Tree crown defoliation: influencing factors

REMIGIJUS OZOLINČIUS, VIDAS STAKĖNAS
The Lithuanian Forest Research Institute,
4312, Girionys, Kaunas distr., Lithuania

Ozolinčius R. and Stakėnas V., 1996. Tree crown defoliation: influencing factors. *Baltic Forestry*, 1: 48-55.

All factors influencing tree defoliation can be grouped into direct (window, snow, ice, frost, disease etc.) and indirect ones (soil acidification, lack of nutrients, drought, soil flooding etc.). The biological attributes of a tree (species, crown, shape, branching habit etc.), the individual particularities (age, resistance against coenotic "pressure" etc.) and the "ecological background" (soil fertility, moisture etc.) affect the "sharpness" of all these factors.

Forest monitoring data (1988-1995) were used. Visual damages were recorded for the 25-30% of all trees observed. Especially high defoliation was recorded on trees damaged by stem insects (*Ips typographus*) and fungus (wood decay).

Crown defoliation is conditioned by tree biological and individual particularities also. For example, the highest defoliation was recorded for conifers -- Scots pine and Norway spruce; with increasing age of trees crown defoliation becomes higher; Norway spruce with pure comb and plate branching habit are found to be the most defoliated etc.

"Ecological background" influences crown defoliation as well - the highest defoliation was observed on dry infertile sites and swamps.

Seven crown injury types have been determinated. The highest defoliation is typical to the peripheral one. The following index have been used for the assessment of defoliation changes under varions factors: $I=(D_{max}-D_{min})/D_{min}$, D_{max} and D_{min} – mean defoliation of damaged (or influenced in the highest degree) and undamaged trees respectively. Trees with symptom of so-called direct damage have the greatest index (I=0.46-3.06).

The defoliation of trees without symptoms of damages remains about 20%. Global environmental changes (including air pollution) are supposed to be crusial factors determining crown defoliation.

Keywords: defoliation, damage, site condition, age, injury type.

Introduction

In the early 1980's large scale of forest decline occurred in central Europe, in the so-called "triangle of death" (between the cities Katowice, Cottbus and Most). Claimes of various authors quickly popularised by the media under the slogan *Waldsterben* (forest death) were maintained by the following facts: a)all tree species were involved; b)the main symptoms were decrease in increment, discoloration and loss of foliage, premature senescence, altered branching habit – symptoms, not recognized before. The most likely couse of that was an ecosystem complex disease triggered by cumulative stress from increasing air pollution and deposition (acid rain, sulphur dioxide, nitrogene oxide, ozone etc.). A clear correlation between the erection of coalfired power stations and damage to spruce trees was revealed (Kandler 1992).

European system of forest condition monitoring was developed very rapidly. The tree crown defoliation became one of the most widely applied tests of tree condition assessment. In the context of forest monitoring this term does not quite corresponds to its initial sense (prefix "de" means moving away, separation; "folium" – leave) – the falling of leaves or their elimination with the help of chemical substances. Defoliation is not simply the loss of leaves. Defoliation is relative loss of foliage generally estimated in 5 or 10% classes relative a tree with full foliage – reference tree. The reference tree can be either a healthy tree in the vicinity (of the same crown shape), a photograph, locally applicable, representing a tree with full foliage (special photo quides have been used), or the sample tree itself with imagined full foliage (Manual..., 1994).

Now it is evident that there is a complex of causes of the defoliation increase (whole range of stresses). The fundamental modes of stresses are both direct and indirect (Tichy 1991). Various authors contrast markedly on which key factors are enphasized. For example, D.R.Houston (1993) emphasizes the central important of secondary action in the demise of stressed trees, while D.Mueller-Dombois (1986) emphasizes the importance of genetics and aging leading to senescence and vulnerability of stressing agents. Each of the decline models involve a number of interacting factors. Now the P.D.Manion (1991) decline desease spiral is the most popular. Manion using the predisposing, inciting and contributing terms, developed a three tiered inward decline spiral model. Within each ring are a number of stressing factors to indicate the interchangeability of various factors.

An important limitation in our present knowledge is the difficulty to interpret the influence of individual factors because of the complex of interaction between different factors and processes. For example, one factor, like deposition of nitrogen, may be stimulating under certain conditions while the reverse effect may occur under slightly changed conditions. Experimental studies dealing with sufficiently large plots and considering the interdisciplinary nature of ecosystem studies covering biological, chemical and physical processes can overcome these difficulties. Such kind of studies, for example, Skogby project in Sweden, must be carried out for a long time, they are expensive, and results can not be wildly applied.

