Ecological aspects of dispersion of gall mites in the vertical profile of the birch crown

I. Buchta, E. Kula, K. Drápela

Faculty of Forestry and Wood Technology, Mendel University of Agriculture and Forestry, Brno, Czech Republic

ABSTRACT: In stands of birch *Betula pendula* Roth in the eastern Krušné hory Mts. the occurrence of the gall mites *Acalitus rudis* Canestrini and *Phyllocoptes lionotus* Nalepa was studied in terms of their dispersion in the tree crown. Statistical analyses of data on the infestation of birch with gall mites in the height transects of the eastern Krušné hory Mts. were conducted (1995–2001) as well as detailed monitoring of their dispersion on selected heavily infested sample trees. In 1995–2001 the infestation of birch stands of the eastern Krušné hory Mts. increased. The population dynamics of *A. rudis* revealed important deviations, the abundance of *P. lionotus* was lower and in terms of time changes it was incidental. Detailed investigations proved that the gall mites favoured leaves formed in the stage of leaf opening in the lower part of the crown. The horizontal distribution of *A. rudis* in the crown was limited.

Keywords: *Acalitus rudis*; *Phyllocoptes lionotus*; tree crown dispersion; ecology

Baudyš (1954), Pfeffer (1954), Blattný et al. (1956) and Vaněčková-Skuhravá (1996a) contributed to the mapping of 90 gall mite species (*Acari*, *Eriophyidae*) occurring in the Czech Republic. However, the northern part of Bohemia and the forest ecosystems of the Krušné hory Mts., which were strongly influenced by the air pollution for a long time, were completely ignored. Kula et al. (1999) informed about the abundance of *Acalitus* (= *Aceria*) *rudis* Canestrini and *Phyllocoptes lionotus* (= *Aculus leionotus*) Nalepa within the spectrum of phytophagous pests of birch (*Betula pendula* Roth) in the eastern part of the Krušné hory Mts. and in the Děčín Sandstone Upland.

Gall mites (*Acari*, *Eriophyidae*) are plant parasites; they produce galls or erinea on the infested parts of the leaves and they deform parts of the plants. They are adapted to sucking the sap on plants or inside them (Vaněčková-Skuhravá 1996b). A number of these pests have been indicated as pests of forest tree species and some are considered vectors of plant viruses. Pfeffer (1954) gave a survey of gall-forming mites of forest tree species, deciduous species in particular. In support of the hypothesis that the gall-forming pests are better protected against unfavourable effects of the environment than the free-living phytophages due to their mode of life (Lindquist et al. 1996) is the fact that they appear more frequently in dry localities, on unfertile soil and in air-polluted regions (Skuhravá, Skuhravý 1986; Fernandes, Price 1992; Blanche 1994).

The investigated gall mite species form characteristic galls on birch (Schnaider 1991). *A. rudis* generally sucks on the underside of leaves. In the course of vegetation the white to light green erinea turn rusty coloured. *P. lionotus* causes globular galls of 0.3–0.9 mm in diameter on the underside of the leaves.

According to hitherto investigations, only these two species of gall-forming mites were found on birch in the eastern Krušné hory Mts. (Kula et al. 1999). In birch stands of the 1st–3rd age categories *A. rudis* was not dependent on the age of the host tree, but older birch trees were much more attractive for *P. lionotus*. In birch stands of the eastern Krušné hory Mts. *A. rudis* favoured lower altitudes (500–700 m); long-term studies of the intensity of infestation of birch showed a decreasing tendency with a higher altitude. *P. lionotus* was found in the 500–900 m height profile favouring the altitude of 500–700 m; the degree of infestation being uneven (Kula et al. 1999). The mite *A. rudis* favours the lower parts of the crown and characteristic of *P. lionotus* is a higher variability of abundance in the crown.

