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Effect of buds manually removal and their damage by large pine weevil (*Hylobius abietis* L.) on Scots pine seedlings in Siversky Donets river valley

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Large pine weevil (Hylobius abietis L.*) damages different organs of Scots pine (Pinus sylvestris* L.*) seedlings in unclosed plantations, including foliage, buds, stem bark and roots. Simulated damage of respective organs, particularly debudding is one of the ways to evaluate qualitative and quantitative influence of such damage on tree condition.*

The aim of research was to evaluate the dependence of Scots pine seedlings mortality and height increment on artificial and large pine weevil caused bud damage.

The growth of apical shoots of Scots pine seedlings was registered since the beginning of May to the end of June. Development of new shoots in seedlings with manually bud removal or large pine weevil damage started in beginning of May and continued in July.

Mortality of Scots pine seedlings with 20 % of lateral buds damaged did not differ from that in undamaged plants. The seedlings with apical and lateral buds manually removed as well as with apical and over 70 % lateral buds damaged by large pine weevil have died in the year of treatment or damage. The seedlings with apical buds damaged as well as with apical and over 50 % lateral buds damaged died in the 4th year after damage.

Removal or damage up to 50 % lateral buds did not affect the growth of Scots pine seedlings. Height increment of seedlings with apical buds manually removed or damaged by large pine weevil did not differ significantly in May and June of the year of treatment or damage. In July the height increment was statistically greater in the variant with manually removal of apical bud.

Previously suggested scale of Scots pine seedlings bud damage satisfactory reflects the score of large pine weevil injuriousness.

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We can suggest that height increment in the next years after bud damage does not depend on damage way and intensity but mainly on ecological conditions.

Key words: *Scots pine (Pinus sylvestris L.); unclosed plantations; apical bud; lateral buds; manually bud removal; large pine weevil (Hylobius abietis L.); seedling mortality; height increment.*

Introduction. Large pine weevil (*Hylobius abietis* Linnaeus 1758) is one of the most spread and dangerous pests of conifer plantations, especially in the first years after planting. Its larvae develop under the bark of stumps or roots of weakened trees, and adults damage different parts of trees during maturation feeding (Wainhouse et al., 2004, Nordlander et al., 2017). Such damage is the most dangerous for the Scots pine (*Pinus sylvestris* L.) transplants of the first three years old, because they have small stem surface, and small number of buds and needles. In the Siversky Donets river valley the large pine weevil depending on weather conditions develops in one or two years. Its swarming, mating, oviposition and maturation feeding occur throughout the summer with two waves. The first wave includes the beetles of hibernating generations of different age (1-3 years old) and is the highest by population number and damage. It starts with beginning of vegetation period (about middle of April), has maximum at the second half of May and the first half of June. The second wave is lower, includes the beetles of the new generation, and begins in July with maximum at the second half of August and the first half of September (Meshkova & Sokolova, 2017).

Attempts are known to evaluate insect injuriousness in different regions with the main aim to substantiate the measures on forest protection (Kulman, 1971, Iyerusalimov, 2004). It was evaluated by crown condition, phytomass of individual organs, radial increment, mortality etc. (Langstrom et al., 1998, Lyytikainen, 1994). To a lesser extent, the changes in stem shape and the associated timber defects were taken into account (Yermakova & Bessonova, 2010).

Simulated defoliation and debudding is one of the ways to evaluate qualitative and quantitative influence of animal damage on tree condition (Hjältén, 2004, Lehtila & Boalt, 2004, Quentin et al., 2010). Such studies on different tree species (Langstrom et al., 1990, 1998, Rozhkov et al., 1991, Chen et al., 2002, Varnagiryte-Kabašinskiene et al., 2015), especially Scots pine (*Pinus sylvestris* L.) (Lyytikainen-Saarenmaa, 1994, 1999, 2002, Wallgren et al., 2014, Nilsson et al., 2016) are very important for Ukraine, where this forest species grows in the 33 % of territory.

It was proved (Lyytikainen-Saarenmaa, 1999) that tree reaction on artificial and natural defoliation does not differ, if the needles are removed gradually and in the dates of actual insect feeding. Simulation of buds, branches or roots damage was studied less (Langstrom et al., 1990, Honkanen et al., 1994). Methodological approaches to simulate pine tree damage by insects and to study its effect on tree growth and health condition have been developed and tested in Forest Steppe and Steppe zones in Ukraine (Meshkova et al., 2015). A score for different types of foliage, buds, shoots, branches, stem and root damage was suggested as well as the principles of damage assessment (Meshkova, 2016).

