BRIEF REPORT

Effect of *Physokermes piceae* Schrank. on Shoot and Needle Growth in Norway Spruce stands in Lithuania

ARTŪRAS GEDMINAS, JŪRATĖ LYNIKIENĖ*, ADAS MARČIULYNAS AND AISTĖ POVILAITIENĖ

Institute of Forestry LRCAF, Liepu str. 1, Girionys, LT-53101 Kaunas district, Lithuania; e-mail: m.apsauga@mi.lt, tel. +370 37 547221

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Abstract

In 2010, the spruce bud scale (*Physokermes piceae* Schrank.) infested 7,700 ha in Lithuania. The effect of the spruce bud scale damages like the reduction of shoot and needle growth in young spruce stands was studied in 2013. In order to determine the growth reduction in the shoots and needles, young (II-IV age class) spruce stands were examined. We have established 33 plots in stands in 9 different regions of Lithuania. Three branches from five trees were collected on each plot. The length (cm) of the shoots and the weight (g) of absolutely dried 100 needles were determined.

During the outbreak (2010), the shoot length and needle weight decreased almost twice ($p < 0.05$) in comparison with shoot and needle growth before the damage (2009). A direct negative effect of spruce bud scale was significantly ($t \geq 2.91$, $p \leq 0.05$) higher in spruces growing in Western Lithuania (Jurbarkas, Kazlų Rūda and Šakiai) than in Central Lithuania (Kaišiadorys, Dubrava and Jonava).

Key words: needle weight, shoot length, spruce bud scale, spruce stands, Norway spruce, *Picea abies*

Introduction

Norway spruce (*Picea abies* (L.) Karst.) is one of the most common tree species in Lithuania. According to the State Forest Service spruce stands cover 0.43 million ha (20.8% of the total forest area) with total growing stock of 82 million m^3 (Anon. 2012). Norway spruce is the second economically important tree species after the Scots pine (*Pinus sylvestris* L.) in Lithuania. Spruce stands grow the most in the western, northern and central part of the country. Norway spruce is sensitive to wind damages. The needles and young shoots may suffer from the late spring frosts, from long periods of drought and often there are damages caused by pests and diseases. The most important insect pest in Lithuania is the spruce bark beetle (*Ips typographus* L.). Damages of this pest are registered every year in Lithuania. During recent years, heavy damages in spruce stands caused by the spruce bud scale (*Physokermes piceae* Schrank.) are observed in Lithuania (Anon. 2010) and also in neighboring countries, e.g., Latvia (Lazdinš et al. 2010). The spruce bud scale infested 7.700 ha in 2010. Most of the infested stands were cut by sanitary felling.

Usually, the spruce bud scale develops in parks on ornamental plants yet. The insect seems to prefer weakened trees growing in sunny places in Lithuania (Belova et al. 2000, Žiogas 1997) as well as in Latvia (Lazdinš et al. 2011). *Physokermes piceae* belongs to *Coccidae* family, order *Hemiptera*. The species is distributed throughout Europe, North America (Wallner 1978) and Mongolia (Kozar 1998). Within the whole distribution area it inhabits spruce (*Picea* spp.) while in Turkey it has also been found on fir (*Abies*) and Blue spruce (*Picea pungens* Engelm.) (Ulgenturk et al. 2004; Ulgenturk and Canakcioglu 2004; Turguter and Ulgenturk 2006).

Significant damages caused by the various species of scale insects have been registered in Hungary (Kosztarab and Kozar 1978), Romania (Kozar 1985), Poland (Logowska 1986; Stocki et al. 2000), Italy (Hellrigl 2004), Croatia (Diminić and Hrašovec 2005), Slovakia (Kolar 2007) and Serbia (Graora et al. 2012).

Sucking sap from all foliage parts of tree, the spruce bud scale causes direct damage, such as the physiological weakening of the plant, disorder in the development of needles, drying of branches and even whole plant (Graora et al. 2012). There is also an indirect effect due to the excretion of honeydew. The needles of the spruce tree are gradually covered by sooty mold (*Apiosporium* sp., *Cladosporium* sp.), leading to the reduction of the photosynthesis. A thick layer of fungi can negatively affect transpiration and photosynthesis causing the so-called winter drying (Новак 1974). The fungi may affect assimilation, breathing, and can cause dieback of tissues (Marčiulynas 2012).

