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The influence of *Oligonychus ununguis* Jacobi (Acari: Tetranychidae) on photosynthetic activity and needle damage of *Picea glauca* 'Conica'

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Abstract: Needle damage and changes in photosynthesis rate of young spruce clones (*Picea glauca* 'Conica') were studied in relation to the population density of spruce spider mite (*Oligonychus ununguis* Jacobi) as well as to the time of its feeding. An increase in the density of the spider mite population feeding on spruce shoots caused an increase in the mean leaf damage index (MLDI). An analysis of regression revealed a positive correlation of the decrease in photosynthesis rate in infested plants (in relation to the control) with spider mite density as well as with MLDI. Photosynthesis was significantly suppressed already after 3 weeks of mite feeding (by a mean of 14.7 mites per 5 cm of shoot length) and at a relatively low level of needle damage (MLDI 2.3–2.6).

Key words: spruce spider mite, photosynthesis, white spruce, needle discolouration, population density

INTRODUCTION

Dwarf Alberta white spruce (*Picea glauca* 'Conica') is a very popular ornamental tree planted in gardens, urban squares and parks. Nevertheless it requires regular monitoring for the presence of a small mite from the family Tetranychidae – the spruce spider mite (SSM) (*Oligonychus ununguis* Jacobi, 1905). Studies conducted in nurseries, botanical gardens and urban parks in Poland, revealed that among the plants grown there, *P. glauca* 'Conica' was one of the species most frequently and abundantly inhabited by this pest (PRZYGODA 2001, PUCHALSKA 2003). Laboratory experiments on mite bionomics, involving various coniferous plants, confirmed that this particular spruce variety offers conditions highly favouring its development (CZAJKOWSKA et al. 2003). SSM feeding leads to mosaic-like discoloration, followed by browning and withering of needles. Young, developing needles are significantly shortened and deformed (LÖYTTYNIEMI 1970, LEHMAN 1998, ŁABANOWSKI et al. 2001). The economic injury level for dwarf spruces was estimated by BOGATKO et al. (1987) as only 2 SSMs per 20 cm of twig sample. Under optimal conditions and when no chemical treatment is applied, the SSM population can reach a high density on *P. glauca* 'Conica' in a short time, causing damage of the photosynthetic apparatus and leading, as a consequence, to a decrease in both plant vitality and aesthetic value.

There are some publications referring to changes in photosynthetic activity of deciduous plants (chrysanthemum, almond, cucumber) infested by spider mites (Andrews & La Pre 1979, Tomczyk 1989). In the case of conifers the only investigations known concern the disturbance of photosynthetic activity as an effect of drought (Aussenac & Finkelstein 1983), irregular fertilization (Hagg et al. 1992), irrigation (Dunn & Lorio 1993) or air pollution with ozone (Weiser & Havranek 1993). Thus, the aim of this study was to estimate how the spruce spider mite feeding affects needle damage and consequently photosynthesis rate in a white spruce cultivar (*Picea glauca* 'Conica').

MATERIAL AND METHODS

Plant material

The plant material consisted of 4-year-old trees of *P. glauca* 'Conica' planted in a peat substrate (spacing 20 cm × 20 cm) in a greenhouse. All the trees were clones derived from the same donor plant.

Experimental design

All plants were divided into the experimental group and the control. Within experimental plants, 3 subgroups were defined. On 7 May 2002, five plants of each subgroup were artificially infested with female SSMs. The density of initial SSM populations equalled: 20 mites per plant in subgroup I (it was assumed infestation grade I), 60 mites per plant in subgroup II (infestation grade II) and 180 mites per plant in subgroup III (infestation grade III). After 3 weeks (28 May), twelve 5-cm-long shoots were collected from each combination for the first measurement of photosynthesis rate. Every 2 weeks, successive readings from freshly collected shoots were performed. The last measurement was made on 20 August. Each time the density of the SSM population was simultaneously assessed on plants representing 3 different infestation grades. Population density of the pest was expressed as mean number of mites per 5 cm of shoot length.