The aim of this research was to evaluate the dependence of Scots pine seedlings mortality and height increment on artificial and large pine weevil caused bud damage.

Objects and methods. Research was carried out in 2013-2017 in two-six-year old Scots pine plantations in the State Enterprise «Zmiyivske Forest Economy».

Over 1000 seedlings were individually marked with soft plate labels in April 2013, considering possible plant damage by unexpected causes, including mechanical damage during weeding or foliage diseases.

For 100 second-year old seedlings were randomly selected for each of two variants with manually removing of buds. In one of them apical buds were manually removed and in other variant apical and lateral buds were manually removed. The dates of such treatment coincided with beginning of large pine weevil maturation feeding and pine shoot growth (Meshkova & Sokolova, 2017).

Such dates were recognized also by needles color change from a yellowish and dull green on a bright green (Meshkova et al., 2015).

The rest labeled seedlings were inspected once a month (end of May, end of June and end of July) in 2013 and once a year (the end of July) in 2014, 2015, 2016 and 2017. Height increment was measured and mortality was registered during such inspection.

Such dates of inspection were chosen considering Scots pine shoot growth timing in the region. It was the most intensive in May and continued up to the end of June. The buds of new generation were formed in July (Meshkova et al., 2015).

At the end of experiment, revision of all records gave the possibility to reject all pines with unplanned damage or disease as well as the plants with buds damage later than in 2013. In result eight groups of 50 pines each with recorded damage history for five years, were selected.

1. Undamaged (control) plants.
2. Apical bud manually removed.
3. Apical and all lateral buds manually removed.
4. Up to 20 % of lateral buds damaged by large pine weevil (low damage).
5. 20–50 % of lateral buds damaged by large pine weevil (moderate damage).
6. Apical bud damaged by large pine weevil (moderate damage).
7. Apical and over 50 to 70 % of lateral buds damaged by large pine weevil (high damage).
8. Apical and over 70 % lateral buds damaged by large pine weevil (high damage).

Plants for variants 4-8 were selected according to the scale (Table 1) (Meshkova, 2016), but groups 7 and 8 were considered as high damage.

Analysis of Scots pine seedlings mortality and height increment in different dates included descriptive statistics. Height increment of Scots pine seedlings in different variants was compared by analysis of variance (ANOVA). Seedlings mortality (percentages) was converted to radians, and the actual value of the Fisher test F was evaluated by formula (1):

$$F = (\varphi_1 - \varphi_2)^2 \times \frac{n_1 \times n_2}{n_1 + n_2}, \quad (1)$$

where φ_1 and φ_2 were the radian values of seedling mortality in compared samples, and n_1 and n_2 were respective sample sizes. The actual value of the Fisher test was compared with the tabulated value for $df_1 = 1$; $df_2 = n_1 + n_2 - 2$ (Atramentova & Utevskaya, 2008). All statistical analyses were performed using Microsoft Excel applications.

Table 1

Intensity of buds damage in unclosed pine plantations (after Meshkova, 2016)

Low (1 point)	Moderate (2 points)	Considerable (3 points)	High (4 points)
Only lateral buds damaged, up to 20 % of the total	– only apical bud damaged; – 20-50 % of lateral buds damaged	Apical bud and up to 70 % lateral buds damaged	Apical bud and over 70 % lateral buds damaged

Results and discussion. Development of new buds in Scots pine seedlings started at the end of April. In the variants with manually bud removal or large pine weevil damage, new shoots developed since the beginning of May depending on kind of damage. Removal or damage up to 50 % lateral buds did not affect the growth. In the case of removal of apical bud in the central shoot, it was replaced with one of the lateral shoots (Fig. 1). Many accessory buds and bundles of shoots developed in the case of considerable part of buds removing or damaging (Fig. 2).

Fig. 1. Scots pine seedlings in the 3rd decade of May after apical buds removal in the 3rd decade of April

Over 20 new buds were formed in some pines with removal of apical and lateral buds. However, the next year the most of these buds have dried.

Both manually buds removal and large pine weevil damage of Scots pine seedlings in the 3rd decade of April caused their mortality during shoot growth period (in May–July), which considerably exceeded natural mortality of undamaged plants (Fig. 3).