The knowledge about the spruce bud scale distribution in the Baltic Sea region and damages caused by this pest is rather limited. The sanitary condition of spruces infested by the spruce bud scale was assessed in Latvia. Authors concluded that the average damage level increased as tree dimensions decreased (Miezite et al. 2013). Also a higher damage incidence was observed for spruce bud scale in Norway spruce stands located on drained mineral soils in Latvia (Lazdinš 2010, Miezite et al. 2013).

The spruce bud scale is able to attack spruces of various age including young forest stands. Young spruce stands of 10-40 years age compose 50% of all spruce stands in Lithuania (Anon. 2012). The infestation of spruce bud scale in combination with other negatively effecting factors (precipitation and temperature changes in winter, late spring and early autumn frost, strong cold wind) may lead even to the total degradation of young spruces (Luguza et al. 2012). Moreover, most authors conclude that scale insects may cause a strong reduction of the spruce foliage growth (Miezite et al. 2012, McCarthy and Skovsgaard 2011).

The aim of this study was to assess the effect of spruce bud scale damages on the shoot length and needle weight in young spruce stands.

Materials and Methods

In 2013, the impact on the growth of shoots and needles caused by the spruce bud scale was examined in young (II - IV age class) stands of Norway spruce. 33 plots (plot size is 30 spruces) were established in spruce stands in Jurbarkas, Šakiai, Kaišiadorys, Jonava, Biržai, Rokiškis and Kupiškis forest enterprises. Spruce stands were ranged by the level of spruce bud scale infestation. The level of infestation was classified according to the percentage of the total number of trees with visible pest damages. 20% of the trees damaged comprise weak infestation level; 21-50% – medium infestation level; 51-70% and more – strong infestation level. There were 4 plots established in each forest enterprise: three of them in spruce stands with various level of bud scale infestation (weak, medium and strong) and one as a control. Trees in control plots were not damaged by the insect during the last 5 years. In Dubrava (2 in damaged spruce stands and 1 control plot) and Kazlų Rūda (1 damaged spruce stand and 1 control) additionally, plots were established. The total number of plots in spruce stands infested by different level was 24, and 9 plots were used as control (undamaged).

Five trees were randomly selected in each research plot and on each tree three branches with terminal shoots of 5 years old (2009-2013) were collected (Figure 1). This sampling allowed us to evaluate the losses in needle weight and shoot length before, during and after the bud scale damages annually. In total, we collected 495 branches. The branches were brought to

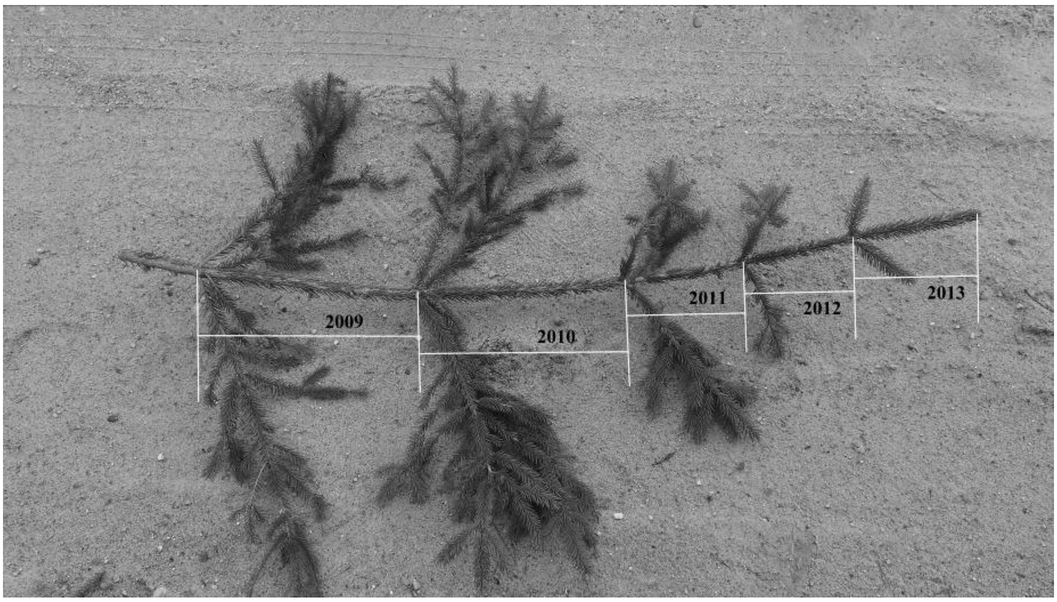

Figure 1. Example of the model branch with terminal shoots and needles of 5 years old

the laboratory for the analysis of shoots and needles. All measurements were made in 1-2 days.