We think that long-time survey studies (forest monitoring) covering large areas can help us to reveal some aspects of factors influencing tree defoliation. All factors influencing tree defoliation can be classified into direct (wind, snow, ice, frost, disease etc.) and indirect ones (soil acidification, lack of nutrients, drought, soil flooding etc.). Direct factors can be easily identified by trained observes. Indirect factors are like an ecological chain between environmental changes (including climate, air pollution) and tree. Sometimes it is impossible to identify them. The biological attributes of a tree (species, crown shape, branching habit etc.), the individual particularities (age, resistance against coenotic "pressure" etc.) and the "ecological background" (soil fertility, moisture etc.) can affect the "sharpness" of direct and indirect factors.

So it is quite clear that just analysis of huge number of sample trees can help us to reveal how (in what degree) various factors (including individual tree particularities and site conditions) influence tree defoliation. Forest monitoring data base gives that opportunity.

Material and methods

Forest condition in Lithuania has been monitoring since 1988. The grid of systematically selected permanent observation plots (POP) – 4x4 km (more than 960 POP) – covered the forest area of a country (in 1992-1995 number of POP was reduced due to well-known economical reasons). On each POP sample trees were systematically selected according to a statistically sound procedure. An example is the 4-point cluster with 4 subplots oriented along the main compass directions at a distance of 25 from the grid point (POP centre). On each subplot the 6 trees nearest to the subplot centre were selected as sample trees (dominant, codominant and intermediate trees – classes 1, 2 and 3 according to Kraft), resulting into 24 sample trees per plot.

Defoliation assessment was performed by two trained observers (experts) using binoculars and colour photoguides (Tree Crown Photos, 1990). The guidlines for field work are described more detail in previous publications (Hanisch 1990; Manual..., 1994).

The following indices were determinated for sample trees: class after Kraft, diameter, top condition, amount of dead branches, needle age, crown shape, branching habit, defoliation, damages, injury type. All causes of recorded damages were group as following: game, insects, fungi and diseases, abiotic agents (wind, snow, frost, wiping, drought etc.), action of man, others. More than 23th trees, including 10152 (or 44.1% of all trees observed) Scots pine (*Pinus sylvestris*), 5787 (25.1%) Norway spruce (*Picea abies*), 3591 birch (*Betula pendula and B. pubescens*) (15.6%), 1004 (4.4%) aspen (*Populus tremula*), 819 (3.5%) black alder (*Alnus glutinosa*), 779 (3.3%) ash (*Fraxinus exelsior*), 434 (1.9%) grey alder (*Alnus incana*), 358 (1.6%) oak (*Quercus robur*) etc., were observed during the period 1988-1991. In 1992-1995 number of sample trees, as it was mentioned above, was reduced. The composition of sample tree species corresponds to the species composition of Lithuanian forests.

Results

After data processing it was determined that mean defoliation of all tree species comprises 24.2±0.2% in 1995. The mean defoliation has not been increasing during the past 2-3 years whereas the significant defoliation increase (t-test have been used) took place in 1989-1991. During period investigated (1989-1995) the mean defoliation of conifers was higher than the corresponding index of broadleaves (Table 1). The steadily high mean defoliation have been recorded in pine stands (from 22.8% in 1989 to 25.5% in 1991). The highest mean defoliation of Norway spruce was estimated in 1995 (mainly because of *Ips typographus* damage). Various tree species can be ranked according to the mean defoliation as follows (forest monitoring data of 1995 have been used): ash – 16.1%, black alder – 17.4%, birch – 20.5%, grey alder – 22.9%, aspen – 23.6%, Scots pine – 24.0%, oak – 25.5%, Norway spruce – 28.6% (Table 1).

and aspen stands. Abiotic agents (snow, wind, wiping etc.) appeared on 7-15% of trees. Particularly high percentage of spruce damaged by wind and wiping was in 1993 (more that 25%). Damage induced by fungi and diseases, game and direct action of man was noted rarer. Fungi and decease are more typical of aspen, and game damages – of ash (14-20% and 4-15% respectively). Man usually injures the stems of trees during felling and logging. It happens more often in spruce stands.