Fig. 2. Development of new buds on the stem of Scots pine seedling after removal buds in the 3rd decade of April

Scots pine mortality in all variants trended to increase during the first three months after damage (Fig. 3). Among undamaged plants and plants with up to 20 % of lateral buds damaged mortality did not increase up to the end of June, and was only 6 and 12 % at the end of June and July of the first year of experiment respectively.

Mortality of plants with up to 50 % of lateral buds damaged was 16, 46 and 76 % at the end of May, June and July respectively.

Comparing of plants with manually removed apical buds and with large pine weevil damage of apical buds did not reveal any differences by mortality – 20, 56 and 92 % at the end of May, June and July respectively (see Fig. 3).

The plants with apical and lateral buds removed were characterized by the highest mortality (30, 60 and 100 % in May, June and July respectively), but the differences were significant only at the end of July ($F_{fact.}$=8.2; $F_{0.05(1; 98)}$ = 4.1).

Plant mortality in variants with damage of apical buds and 50 or 70 % of lateral buds was not significantly different.

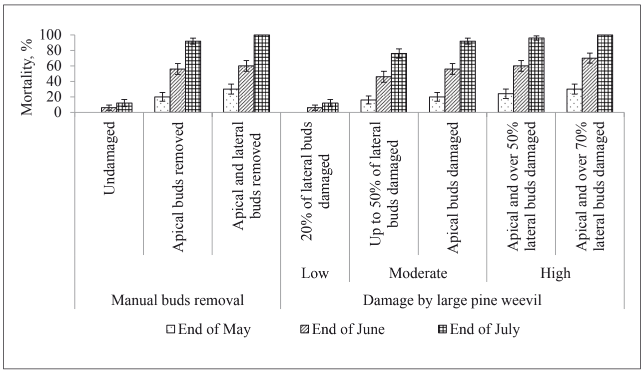

Fig. 3. Mortality of two-year-old Scots pine seedlings during shoot growth period in the first year of experiment (2013) on buds manually removal or their damage by large pine weevil

In the frame of moderate level of damage significant difference was absent by plant mortality at the end of May ($F_{fact.}$= 1.0; $F_{0.05(1;\ 98)}$ = 4.1) and at the end of June ($F_{fact.}$= 0.3; $F_{0.05(1;\ 98)}$ = 4.1) between variants of up to 50 % of lateral buds damaged and apical buds damage. However such difference became significant in July ($F_{fact.}$= 5.1; $F_{0.05(1;\ 98)}$ = 4.1).

In the frame of high level of damage significant difference was absent during shoot growth period in the first year of experiment between variants of damage of apical and over 50 % lateral buds and damage of apical apical and over 70 % lateral buds.

Analysis shows, that Scots plant seedlings mortality slowly increased during the next four years, and differences between variants stayed almost the same as in the first season (Fig. 4).

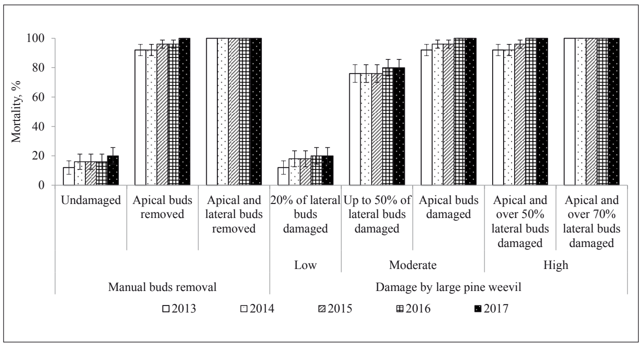

Fig. 4. Mortality in 2013–2017 of two-six-year old Scots pine seedlings in different variants of buds manually removal or their damage by large pine weevil

The plants with apical and lateral buds removed as well as with apical and over 70 % lateral buds damaged have died in the first season (see Fig. 3). The plants with apical buds damaged by large pine weevil have died on the 5th year (in 2017). The plants with apical buds damaged as well as the plants with apical and over 50 % lateral buds damaged have died on the 4th year (in 2016).

Mortality of the plants with up to 50 % of lateral buds damaged in 2013 was 76 % in the first year and increased up to 80 % in 2016.

Mortality of the plants with 20 % of lateral buds damaged in 2013 did not differ from that in undamaged plants (see Fig. 4).

In the first year of experiment the growth of apical shoots of Scots pine continued mainly since beginning of May to the end of June. However, it continued also in July in variants, where apical buds were removed at the end of April (Fig. 5).