Method of photosynthesis rate measurement

The area of needles on a shoot was determined with the use of a Portable Leaf Area Meter CI 202 (CID, USA). Photosynthesis rate was measured by the analyser LICOR 6200, at 360 ppm CO_2 in the measurement chamber and PAR (photosynthetically active radiation) over 600nm. Readings are presented in $\mu mol\ CO_2 \cdot m^{-2} \cdot s^{-1}$.

Statistical analysis

To check the significance of differences in photosynthesis rate between infested plants and the control, the Mann-Whitney test (for detecting a shift in median) was applied for 2 independent samples. In order to estimate a relationship between a decrease (as compared to the control) in photosynthesis rate of infested plants (y) and in density of the SSM population (x), a regression analysis was performed and the coefficient of determination (R^2) and Pearson's correlation coefficient (r) were determined. The decrease in photosynthesis rate in relation to the control was expressed as a percentage, so that the data were subjected to Bliss transformation before the regression analysis.

Assessment of needle damage

Assessment of needle damage caused by the SSM was performed simultaneously with the experiment described above. Every time after measuring the photosynthetic activity, needles of infested and control shoots were observed under a stereomicroscope at 12× magnification. To assess the level of needle damage, a 5-grade scale proposed by BOGATKO et al. (1987) was used: I – completely green needles; II – needles with yellow base and singular discoloured spots on the surface; III – needles with yellow base and 20% of surface covered with spots; IV – 20–50% of needle surface covered with yellow and brown spots; V – over 50% of needle surface covered with spots, completely yellow or brown needles.

After the assessment of damage level in needles coming from 12 shoots of various experimental groups (the control and 3 grades of infestation), the mean leaf damage index (MLDI) was calculated according to the formula of HUSSEY & SCOPES (1985):

$$MLDI = \frac{\sum (A*B)}{n}$$

where: A = number of needles representing a particular damage grade (according to I–V scale); B = damage grade; n = number of needles within particular sample.

To estimate the relationship between MLDI and density of the SSM population (x), a regression analysis was performed and determination coefficient (R^2) as well as Pearson's correlation coefficient (r) were assessed.

In the same way, the relationship between a decrease in photosynthesis rate of infested plants (referred to the control) and MLDI of needles attacked by the SSM (x) was determined. Values expressing the decrease in photosynthesis rate in relation to the control had been first subjected to Bliss transformation.

RESULTS

Disturbances in photosynthesis resulting from SSM feeding

The biweekly investigations of SSM population density on *P. glauca* 'Conica' showed that during the 15 weeks, mean numbers of feeding mites per 5 cm of shoot length were 3.3 and 9.1 on plants of infestation grades I and II, respectively. On the plants of infestation grade III, whose needles were completely damaged after 11 weeks, the mean number of mites was 14.7 per 5 cm of shoot length.

Photosynthetic activity observed during the experiment (15 weeks) differed significantly between the control and particular groups of artificially infested plants ($F_{6,154}$ = 28.7 at $P < 0.0001$ for infestation grade I; $F_{6,154}$ = 40.5 at $P < 0.0001$ for infestation grade II; and $F_{6,154}$ = 44.66 at $P < 0.0001$ for infestation grade III).

Within plants where the smallest amount of SSM females had been introduced (infestation grade I), no significant changes in photosynthesis rate were noted during the first 5 weeks of spider mite feeding, compared to control plants. Only after