The objective of the present study is to evaluate the dispersion of the gall mites *A. rudis* and *P. lionotus* in

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Table 1. Scale for evaluations of the infestation of leaves with gall mites

Infestation category	*Acalitus rudis* leaf surface with erineum (%)	*Phyllocoptes lionotus* number of galls	Characteristics of the abundance/ infestation
0	0	0	not infested
I	< 10	1–3	sporadic abundance
II	11–25	4–10	low abundance
III	26–50	11–15	medium abundance
IV	51–75	16–25	strong abundance
V	> 75	26 and more	very strong abundance

birch crowns and to specify further methods of monitoring populations of gall mites of the eastern Krušné hory Mts.

METHODS AND MATERIAL

Investigations were conducted in 54 stands on 162 permanent sample birch trees (*B. pendula*) of the 2nd and 3rd age categories situated in the height transects (500 to 1,000 m alt.) in the Forest Districts Klášterec, Janov, Litvínov (eastern Krušné hory Mts.) and Forest District Sněžník (Děčín Sandstone Upland) (KULA, HRDLIČKA 1998). More than 150 thousand leaves were controlled using the method of unit branches from various profiles of the crown (KULA et al. 2002). The species spectrum of phytophagous mites was defined on the basis of the erinea and galls (SCHNAIDER 1991).

The repeated-measures analysis of variance (ANOVA) was used to evaluate the differences in the abundance of the gall mites in the respective storeys, which allows identification of divergence not only between the respective groups (crown storeys) but also between individual measurements, and enables simultaneous analysis of the time series. This method can also identify if the core of the mite attack changes in the course of repeated measurements. As Mauchley's test did not prove the independence of repeated measurements, multi-dimensional Wilks', Pillai's, Hotelling's and Roy's tests were used at a level of significance $\alpha = 0.05$. Calculations were elaborated separately for groups of trees where branches were taken from two and from three storeys.

Detailed investigations of the dispersion of gall mites in the tree crowns were performed on sample trees with full crowns in all the available age categories, which were heavily infested with at least one species of the phytophagous mite. Sampling (VI–VIII/2002) was based on the method of unit branches taken from the top, middle and bottom parts of the crown immediately close to the stem from the north and south exposures. For further analysis all the sample branches were divided into internal (with leaves closer to the stem, less exposed to environmental effects and sunlight) and peripheral branches (parts of the crown making up the case of the crown of hypothetical depth of 50–70 cm). From each branch segment 70 younger and 70 fully developed leaves were randomly chosen and they were used for evaluations of the degree of infestation.

The tree crown dispersion of *A. rudis* was assessed on more than 21 thousand leaves from 32 sample trees; the dispersion of *P. lionotus* on 9,000 leaves from 7 sample trees. The rate of infestation was expressed as the percentage proportion of the leaf area covered with galls and classified in categories 0–V (Table 1). Single-factor ANOVA (Statistica 6.0) was used to discover the differences between horizontal and vertical dispersion within each category of infestation; as independent variables we specified the categories of the crown part, horizontal division into peripheral and internal leaves and the exposure. The normality of input sets was confirmed.

RESULTS AND DISCUSSION

Statistical analyses of time series revealed differences between the respective storeys in the profiles of trees attacked by *A. rudis* collected from two crown layers. The differences in *A. rudis* infestation in the individual years were significant, while this difference was not statistically significant in terms of *P. lionotus* infestation (Tables 2 and 3). No other important differences in the vertical profile, time of sampling and abundance of the gall mites were discovered (Tables 3 and 4).

The graphs of the infestation averages in storeys correspond with the results of statistical tests. In 1995–2001 the trend of *A. rudis* infestation was similar in both groups of sample trees. In 1996 and 1997 *A. rudis* infestation was insignificant; in the following years the rate of infestation increased with gradation in 1999 (sample trees of the 3rd age category). No substantial culmination was seen in

Table 2. Degree of disturbance of the assimilatory organs of birch in the crown profile in long-term investigations – *p*-values. The statistically significant differences are indicated in boldface

	Divergence between storeys (2 storeys)	Divergence between storeys (3 storeys)
Acalitus rudis	**0.001339**	0.393662
Phyllocoptes lionotus	0.252387	0.285593

Table 3. Multi-dimensional tests of the dependence of repeated measurements – *p*-values. The statistically significant differences are indicated in boldface

