVA) test was used to ascertain the significant differences in dry mass between the control, 3 and 6 holes per leaf and clipped one-third of leaf. The data presented in the text, tables and figures are given as means with the standard error of the mean. A level of significance of $\alpha = 0.05$ was chosen. Statistical analyses were conducted using the software Statistica 7.0.

Results and Discussion

In order to clarify how the trees damaged by insects respond to this stress, how they grow, what increment could be expected in the future, the field experiment with artificially perforated birch seedlings was performed in the summer of 2014. The two types of damage were examined: the first, the effect of 3 and 6 holes per each leaf, and, the second, the leaf clipping effect.

Irrespective of insect damage type and intensity, the mean leaf mass varied between 1.8±0.1 and 2.0±0.1 g per seedling, and these values were up to 15% lower than leaf mass in the control seedlings (Fig. 1). When the cumulative leaf dry mass of the silver birch seedlings was calculated, the significant main effect on the leaf mass was found in the seedlings with clipped leaves. Here, the greatest mean cumulative leaf mass (2.5±0.1 g per seedling) was recorded. As a point of comparison, the birch seedlings that were subjected to the insect holes did not change their cumulative mass and it varied in the range similar to the control (Fig. 1).

Except for leaf dry mass, no statistically significant effect on other aboveground biomass compartments (shoot, stem) were obtained after insect damage simulation. The mean values of stem mass varied in a range between 3.6±0.1 (clipped 1/3 of leaf) and 4.1±0.2 g (control) per seedling, with a slight reduction moving from 3 to 6 holes, and further to the clipped treatment (data not shown). Root dry mass statistically non-significantly declined in the following sequence: control > 3-holes ≥ 6-holes

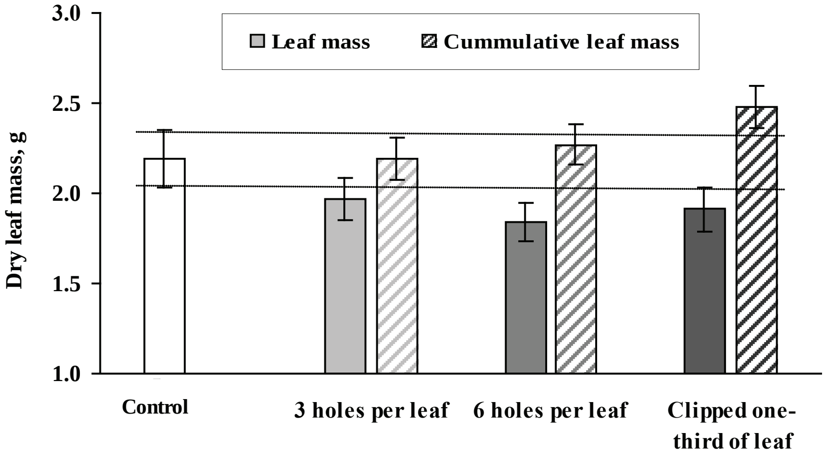

Figure 1. The comparison of leaf and cumulative (*leaf mass at harvest plus leaf mass removed during simulations*) leaf dry mass of silver birch seedlings eight weeks post-simulations.

Note: One column for the Control shows the same value both for leaf and cumulative leaf mass.

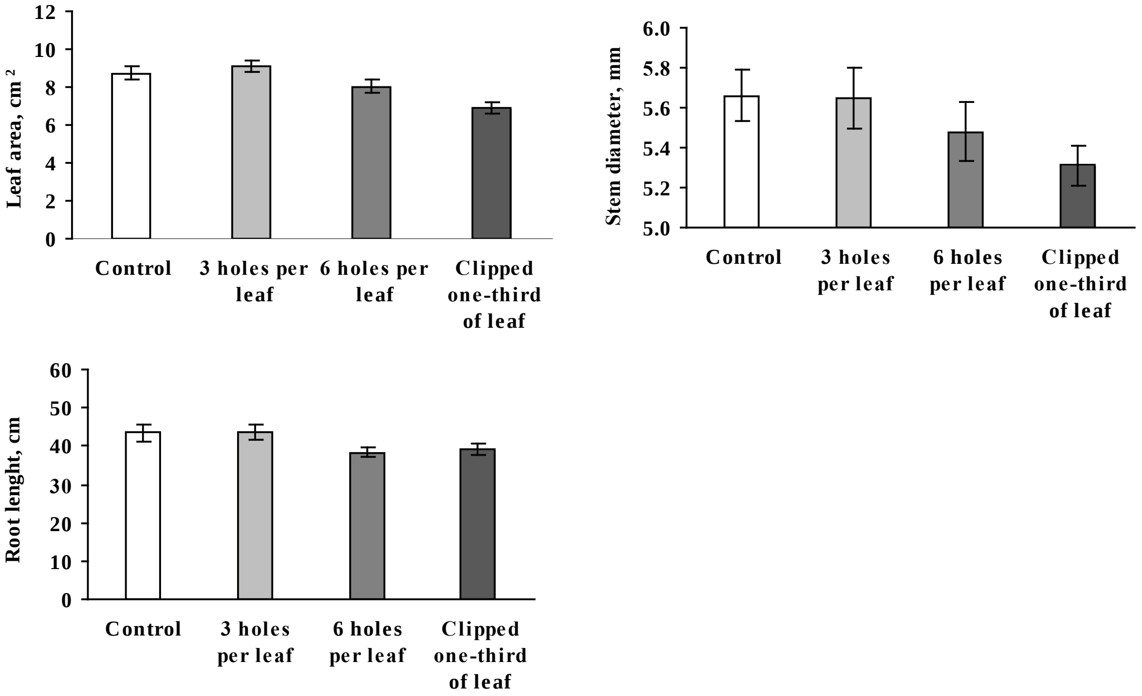

Figure 2. Impact of different insect damage on mean leaf area, stem diameter and length of the main root of the silver birch seedlings eight weeks post-simulation.