The length of each terminal shoot was measured in cm. The lateral shoots were then removed from the each branch. The branches were cut into sections. Each section corresponded to the shoot of the different year (2009-2013). The samples were marked and dried in the heating oven with 105°C temperature. Duration of the drying (approximately 1-1.5 hour) depended on the sample size (Mikšys and Urbaitis 2013). Dried needles (n = 100) were removed from each terminal shoot and weighted (g) with 0.002 g accuracy. The statistical analyses included the mean and standard error of needle weight and shoot length were computed. The t-test and probability (p) were calculated (Čekanavičius and Murauskas 2000; Čekanavičius and Murauskas 2004). The correlation between the needle weight and shoot length was calculated (StatSoft Software, Ver. 7).

Results

Weight of needles

The weight of needles from 2009 shoots was the highest ($p < 0.05$). In 2010, the needle weight was significantly ($p < 0.05$) less in medium (1.3 times) and strongly (2 times) infested stands than in control. There was no difference in weight of needles between weakly damaged and control stands (Figure 2).

In 2011, the needle weight (n=100) started to increase and on average ranged from 0.33 to 0.38 g in spruce stands with different infestation level. In 2012, the needles on average weighted 0.36 ± 0.02 g in strongly damaged spruce stands. This weight was the same as before the damages. The needle weight did not exceed 0.33 ± 0.02 g in all infested stands and in control in 2013 (Figure 2).

Before the spruce bud scale infestation, the mean weight of the needles was 0.35 ± 0.04 g in spruce stands of Western Lithuania (Jurbarkas, Kazlų Rūda and Šakiai). During the mass attack, this weight significantly ($p < 0.05$) decreased to 0.19 ± 0.02 g and was less twice (53 %) than in control (Figure 3).

Comparing the periods before and during the outbreak, the mean weight of needles decreased from 0.40 ± 0.04 g to 0.36 ± 0.04 g and from 0.45 ± 0.03 g to 0.32 ± 0.03 g in Central and Northern Lithuania, respectively. In these two regions, the needle weight of infested spruces was about 20% less than in the control. Next year after damages (2011), the reduction in needle growth of infested spruces comprised 14% and 5% in Western and Central Lithuania, respectively. In Northern Lithuania, the weight of needles in damaged and control sites was the same. Needle weight was 10% lower in infested spruce stands compared to control stands in Western and Central Lithuania in 2012-2013. During this period, the needle weight of infested spruces was high in Northern Lithuania than in control (Figure 3). Comparing the periods before and during the outbreaks, the needle growth significantly decreased in forest stands with medium damages in Jurbarkas (4.5 times, $t = 4.63$, $p < 0.001$), Kupiškis (3.4 times, $t = 7.88$, $p < 0.001$) and Rokiškis (1.7 times, $t = 3.32$, $p < 0.01$).

Length of shoots

The shoots were significantly ($p < 0.05$) shorter in infested spruce stands in 2010 than before the damages. The average of shoot length in control sites was (12.45 ± 0.48 cm) 1.2 times longer than in strongly (10.44 ± 0.52 cm) and medium (10.78 ± 0.87 cm) infested plots in 2010 ($p < 0.05$). In 2011, shoot length was similar (about 12.00 ± 0.90 cm) on all plots. In 2012, shoot length was the same (13.26 ± 1.09 cm) in strongly in-