	Divergence of annual change			
	Wilks	Pillai	Hotelling	Roy
Acalitus rudis – 2 storeys	**0.000007**	**0.000007**	**0.000007**	**0.000007**
Acalitus rudis – 3 storeys	**0.000389**	**0.000389**	**0.000389**	**0.000389**
Phyllocoptes lionotus – 2 storeys	0.128472	0.128472	0.128472	0.128472
Phyllocoptes lionotus – 3 storeys	0.361126	0.361126	0.361126	0.361126

Table 4. Multi-dimensional tests of the dependence of interactions between the vertical structure of gall-mite infestation in the crown and time of sampling – *p*-values

	Storey vs. annual change interactions			
	Wilks	Pillai	Hotelling	Roy
Acalitus rudis – 2 storeys	0.339992	0.339992	0.339992	0.339992
Acalitus rudis – 3 storeys	0.765475	0.762410	0.768600	0.394939
Phyllocoptes lionotus – 2 storeys	0.484571	0.484571	0.484571	0.484571
Phyllocoptes lionotus – 3 storeys	0.490917	0.502738	0.479622	0.094797

sample trees of the 2nd age category (Fig. 1). In the case of low infestation the illustrated trend also captures the interactions between the storeys. If the abundance was higher, the damage was concentrated in the bottom layer of the crown (Fig. 1). *P. lionotus* did not show any trend, the average extent of leaf disturbance was very low and ranged between 0 and 2% of the leaf area (Figs. 2 and 3).

The phytophagous mites were gathered on the leaves already developed in spring, while the continually growing leaves were infested only sporadically (*A. rudis* 0.7%, *P. lionotus* 1.1%). These data are in accordance with information about the life cycle of phytophagous mites specialised in sucking deciduous tree species (LINDQUIST et al. 1996).

We included only fully developed leaves in evaluations of the significance of the exposure, vertical and horizontal position in the crown. Based on the test of the dependence of the abundance of gall mites on the exposure there was no statistically significant difference (Table 5). The differences in infestation between leaves from the northern and southern part of the crown were minimal and no regularity was found. The differences in the disturbance of internal and peripheral leaves were statistically significant for *A. rudis* in categories I–III (Table 5). The crucial proportion of infested leaves was found in the inside part of the crown (54.3% of leaves from the segment). In the outer part of the crown 41% of the leaves, on average, were attacked. No statistically significant difference between the inside and outside leaves was discovered in the case of *P. lionotus* (Table 5).

The statistically significant difference in the abundance of both mites was discovered in the vertical crown profile (Table 5). Both species favour the bottom part of the crown and they appear only sporadically in the crown top (Figs. 2 and 3). The difference between analysis of long-term series and results of detailed investigations may be attributed to the high variability of the set of data from the entire area of the eastern Krušné hory Mts. While only

Table 5. Tests of significance of differences showing the test results' *p*-values. Data presented in boldface indicate a significant difference; the values immediately beyond the limit of acceptance of the hypothesis of significance of the difference are printed in italics

Infestation category	0	I	II	III	IV	V
Acalitus rudis						
Exposition	0.1432	0.5800	0.7113	0.2766	0.5149	0.8562
Horizontal position	**0.0038**	*0.0650*	*0.0644*	*0.0669*	0.9430	0.7746
Vertical position	**0.0000**	**0.0000**	**0.0000**	**0.0069**	0.0790	0.1333
Phyllocoptes lionotus						
Exposition	0.2703	0.1726	0.4589	0.9234	0.8191	0.9782
Horizontal position	0.2292	0.5235	0.9077	*0.0657*	0.2867	0.1712
Vertical position	**0.0000**	**0.0001**	**0.0026**	**0.0010**	*0.0569*	**0.0328**