Height increment of undamaged Scots pine plants was 14.2; 20.1 and 20.6 cm at the end of May, June and July 2013 and did not differ significantly from that in the variants with 20 % or 50 % of lateral buds damaged (in May $F_{fact.}$ = 0.2; $F_{0.05}$= 3.1; in June $F_{fact.}$ = 0.7; $F_{0.05}$= 3.1; in July $F_{fact.}$ = 0.4; $F_{0.05}$=3.1).

Height increment of plants with apical buds removed or damaged was significantly lower (see Fig. 5).

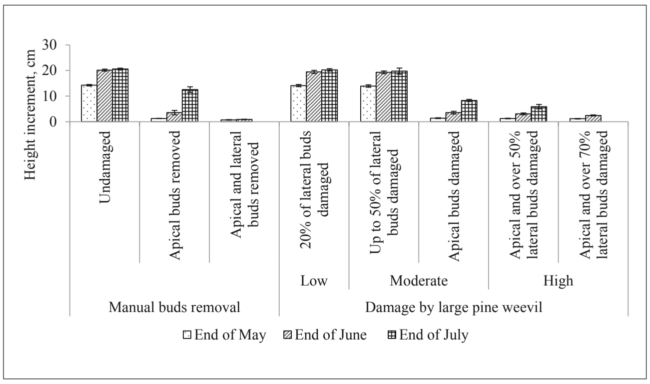

Fig. 5. Height increment of two-year-old Scots pine seedlings during shoot growth period in the first year of experiment (2013) on buds manually removal or their damage by large pine weevil

Height increment of plants in the variants with apical buds removed and damaged by large pine weevil did not differ significantly in May and June (in May $F_{fact.}$= 0.4; $F_{0.05}$= 4.0 and in June $F_{fact.}$= 0.001). However, in July only four plants remained in each variant with average height increment 12.6 and 8.3 cm, and the greater value of this index was statistically proved for variant with manually removing of apical bud ($F_{fact.}$= 13.1; $F_{0.05}$= 6.0).

In the variants of apical buds manually removal, the height increment in May and June was significantly higher, than in the variant with apical and lateral buds manually removal (in May 1.3 and 0.7 cm respectively; $F_{fact.}$= 22.9; $F_{0.05}$= 4.0; in June 3.5 and 0.9 cm respectively; $F_{fact.}$= 8.7; $F_{0.05}$= 4.1). In July any plant did not survive in the variant with apical and lateral buds manually removed.

Comparison of the variants with apical and different proportion of lateral buds damaged show that at the end of May height increment of plants with less proportion of lateral buds damaged was greater. So in May it was 1.2; 1.1 and 0.7 cm in the variants with over 50 %, over 70 % and 100 % buds damaged ($F_{fact.}$= 6.5; $F_{0.05}$= 3.1), and in June it was 3.1; 2.4 and 0.9 cm in respective variants ($F_{fact.}$= 20.8; $F_{0.05}$= 3.2).

In July four living plants were found in the variant with apical and over 50% lateral buds removed.

Annual height increment of undamaged pines increased for 2013-2017 from 20.6 to 41.1 cm (Fig. 6). In 2014 the height increment of plants in the variant with 50 % lateral buds removed in 2013 (29.4 cm) was significantly greater than in undamaged plants (26.7 cm) ($F_{fact.}$= 3.2; $F_{0.05}$= 3.1). However, the differences between damage of 20 and 50 % of lateral buds were not significant ($F_{fact.}$= 0.4; $F_{0.05}$= 4.0).

The same feature for height increment in the mentioned variants was revealed for 2015 ($F_{fact.}$= 11.4; $F_{0.05}$= 3.1). In 2016 height increment in the variant of 20 % of lateral buds removal was significantly less, than in undamaged plants and in plants with 50 % of lateral buds removal ($F_{fact.}$= 11.9; $F_{0.05}$= 3.1).