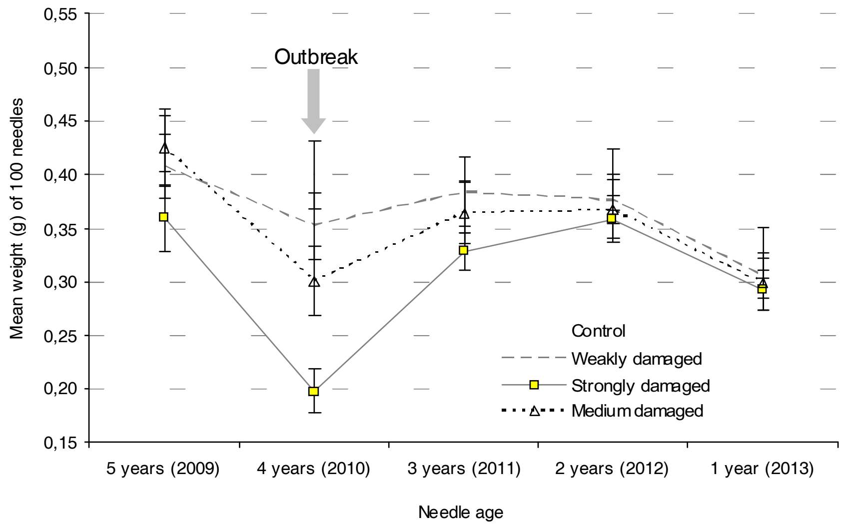

Figure 2. Average needle weight in young spruce stands with different infestation level of spruce bud scale

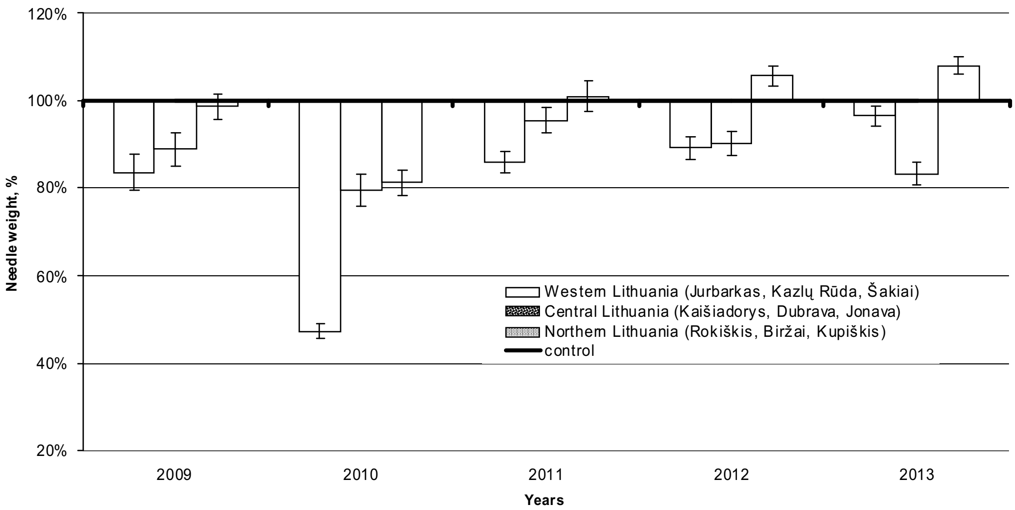

Figure 3. Needle weight in young spruce stands growing in different regions of Lithuania

Note: the percentage of needle weight was calculated from the meaning in control sites in each region

fested and control stands. The difference between them was insignificant in 2013. The reductions in shoot growth were insignificant in weakly damaged stands in which the average shoot length was about 12.00 ± 0.98 cm during 2009-2013. (Figure 4).

The total recovery of the increment was recorded in terminal shoots in 2012. It was particularly visible in spruce stands under strong infestation. There the length of shoots was almost the same as before the bud scale damages. Similar trend in the shoots growth was observed in control spruce stands. Recovery of shoots growth was not appreciable in moderately damaged stands, in which the length of 2010-2013 terminal shoots remains the same. The growth of shoots did not change in weakly infested stands in the period of 2009-2013 (Figure 4).

In Jurbarkas, Kazlų Rūda and Dubrava ET forest enterprises, shoot length and needle weight were reduced 2.0 and 3.5 times during the mass outbreak than before damages, respectively (differences significant $p > 0.001$).