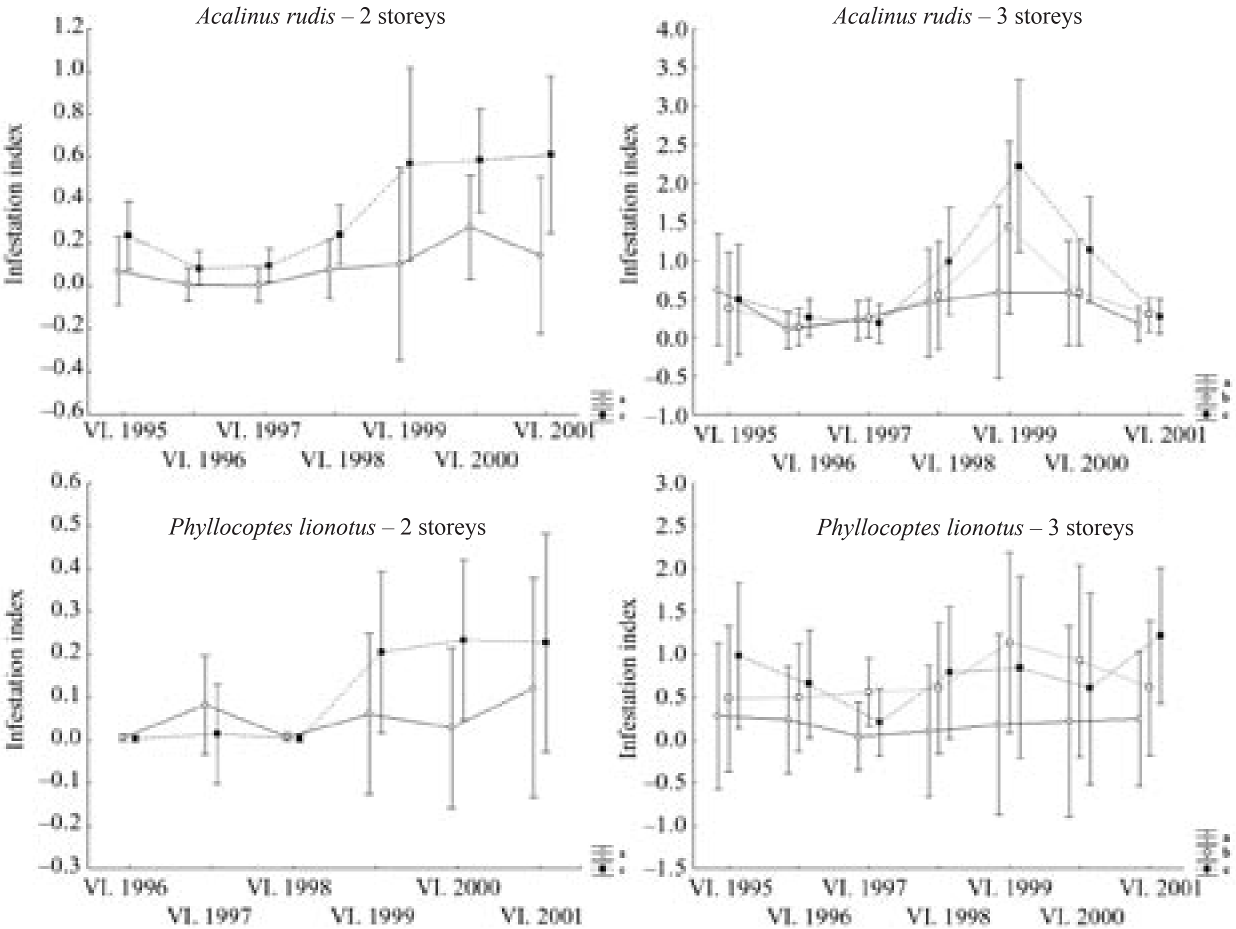

Fig. 1. Dynamics of the infestation of stands by gall mites in the crown profile (a – top, b – middle part, c – bottom part)

heavily infested sample trees were selected for detailed investigations, we included all the trees from all localities in statistical evaluations, including sample trees and localities free from gall mite attacks.