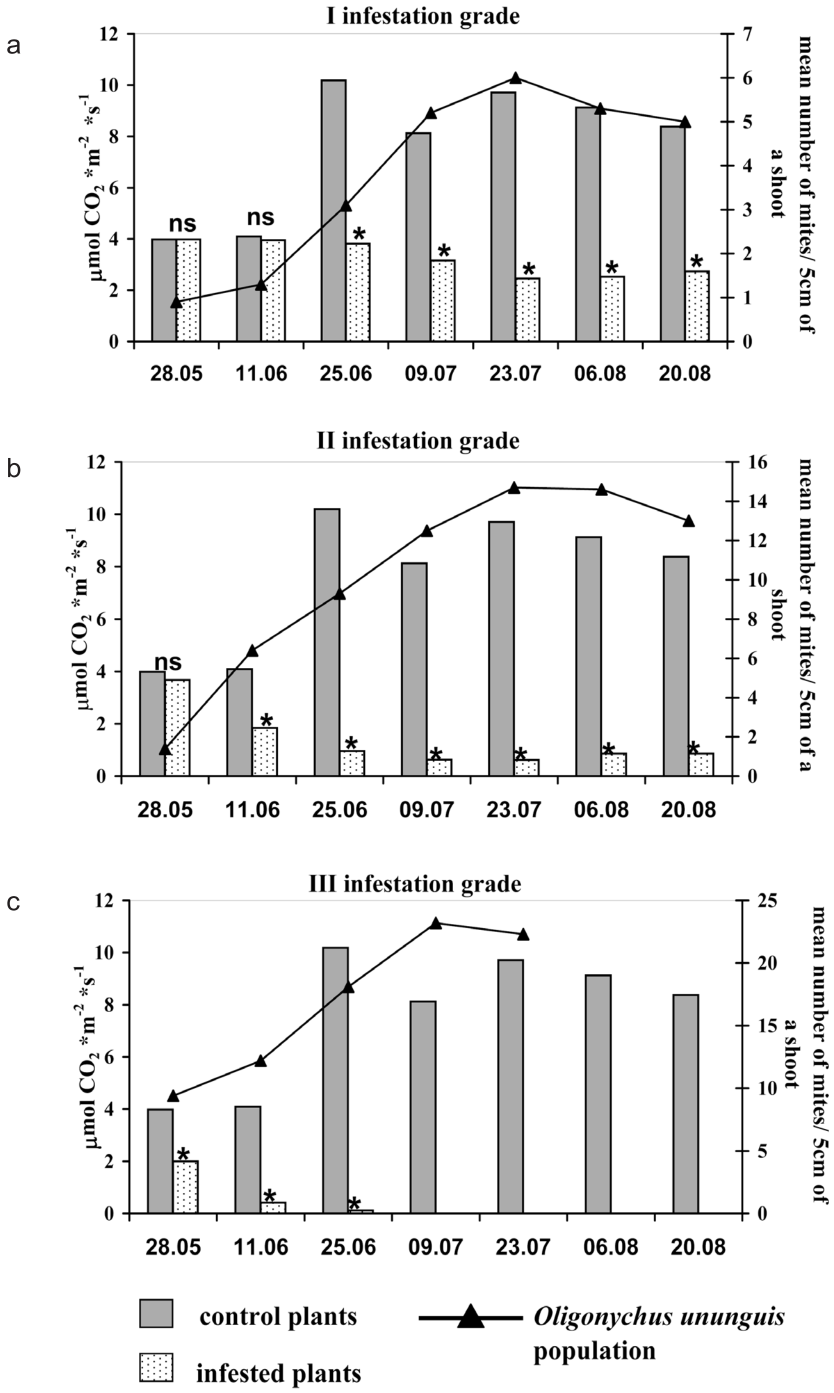

Fig. 1. Impact of 3 different grades of infestation by *Oligonychus ununguis* on photosynthesis rate in *Picea glauca* 'Conica' (* significantly different from the control at $P < 0.05$, Mann-Whitney test)

7 weeks of the pest feeding, a 62% decrease in CO_2 assimilation in relation to the control was observed. During consecutive months of the spider mite feeding, the difference between photosynthesis rate of infested plants and the control was even intensified (Fig. 1a).

In the case of the plants on which 3-fold more mites had been introduced (infestation grade II), a significant limitation of photosynthesis (by 55%, compared to the control) was observed after 5 weeks of the experiment. During succeeding weeks of SSM feeding, photosynthetic activity of the plants infested was reduced by 90%, compared to undamaged plants (Fig. 1b). In both experimental groups (infestation grades I and II) the photosynthesis rate was the lowest in mid-summer (23 July).

Nevertheless, within spruces of infestation grade II, CO_2 assimilation was at that time 4-fold lower (0.6183 mmol $CO_2 \cdot m^{-2} \cdot s^{-1}$) than within plants of infestation grade I (2.4573 mmol $CO_2 \cdot m^{-2} \cdot s^{-1}$). On spruces inhabited by the most numerous SSM colony (infestation grade III), already after only 3 weeks of mite feeding a significant reduction (by 50%) in photosynthesis rate was recorded, compared to the control. In late June, photosynthesis rate of these plants was 98% lower than in the control, whereas and in early July (09 July) the spruces damaged by spider mites stopped photosynthesis completely (Fig. 1c).