Relation between shoots and needles

Spruce bud scale and its associated sooty mold reduced the growth of the spruce shoots and needles. There is the direct relation between the shoots length and needles weight: if the length of shoot increased, the weight of needles was larger in control and in infested spruce stands. The increment of shoots and needles significantly decreased in strongly infested spruce stands and the strong correlation was established between needle weight and shoot length. Moderate correlation (r =

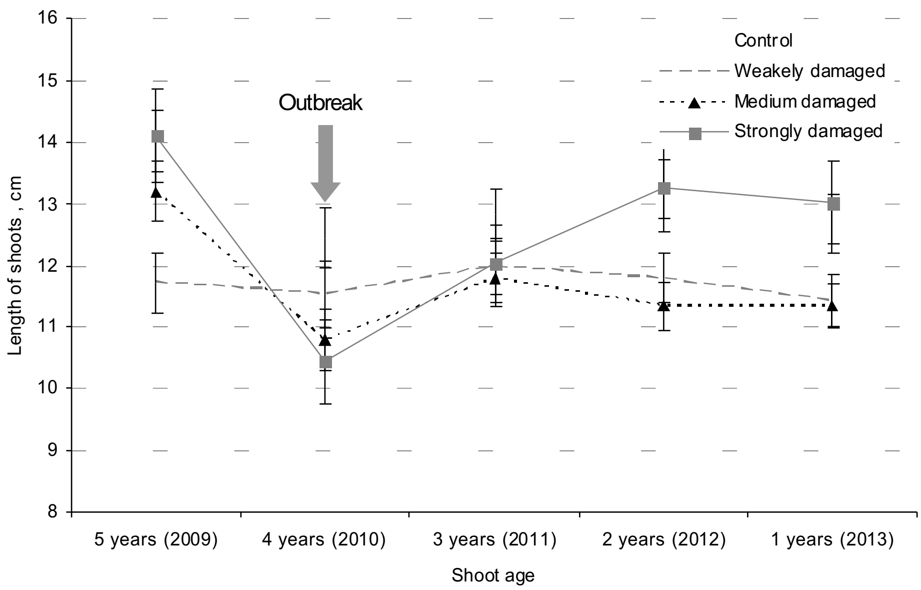

Figure 4. Average length of shoots in young spruce stands with different infestation level of spruce bud scale

0.64 and $r = 0.54$, $p \le 0.05$,) was revealed between the needle weight and shoot length in strongly and moderately infested stands, respectively. In control stands, the correlation between these two parameters was $r = 0.68$, $p \le 0.05$. A lower correlation ($r = 0.46$, $p \le 0.05$) was in weakly damaged stands (Figure 5).

Before the spruce bud scale infestation (2009), the relationship between the needle weight and shoot length was moderate in control and in strongly damaged stands while this relation was low in weakly and moderately damaged stands. During the mass attack (2010), correlation between the needle weight and shoot length was strong ($r = 0.75$) in control and strongly damaged stands but it was moderate in weakly and moderately damaged stands.

Discussion and Conclusions

During 2009-2010, the mass attack by spruce bud scale on Norway spruce was registered not only in Lithuania. The first Norway spruce damages by the pest were observed in Latvia in 2009. Especially middle-aged spruce stands growing on drained soils were damaged (Miezite et al. 2013). Soil properties were suggested to be the main reason of spruce bud scale outbreak (Lazdinš et al. 2011). However, in Lithuania, spruce bud scale infested spruces grow on their typical forest sites. Other species of scale insect (Hungarian spruce scale *Physokermes inopinatus* Danzig & Kozar) in 2010 appears to have been triggered by a sequence of droughts in Sweden (McCarthy and Skovsgaard 2011). In Lithuania, the last extreme drought was registered in 2006. It is hardly credible that this drought could cause the increase in the spruce bud scale population in 2009. It seems that the complex of