The discovered vertical variability in the dispersion of gall mites is consistent with the conclusions of KULA et al. (1999). The abundance of the studied species is collocated with the bottom part of the crown and the less exposed leaves in the inside part. The reason may be that the inside leaves have a higher rate of protection against unfavourable effects (precipitation, sunlight) (LINDQUIST et al. 1996) and against the deposition of air pollutants (KORICHEVA et al. 1996). The resulting dispersion of the gall mites in the crown could be affected by their passive spreading in the air. Besides, we cannot neglect the hypothesis of different physiology or chemical status of the leaves in different parts of the crown and on it based different attractiveness for these specific phytophagous species.

The almost complete absence of gall mites on the young developing leaves growing out in the course of the veg-

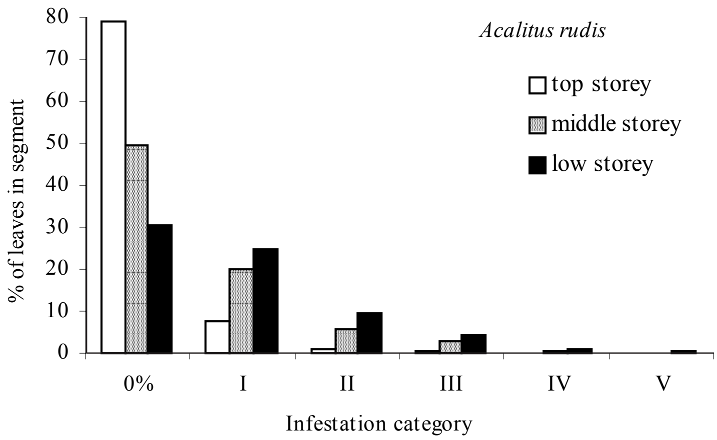

Fig. 2. Distribution of leaves infested by *A. rudis* in the vertical crown profile

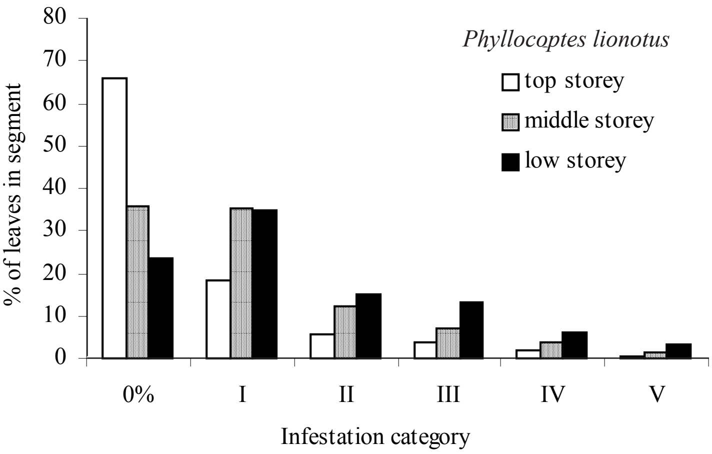

Fig. 3. Distribution of leaves infested by *P. lionotus* in the vertical crown profile

etation period is probably due to the low mobility of the species and mode of overwintering of the eggs or mature females at the base of the buds (VANĚČKOVÁ-SKUHRAVÁ 1996c). The termination of sucking may also be associated with the changed chemical status of the leaves. The galls on the leaves developed later during the season are probably produced by single specimens that had been blown to these leaves. The fact that galls were discovered on younger leaves of heavily infested branches supports this hypothesis.

The finding that leaves heavily infested with *A. rudis* appear incidentally in the crown in terms of vertical stratification is at variance with other parameters and may be caused by the fact that the amount of heavily attacked leaves in the set was insufficient (in the category of infestation of 51–100% of the leaf area). Increasing the number of samples will provide more accurate information about the dependence of the horizontal abundance of *A. rudis* in the crown in cases when the tests were on the margin of acceptance of the hypothesis about the significance of the difference (Table 5).

Assessment of the effect of the age of the host tree on the rate of infestation, test of the interactions between horizontal and vertical distribution of infested leaves, or parallel abundance of both gall mite species, will require updating and extension of the database in the course of vegetation seasons in the future.