A positive logarithmic relation ($y = 9.1301 + 25.1751 \ln x$) between a decrease in photosynthesis rate of plants infested by the SSM (in relation to the control) and density of the pest population on these plants ($r = 0.96$; $R^2 = 0.92$; $F_{1,17} = 188.65$; $P < 0.0001$) was revealed.

Needle damage caused by SSM feeding

The progress in needle damage of *P. glauca* 'Conica' due to SSM populations with 3 different initial densities (3 infestation grades) is presented in Fig. 2.

On spruces of infestation grade I (mean 3.3 mites per 5 cm of shoot length during 15 weeks), first symptoms of damage were observed no sooner than after 7 weeks of mite feeding. Since then, MLDI increased in this group of plants, reaching a maximum (3.03) at the end of the experiment (August 20).

In the case of the plants infested by the pest almost 3-fold more abundantly (infestation grade II – mean 9.1 mites per 5 cm of shoot length during 15 weeks), symptoms of damage in the form of discoloured surface spots were first recorded after 5 weeks of SSM feeding (MLDI 2.4). During succeeding weeks, progressing needle damage (MLDI ca. 3) was recorded from plants of this infestation grade. Fifteen weeks after starting the experiment (20 August), 20–50% of their needle surface was covered by yellow or brown spots (MLDI 4.1).

On spruces of infestation grade III (mean 14.7 mites per 5 cm of shoot length during 11 weeks), MLDI reached 2.6 already 3 weeks after mite introduction, and after another 4 weeks (25 June) it exceeded 4. At the beginning of July, a majority of needles belonging to plants of this group were completely yellow or light-brown (MLDI 4.9–5). In late July and early August, needles started to wither and the plants died gradually. In contrast, needles of control plants remained green till the end of the experiment (for 15 weeks).

The analysis of regression revealed that the increase in SSM population density, was associated with an increase in MLDI of spruce needles, according to the formula $y = 1/(0.2325 + 0.8308/x)$. Correlation coefficient was estimated at $r = 0.96$

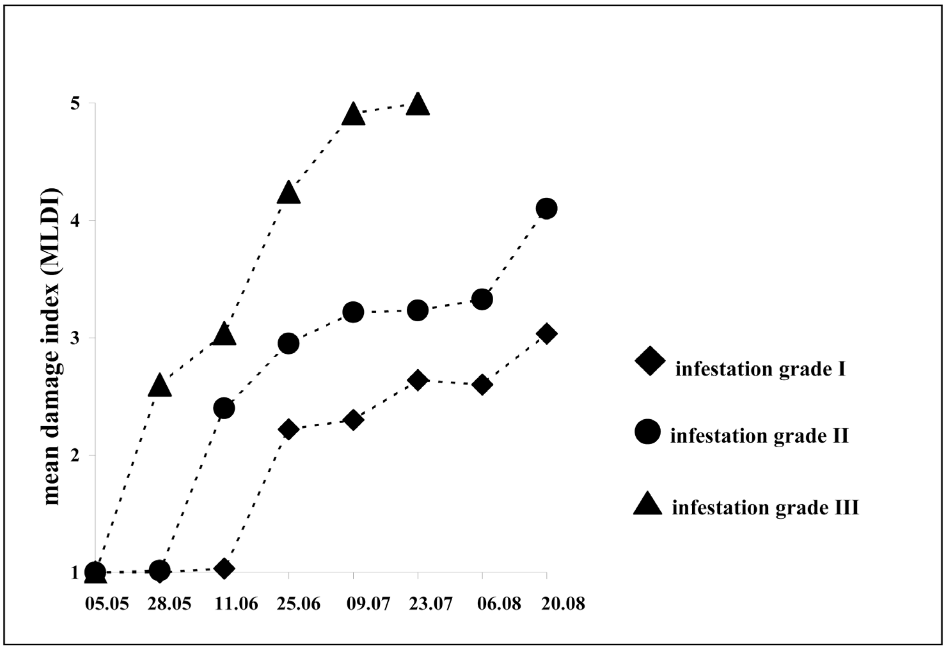

Fig. 2. Changes in needle damage of *Picea glauca* 'Conica' under the influence of 3 different grades of infestation by *Oligonychus ununguis*