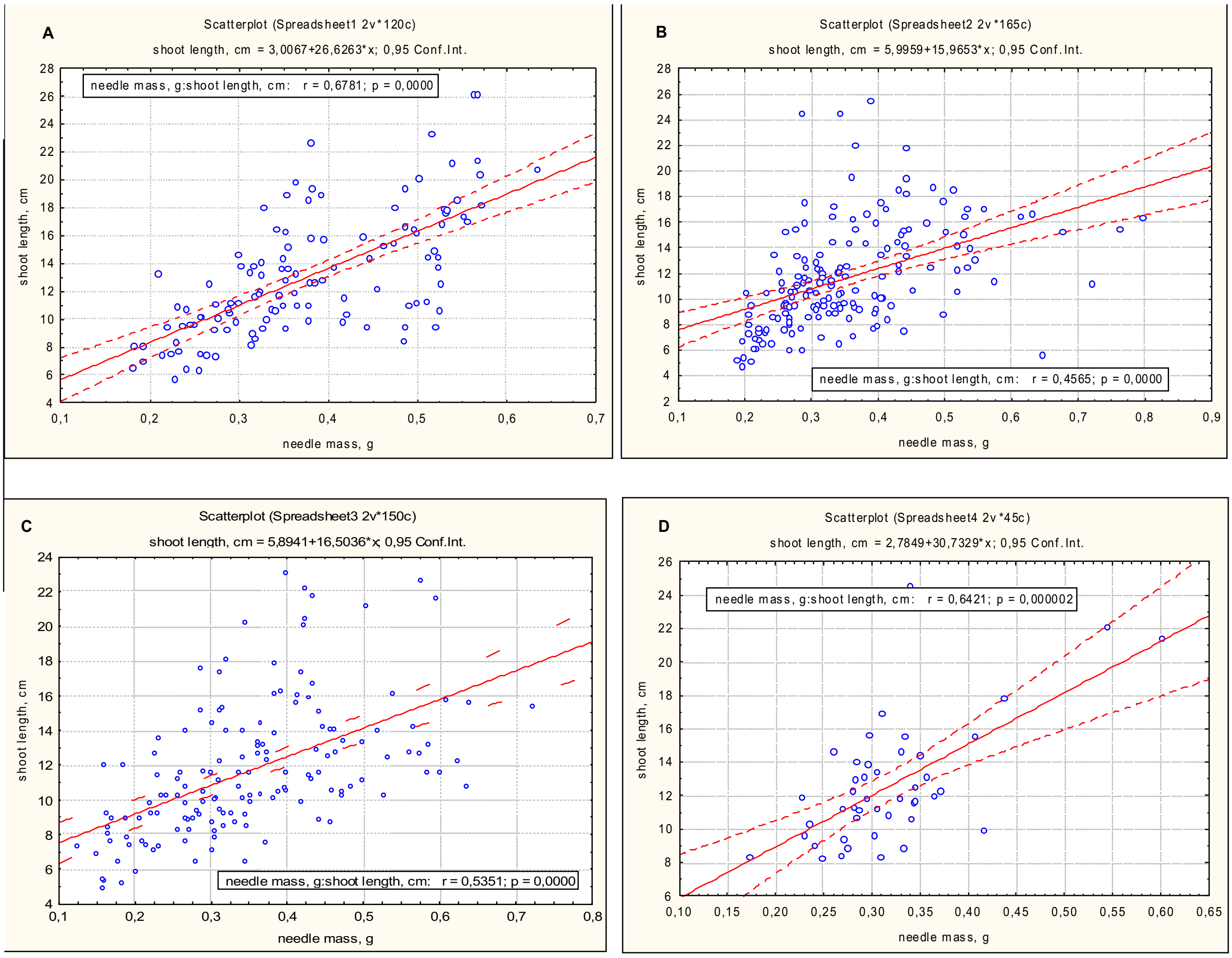

Figure 5. Relationship between needle weight (g) and shoot length (cm) not regarding to their age in spruce stands with various level of infestation by spruce bud scale: A – control, B – weakly damaged, C – medium damaged, D – strongly damaged

environmental conditions may evoke the development of the spruce bud scale population.

Reduction in the increment of shoots and needles is characteristic for trees heavily affected by spruce bud scale (Lazdiņš et al. 2011). This is one of the direct symptoms of the spruce bud scale infestation. The examination of the spruce foliage growth reduction was made using the methods of forest biomass assessment (Mikšys and Urbaitis, 2013). It should be mentioned that the main visible damage of spruce bud scale is shorter needles. In this study, the shortness of the damaged needles was expressed by the weight in assumption that the weight of the shorter needles should be less than the weight of normally growing needles. Similar method was used by other authors in order to estimate the effect of the fungal needle rust (*Crysomyxa rhododendri*) on Norway spruce seedlings. Shoot and root dry mass of once severely infested seedlings were 32 and 48 % less than in control seedlings (Plattner et al. 1999).