CONCLUSION

In 1995–2001 the rate of gall mite infestation of birch stands of the eastern part of the Krušné hory Mts. increased. Compared to other pests the extent of disturbance of the assimilation apparatus was not significant. In the case of *A. rudis* a significant difference in birch infestation between the individual years was discovered as a consequence of the higher sensitivity of the mite to conditions affecting the population dynamics. In the case of *P. lionotus* the total rate of infestation was lower and in terms of time changes incidental. Although only *A. rudis* showed important differences in the rate of infestation in terms of the vertical position on the birch, in detailed investigations it was discovered that in the case of heavily infested sample trees the rate of infestation by both species was the highest in the bottom part of the crown.

The damage caused by both species of phytophagous mites was concentrated on the fully developed leaves arising during birch flushing. The leaves that developed in the course of the vegetation period were attacked only sporadically. In terms of gall mite infestation no differences were detected between the northern and southern part of the crown. The degree of infestation was dependent on the position in the crown profile; both *A. rudis* and *P. lionotus* favoured the bottom part of the crown. To a limited extent *A. rudis* was also dependent on the horizontal position in the crown; an increased abundance of this species was detected on leaves of the inside part of the crown. Partial differences in the regularities of dispersion in the crown between the studied species were observed. The present investigations were the first step towards the explanation of the aspects of the abundance and dispersion of the above species of gall mites. Investigations focused on the population dynamics of *A. rudis* and *P. lionotus* in birch stands in the eastern part of the Krušné hory Mts. will follow and link up with the present study.

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Ekologické aspekty disperze vlnovníků ve vertikálním profilu koruny břízy

I. BUCHTA, E. KULA, K. DRÁPELA

Lesnická a dřevařská fakulta, Mendelova zemědělská a lesnická univerzita, Brno, Česká republika

ABSTRAKT: V porostech břízy *Betula pendula* Roth ve východním Krušnohoří byl sledován výskyt vlnovníků *Acalitus rudis* Canestrini a *Phyllocoptes lionotus* Nalepa z hlediska disperze v koruně. Byla provedena statistická analýza údajů o napadení břízy ve výškových transektech východního Krušnohoří z období 1995–2001 a detailní sledování disperze na vybraných silně napadených vzorníkových stromech. Bylo zjištěno, že v letech 1995–2001 došlo k nárůstu napadení porostů břízy východního Krušnohoří vlnovníky. V případě *A. rudis* byl nalezen významný rozdíl v napadení mezi jednotlivými roky, u *P. lionotus* bylo napadení nižší a z hlediska časových změn nahodilé. Detailní šetření ukázalo, že napadení oběma vlnovníky se soustředilo ve skupině plně vyvinutých listů a oba roztoči byli nejvíce zastoupeni ve spodní části koruny. Závislost na horizontální poloze v koruně břízy byla v omezené míře zjištěna u *A. rudis*.

Klíčová slova: *Acalitus rudis*; *Phyllocoptes lionotus*; korunová disperze; ekologie

Při mapování populací vlnovníků (*Eriophyidae*, *Acari*) v České republice (VANĚČKOVÁ-SKUHRAVÁ 1996a) zůstala zcela opominuta severní část Čech a lesní ekosystémy Krušných hor, ovlivněné dlouhodobým působením imisí. Z dosavadních šetření vyplývá, že v oblasti východního Krušnohoří se v rámci spektra fytofágních škůdců břízy (*Betula pendula* Roth) vyskytují pouze vlnovníci *Acalitus* (= *Aceria*) *rudis* Canestrini a *Phyllocoptes lionotus* (= *Aculus leionotus*) Nalepa (KULA et al. 1999). V porostech břízy ve východním Krušnohoří preferovala *A. rudis* nižší polohy (500–700 m n. m.) s dlouhodobě stanoveným trendem poklesu intenzity napadení břízy s nadmořskou výškou. *P. lionotus* byl potvrzen ve výškovém profilu 500–900 m n. m. s preferencí pro území 500–700 m n. m. při nejednotném stupni napadení. Roztoč *A. rudis* preferuje nižší partie koruny a druh *P. lionotus* se vyznačuje vyšší variabilitou výskytu v koruně (KULA et al. 1999).