($R^2 = 0.92$; $F_{1,17} = 197.66$; $P < 0.0001$). Positive logarithmic correlation ($y = 8.0171 + 51.5582 \ln x$) was found between the decrease in photosynthesis rate in the plants infested by the SSM (in relation to the control) and their MLDI ($r = 0.97$; $R^2 = 0.94$; $F_{1,17} = 266.41$; $P < 0.0001$). The decrease in photosynthesis rate in relation to the control was statistically significant already at MLDI ranging from 2.3 to 2.6.

DISCUSSION

This study showed that MLDI of spruce needles increased with growing pest density on the plant. Plant damage caused by the feeding of a mean of 3.3 spider mites per 5 cm of shoot length during 15 weeks, did not exceed 20% of the overall needle surface. By contrast, the feeding of 14.7 mites per 5 cm of shoot length, led to the plants withering just after 11 weeks. Regression analysis performed in the present study showed a significant correlation between the decrease in photosynthesis rate of the infested plants (in relation to the control), and SSM density as well as the MLDI of infested spruce needles. The reaction of coniferous plants to spruce spider mite feeding during this study was similar to the reaction provoked by other species of the family Tetranychidae, observed on deciduous plants. VAN DE VRIE et al. (1972) and BRITO et al. (1986) reported that the inhibition of photosynthetic activity is usually proportional to the feeding period and population density of spider mites. MOBLEY & MARTINI (1990) claimed that photosynthesis rate of apple and pear leaves decreased linearly during the increase in population density of the 2-spotted spider mite *Tetranychus urticae* (Koch, 1836) and European red mite *Panonychus ulmi* (Koch, 1836). ANDREWS & LA PRE (1979), showed a negative correlation between the area of leaf damage caused by the feeding of *Tetranychus pacificus* (McGregor, 1919), and photosynthetic activity of almond tree leaves.

In my study, the plants on which a large SSM population was feeding (mean 14.7 mites per 5 cm of shoot length during 11 weeks) showed a 50% reduction in photosynthesis rate just after 3 weeks, as compared to the control. At the beginning of July, these plants stopped photosynthesis completely. Spruces inhabited by smaller colonies of SSMs (3.3 or 9.1 mites per 5 cm of shoot length during 15 weeks) did not show any significant changes in photosynthesis rate during the first 3–5 weeks of pest feeding. This confirms the possibility of tolerating the loss resulting from the feeding of small populations of the pest. On the other hand, a consistent increase in SSM density caused a serious limitation of CO_2 assimilation.

The process of photosynthesis in *P. glauca* 'Conica' plants was significantly suppressed even at a relatively low level of needle damage (MLDI 2.3–2.6). A similar phenomenon was observed in the case of black currant reaction to the 2-spotted spider mite feeding. Even moderate leaf damage decreased the photosynthesis rate (KROPCZYŃSKA et al. 1996, TOMCZYK et al. 1996, TOPA et al. 1999). In weakly damaged leaves (below 10% of surface area), CO_2 assimilation was reduced by 35% (TOPA et al. 1999).

According to KOŁODZIEJ (1976), one of the causes of photosynthesis suppression is the accumulation of phenolic compounds in plant tissues. Our previous studies, concerning changes in the chemical content of *P. glauca* 'Conica' needles, showed an increase in phenolic compounds in the plants infested by the spruce spider mite, in relation to the control (PUCHALSKA 2003, KIEŁKIEWICZ et al. 2005). It can be therefore assumed that the limitation of photosynthesis rate was in this case caused by phytochemical changes rather than by the mechanical damage to the photosynthetic apparatus provoked by the mite.

Referring to my results, it is important to observe SSM density. When the population density does not exceed 4 mites per 5 cm of shoot length, the chemical control by up to 5 weeks can be delayed or predatory mites can be introduced. On the other hand, we have to prevent even small damage of spruce needles, because it significantly suppresses the photosynthetic activity of plants.

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