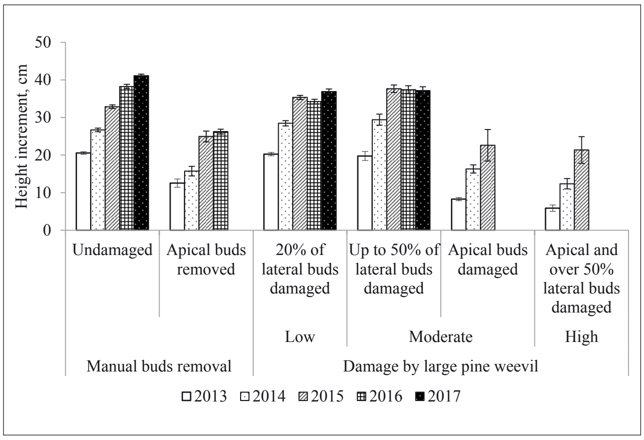

Fig. 6. Height increment in 2013–2017 of two-six-year old Scots pine seedlings in different variants of buds manually removal or their damage by large pine weevil

In 2017 undamaged plants had the greatest height increment (41.1 cm), which was significantly greater than in the variants with 20 and 50% of lateral buds removal ($F_{fact.}$= 15.7; $F_{0.05}$= 3.1).

Height increment of plants in the variants with apical buds removed and apical buds damaged by large pine weevil did not differ significantly in 14 ($F_{fact.}$= 0.08; $F_{0.05}$= 7.7) and in 2015 ($F_{fact.}$= 0.28; $F_{0.05}$= 18.5).

We can suggest that the features of growth increment in the next years after damage do not depend on the way and intensity of damage but mainly on ecological conditions.

Conclusions. The growth of apical shoots of Scots pine seedlings was registered since the beginning of May to the end of June. In the seedlings with manually bud removal or large pine weevil damage, new shoots developed since the beginning of May. Shoot growth continued also in July in seedlings where all apical buds being removed at the end of April.

Mortality of Scots pine seedlings with 20% of lateral buds damaged did not differ from that in undamaged plants. The plants with apical and lateral buds manually removed as well as with apical and over 70% lateral buds damaged by large pine weevil have died in 2013. The plants with apical buds damaged as well as the plants with apical and over 50% lateral buds damaged have died on the 4th year after damage.

Removal or damage up to 50% lateral buds did not affect the growth of Scots pine seedlings. Height increment of plants with apical buds manually removed and damaged by large pine weevil did not differ significantly in May and June of the year of treatment. In July the greater height increment was statistically proved for variant with manually removing of apical bud.

Previously suggested scale of Scots pine seedlings bud damage satisfactory reflects the score of large pine weevil injuriousness.

We can suggest that growth increment in the next years after damage does not depend on damage way and intensity but mainly on ecological conditions.

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Вплив ручного вилучення бруньок та їхнього пошкодження великим сосновим довгоносиком (*Hylobius abietis* L.) на сіянці сосни звичайної у Придонецьких борах

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Великий сосновий довгоносик (*Hylobius abietis* L.) пошкоджує різні органи саджанців сосни звичайної (*Pinus sylvestris* L.) у незімкнених лісових культурах, зокрема хвою, бруньки, кору стовбурів і коренів. Імітація пошкодження відповідних органів, зокрема відривання бруньок, є одним із шляхів оцінювання якісного та кількісного впливу такого пошкодження на стан дерева.

Мета дослідження – оцінити залежність відпаду та приросту за висотою саджанців сосни звичайної від інтенсивності штучного та спричиненого великим сосновим довгоносиком пошкодження бруньок.

Дослідження здійснено впродовж 2013-2017 рр. у 2-6-річних соснових культурах державного підприємства «Зміївське лісове господарство».

Дослід охоплював непошкоджені саджанці (контроль), два варіанти з вилученням бруньок сосни вручну (вилученням термінальних бруньок і

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вилученням термінальної та всіх латеральних бруньок), а також варіанти різних типів і рівня пошкодження бруньок великим сосновим довгоносиком: до 20 % латеральних бруньок; 20-50 % латеральних бруньок; термінальні бруньки; термінальні бруньки та 50-70 % латеральних бруньок; термінальні бруньки та понад 70 % латеральних бруньок.

Ріст термінальних пагонів саджанців сосни звичайної на дослідних ділянках реєстрували від початку травня до кінця червня. Початок розвитку нових пагонів саджанців, бруньки яких вилучали вручну або пошкоджував великий сосновий довгоносик, реєстрували від початку травня до середини липня.

Відпад саджанців сосни звичайної, в яких було пошкоджено 20 % латеральних бруньок, достовірно не відрізнявся від відпаду непошкоджених рослин. Саджанці, в яких були вручну вилучені термінальні й латеральні бруньки, а також саджанці, в яких термінальні та понад 70 % латеральних бруньок були пошкоджені великим сосновим довгоносиком, загинули у рік вилучення або пошкодження бруньок. Саджанці, в яких були пошкоджені термінальні бруньки або термінальні та понад 50 % латеральних бруньок, загинули на четвертий рік після пошкодження.