Šetření se uskutečnilo v 54 porostech na 162 trvalých vzorníkových stromech břízy (*B. pendula*) 2. a 3. věkové třídy situovaných do výškových transektů (500 až 1 000 m n. m.) v LS Klášterec, Janov, Litvínov (východní Krušnohoří) a LS Sněžník (Děčínská vrchovina) (KULA, HRDLIČKA 1998). Kontrola více než 150 tisíc listů se uskutečnila metodou jednotkových větví odebraných z různých výšek profilu koruny (KULA et al. 2002). Druhové spektrum fytofágních roztočů bylo determinováno podle erinea a hálek (SCHNEIDER 1991). K vyhodnocení rozdílu ve výskytu vlnovníků v jednotlivých etážích byla užita ANOVA s opakovanými měřeními (repeated-measurements ANOVA).

Pro detailní šetření disperze vlnovníků v koruně stromu byly vybrány vzorníkové stromy s kompletní korunou ve všech disponibilních věkových kategoriích, které byly silně napadeny alespoň jedním druhem fytofágního roztoče. Odběr vzorků (VI.–VIII. 2002) se uskutečnil metodou jednotkových větví. Pro další analýzu byly všechny jednotkové větve rozděleny podle vertikální a horizontální pozice v koruně a expozice. Z každého segmentu větve bylo náhodně vybráno 70 mladších a 70 plně vyvinutých listů, na nichž bylo provedeno hodnocení stupně napadení. Napadení bylo vyjádřeno jako procentuální podíl plochy listu pokryté hálkami a klasifikováno v kategorii 0–V (tab. 1). Ke zjištění rozdílů v horizontální a vertikální disperzi v rámci každé kategorie poškození byla použita jednofaktorová ANOVA, přičemž jako nezávisle proměnné byly určeny kategorie korunové části, horizontální rozdělení na plášťové a vnitřní listy a expozice.

Ze statistické analýzy časových řad vyplynul rozdíl mezi jednotlivými etážemi v profilu stromů napadených *A. rudis* při odběru ze dvou úrovní koruny. Významné rozdíly v napadení byly stanoveny mezi jednotlivými roky u *A. rudis*, zatímco u *P. lionotus* nebyl rozdíl statisticky významný (tab. 2 a 3). Další významné rozdíly ve vertikálním profilu, v době odběru a ve výskytu vlnovníků nebyly zjištěny (tab. 3 a 4).Výsledkům statistického hodnocení odpovídají grafy časových průměrných hodnot napadení podle etáží (obr. 1).

Z detailních šetření vyplynulo, že fytofágní roztoči se soustředili na listy vyvinuté v jarním období, zatímco kontinuálně narůstající listy byly napadeny sporadicky. Test závislosti výskytu na expozici neprokázal u vlnovníků statisticky významný rozdíl, u obou roztočů byl zjištěn statisticky významný rozdíl ve výskytu ve vertikálním profilu koruny (tab. 5). Oba druhy preferovaly spodní část koruny a ve vrcholu koruny byl zaznamenán jen ojedinělý výskyt (obr. 2 a 3). Rozdíl mezi analýzou dlouhodobých řad a výsledky detailního šetření lze přičíst vysoké variabilitě souboru dat z celého východního Krušnohoří.

Zjištěná vertikální variabilita disperze vlnovníků se shoduje se závěry KULY et al. (1999). Výskyt sledovaných druhů je vázán na spodní část koruny a na méně exponované listy v její vnitřní části. Příčinou může být vyšší míra ochrany před nepříznivými vlivy (srážky, sluneční záření – LINDQUIST et al. 1996) nebo depozice imisí (KORICHEVA et al. 1996).

Corresponding author:

Prof. Ing. EMANUEL KULA, CSc., Mendelova zemědělská a lesnická univerzita, Lesnická a dřevařská fakulta, Lesnická 37, 613 00 Brno, Česká republika
tel.: + 420 545 134 127, fax: + 420 545 211 422, e-mail: kula@mendelu.cz