Our results have shown significant differences between the foliage growth of damaged and undamaged spruces. Damages caused by the spruce bud scale negatively affected the weight of needles and the length of terminal shoots. The main negative reductions due to the pest was registered during the mass attack in 2010. This type of physiological weakness of trees may to effect the stability of whole stand. The needle weight is the one of the main quantitative parameters indicating the ability of the tree assimilation (Ozolinčius 1998). Tree foliage is very important in a biological system. Moreover, it is the major chain in transforming non-organic substances into organic. Consequently, foliage mass may be an external index of the ability of the tree to perform a "job" or the external reflection of "energy" of a tree. So tree stability may be defined as the ability of the tree to keep stable ratio between bud increment and foliage mass (Ozolinčius 1998).

Spruce bud scale is considered as a pest who promotes processes, which may cause tree mortality (Miezite et al. 2013). During the monitoring of infested stands in Latvia, 10% of the damaged trees were reported as dead (Lazdiš et al 2011). During our examination, mortality of infested young spruces was not observed. According to our results, strongly affected young trees begin recovery in the increment of shoots and needles next year (2011) after the bud scale infestation. The epiphytotic distribution of the spruce bud scale may usually continue for 2-3 years (Lazdinš et al. 2011). In Lithuania, the outbreak of spruce bud scale was short (one year; consequently, spruces recovered their increment rapidly. Other authors have obtained similar results. The recovery of Norway spruce foliage next year after the Hungarian spruce scale damages was observed in Sweden (Mc Carthy and Skovsgaard 2011). The mechanisms how the spruces recover their foliage after the spruce bud scale damage is not yet analyzed. This process could be explained only theoretically. Insect feeding usually brings about an abrupt reduction in tree growth during the outbreak, which can severely diminish forest productivity. Moreover, any type of tree crown damage may provoke a variety of physiological responses of the plant. The impact of insect feeding in terms of biomass loss has been extensively studied, and physiological responses were less considered (Gori et al. 2014). As a consequence of insect defoliation or other crown damages, host plants can change their physiology by alerting water relations, and modifying photosynthate allocation and photosynthetic capacity (Kozlowski 1969). Many studies have highlighted an increase in photosynthetic activity as a compensatory mechanism during insect feeding (Gori et al. 2014). Moreover, there are two types of tree reaction to the stressor. Irreversible tree reaction shows the progressive degradation in tree state. The second one – reversible reaction is changeable and indicates only the stressful state after which the tree enable to start its normal grow (Ozolinčius 1998). It seems that short outbreak (one year) of spruce bud scale caused only the short-term growth reductions of young spruces in Lithuania.

The strong correlation between the shoot length and needle weight shows that shoot length and needle weight proportionally decrease regarding to the strong stress caused by the spruce bud scale. It is known that under undisturbed environmental conditions, the strong correlation exists (r = 0.91) between the length of shoots and the weight of needles in the Norway spruce (Metslaid et al. 2005, Metslaid et al. 2007). All parts of the Norway spruce foliage are sensitive to any type of stress. The increment of shoots and needles is significantly reduced during a stress, i.e. the crown shading (Ozolinčius 1998).

The results obtained from the various regions of Lithuania have shown that reduction in shoot and needle growth due to bud scale and sooty mold was more appreciable in all forest stands with strong level of the infestation in comparison with forest areas, which were presented as a weakly and moderately damaged. It should be noted that more sensitive to spruce bud scale damage were needles than shoots. The shorter needles have already weighted less in spruce stands with medium and weak infestation level. Our results show that the effect of spruce bud scale was significantly highest in infested young spruces growing in Western Lithuania (Jurbarkas, Kazlų Rūda and Šakiai) in comparison with young spruce trees in the Central (Kaišiadorys, Dubrava and Jonava) and Northern (Rokiškis, Biržai and Kupiškis) regions of the country. It is known that the spruce bud scale is able to colonize the trees of various age. Pest damages were firstly observed in the middle-aged and premature (51-70 years-old) spruce stands in Lithuania. In this study we observed also young spruces infested by the spruce bud scale. The most serious damages were observed in young spruces in Western Lithuania, where the area of colonized middle-aged and premature stands comprised almost the third of all damaged area in Lithuania.

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