Вилучення вручну або пошкодження великим сосновим довгоносиком до 50 % латеральних бруньок не впливає на приріст саджанців сосни звичайної. Приріст за висотою саджанців, у яких термінальні бруньки були вилучені вручну або пошкоджені великим сосновим довгоносиком, достовірно не відрізнявся у травні та червні у рік, коли заподіяне таке пошкодження. У липні приріст саджанців за висотою був достовірно більшим у варіанті, де термінальну бруньку вилучали вручну.

Проведені дослідження підтверджують, що запропонована раніше шкала оцінювання рівня пошкодження бруньок саджанців сосни звичайної задовільно відображає рівні шкідливості великого соснового довгоносика.

Можливо припустити, що приріст за висотою саджанців сосни у наступні роки після пошкодження бруньок залежить не від способу та інтенсивності пошкодження, а переважно від екологічних умов.

Ключові слова: *Pinus sylvestris* L.; незімкнені культури; термінальна брунька; латеральні бруньки; штучне вилучення бруньок; *Hylobius abietis* L.; відпад саджанців; приріст за висотою.

Влияние ручного удаления почек и их повреждения большим сосновым долгоносиком (*Hylobius abietis* L.) на сеянцы сосны обыкновенной в Придонецких борах

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Большой сосновый долгоносик (*Hylobius abietis* L.) повреждает разные органы саженцев сосны обыкновенной (*Pinus sylvestris* L.) в несомкнутых культурах, в том числе хвою, почки, кору стволов и корней. Имитация повреждения этих органов, в частности отрыв почек, дает возможность оценить качественное и количественное влияние повреждения на состояние дерева.

Цель исследования – оценить зависимость отпада и прироста по высоте саженцев сосны обыкновенной от интенсивности искусственного и вызванного большим сосновым долгоносиком повреждения почек.

Исследования проведены в 2013-2017 гг. в 2-6-летних сосновых культурах государственного предприятия «Змиевское лесное хозяйство». Опыт включал неповрежденные саженцы (контроль), два варианта с удалением почек вручную (удаление только терминальной почки и удаление терминальной и всех латеральных почек), а также варианты разных видов повреждения почек большим сосновым долгоносиком: до 20 % латеральных почек; 20-50 % латеральных почек; только терминальных почек; терминальных и 50-70 % латеральных почек; терминальных и свыше 70 % латеральных почек.

Рост терминальных побегов саженцев сосны обыкновенной на опытных участках регистрировали с начала мая до конца июня. Развитие новых побегов саженцев, почки которых удаляли вручную или повреждал большой сосновый долгоносик, начиналось в начале мая и продолжалось в июле.

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Отпад саженцев сосны обыкновенной, у которых было повреждено 20% латеральных почек, достоверно не отличался от отпада неповрежденных растений. Саженцы, у которых вручную были удалены терминальные и латеральные почки, а также саженцы, у которых терминальные и свыше 70% латеральных почек были повреждены большим сосновым долгоносиком, погибли в год удаления или повреждения почек. Саженцы, у которых были повреждены терминальные почки или терминальные и свыше 50% латеральных почек, погибли на четвертый год после повреждения.

Удаление вручную или повреждение большим сосновым долгоносиком до 50% латеральных почек не влияет на прирост саженцев сосны обыкновенной. Прирост по высоте саженцев, у которых терминальные почки были удалены вручную или повреждены большим сосновым долгоносиком, достоверно не отличался в мае и июне года нанесения такого повреждения. В июле прирост саженцев по высоте был достоверно большим в варианте, где терминальную почку удаляли вручную.

Проведенные исследования подтверждают, что предложенная ранее шкала оценки уровня повреждения почек саженцев сосны обыкновенной удовлетворительно отражает уровни вредоносности большого соснового долгоносика.

Можно предположить, что прирост по высоте саженцев сосны в следующие годы после повреждения почек зависит не от способа и интенсивности повреждения, а преимущественно от экологических условий.

Ключевые слова: сосна обыкновенная (*Pinus sylvestris* L.); несомкнутые культуры; терминальная почка; латеральные почки; искусственное удаление почек; большой сосновый долгоносик (*Hylobius abietis* L.); отпад саженцев, прирост по высоте.