= clipped 1/3 of leaf, and it amounted to 5.3±0.3; 4.9±0.3; 4.7±0.3 and 4.8±0.3 g, respectively.

Rising step upwards, the differences between the treatments disappeared in the aboveground biomass measurement, without the interpretation of the calculated total biomass. Total cumulative dry mass of birch seedlings varied in a very narrow range between 11.2±0.5 and 12.0±0.7 g per seedling.

Most of the measurements, which were conducted for the birch seedlings eight weeks post-simulation, confirmed our earlier findings. The clipping of each leaf per seeding induced the reduction of leaf area and stem diameter compared both with the control and hole-damaged seedlings (Fig. 2). However, the estimated root length remained unaffected.

No significant response of 3-, 6-holes per leaf, or clipped leaf treatment to the root/shoot ratio was obtained (Fig. 3). However, the cumulative leaf mass/root ratio increased toward a higher intensity of the damage, i.e. clipped treatment was higher than 6 holes, which, in turn, was higher than 3 holes. Generally, the data showed an increase trend in all estimates, compared to the control (Fig. 3). During our experiment we were not able to sustain the Markkola et al. (2004) finding that the root/shoot ratio decreased as a response of insect damage. Probably, in our case, the damage was not very significant.

Continuing discussion, we can state that until the current decade, birch stands have not been well evaluated in Lithuania because of economic reasons. However, the situation has changed and, recently, this tree species is one of the most promising, which comprise over 22.4% of all stands (ME/SFS, 2014). Silver birch (*Betula pendula* Roth.) is more common in Lithuanian forests. Mean defoliation of birch trees in Lithuania during the last two decades ranged between 16.2 and 23.0% and showed a very slight trend of degradation (Araminienė et al., 2013). According to the Forest statistics and our earlier findings, the number of birch trees damaged by insects comprises about 62% of biotic damage and almost half of total birch damage (Araminienė et al., 2013; Stakėnas et al., 2013). Severe insect damage could result in economic loss to birch plantations because it may lead to enhanced loss of foliage and lower final biomass. As it is already known from Hoogesteger and Karlsson (1992), severe defoliation (more than 80% loss of foliage) reduces the annual ring width considerably for one or more years.

Our results indicated that simulated insect damage affected the growth and biomass of the studied silver birch seedlings, and that the magnitude of the effect depended on the damage intensity and type. Among those silver birch seedlings that were damaged by holes and clipped, it is typical that main effects occurred in the birch foliage. It seems that the differences disappeared when the total biomass was re-calculated. No evident changes of stem, branches and root mass compared with the control were obtained. Both tested simulations of insect holes had similar effects on

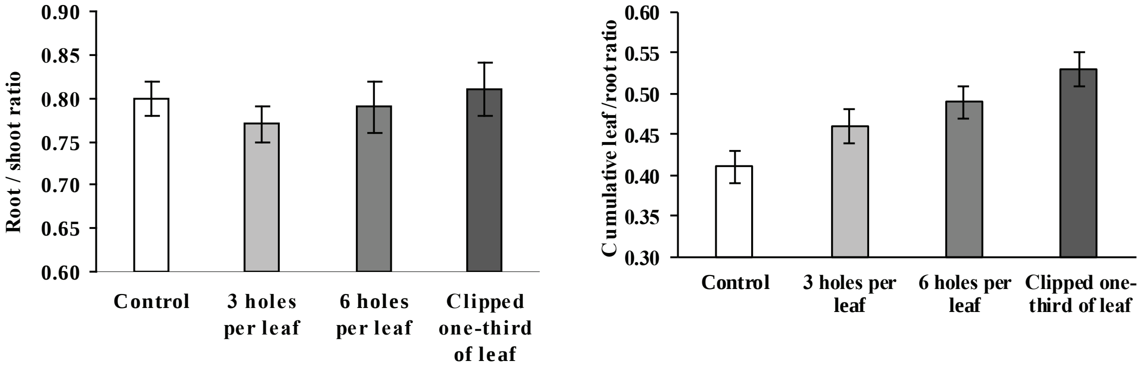

Figure 3. The comparison of the root / shoot and cumulative leaf / root mass ratios (dry mass per each biomass compartment) in the silver birch seedlings eight weeks after the insect-damage simulations.

seedlings; they both were less different than control, compared with the clipped treatment.

As presumed in our hypothesis, we partly confirmed the assertion that insect damage induced to some extent a higher ability to regrow the lost foliage. Some further assumption could be made, as the recovery time during one vegetation season possibly was too short. It is worth mentioning that some of insects attack plants at different times of the season. In this case, we were not able to demonstrate the response of repetitive attacks.

Nevertheless, if we succeed to observe the increased trend of cumulative biomass over very short period, the longer time for regrowth should be even more promising.

Conclusions

1. Despite the decrease of leaf dry mass in response to leaf perforation with 3 and 6 holes, and leaf clipping, the final cumulative dry mass amounted to the control level. No statistically significant effect on the aboveground and total biomass was found after insect damage simulation.
2. No significant response of 3-, 6-holes per either leaf, nor clipped leaf treatment to the root/shoot ratio was obtained. The clipping of each leaf per seeding decreased the leaf area and stem diameter compared to the control and hole-damaged seedlings.
3. The study results showed that birch seedlings, to which the insect damage was simulated, were able to compensate their growth up to the control level in eight weeks.

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