The effect of damage on tree defoliation is presented in table 3 and 4. Mean defoliation of all trees (all tree species) with identified damage constitutes 28.4-34.8%, i.e. it is 7-14% higher than that of undamaged trees (Table 3). The greatest difference in defoliation of damaged and undamaged trees has been ascertained for conifers (it is found to be 11.3% in 1993 and 21.1% in 1995) while it comprises only 3-4% for broadleaves.

Above mentioned differences depend on species. It is associated with different nature of damage for each tree species and with different influence of corresponding damage on tree condition (tree growth and defoliation). For example, differences between average defoliation of damaged and

Table 1. Mean defoliation of all species (1989-1995)

Species	Mean defoliation, %						
	1989	1990	1991	1992	1993	1994	1995
Scots pine	22.8±0.1	23.3±0.1	25.5±0.1	23.6±0.4	25.2±0.3	24.4±0.9	24.0±0.2
Norway spruce	15.6±0.2	16.5±0.2	17.9±0.2	17.5±0.5	23.1±0.4	21.7±1.0	28.6±0.6
Conifers	20.1±0.1	20.8±0.1	22.7±0.1	21.2±0.3	24.4±0.3	23.4±0.7	25.5±0.3
Oak	19.3±0.8	21.7±0.9	23.3±0.8	19.7±1.0	33.8±2.3	20.7±5.5	25.5±1.6
Ash	12.4±0.4	12.4±0.4	13.8±0.5	19.9±1.5	15.4±0.8	26.9±4.0	16.1±0.7
Birch	16.2±0.2	18.0±0.2	18.6±0.2	18.8±0.6	21.5±0.5	21.9±1.3	20.5±0.4
Black alder	11.9±0.4	12.2±0.3	15.1±0.4	18.3±2.2	17.0±0.8	18.8±2.6	17.4±0.8
Aspen	19.4±0.6	20.4±0.5	22.6±0.6	26.8±2.3	25.4±1.2	22.5±2.9	23.6±0.8
Grey alder	14.7±0.6	14.5±0.5	15.5±0.5	30.2±3.3	22.3±1.5	23.6±3.6	22.9±1.0
Broadleaves	15.8±0.2	14.7±0 5	18.1±0.2	20.8±0.6	21.4±0.4	22.2±0.9	20.6±0.3
All species	18.8±0.1	19.7±0.1	21.3±0.1	21.0±0.3	23.4±0.6	23.0±0.5	24.2±0.2

About 25-30% of all trees observed have symptoms of visually assessable damages. Broadleaves are most frequently damaged (35-50% of all trees observed). The highest percentage of damaged trees was recorded in alder and aspen stands: grey alder – 80-90%, black alder – 50-80%, aspen – 50-60% (Table 2). Birch and pine stands has the lowest number of damaged trees (15-30% and 10-20% respectively).

While analysing various groups of damage it has been determined that the most common type of damage – insect damages. About 15% of trees (16.0% in 1993 and 11.9% in 1995) were damaged by insects. Insect damages were recorded especially often (40-80% of all trees observed) in alders

undamaged trees in grey alder stands are not significant (sometimes defoliation of damaged alder trees is less than undamaged ones) despite the fact that number of damaged trees exceeds 80% (the more typical damage of alders is foliage damage caused by insects), while the corresponding differences in Norway spruce stands are rather big – 10-30%, because the most popular damage – damage caused by *Ips typographus* – has very significant influence to the crown defoliation: mean defoliation of damaged trees exceeds 80% (Table 4).

Mean defoliation of trees which stems have been damaged by insect is particularly high – 85.8%. Fungi (wood

Table 2. Percentages of damaged trees

Tree species	Number of damaged trees (% of all observed)											
	Game		Insects		Fungi and deseases		Abiotic agents		Direct action of man		All damages	
	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995	1993	1995
Scots pine	1.0	0.0	8.0	3.9	1.1	0.6	10.2	6.0	1.4	1.1	21.0	12.0
Norway spruce	4.2	1.3	2.5	14.3	3.0	2.0	27.8	10.9	1.0	2.4	35.2	29.3
Conifers	**2.3**	**0.5**	**5.9**	**7.7**	**1.8**	**1.1**	**16.9**	**7.8**	**1.2**	**1.6**	**26.5**	**21.8**
Birch	0.2	0.3	21.1	10.0	2.4	1.2	8.9	4.7	0.4	1.3	30.7	17.4
Aspen	3.7	1.0	42.4	31.3	20.4	14.1	18.4	6.6	0.0	0.7	57.1	50.6
Black alder	0.8	0.5	79.3	45.2	0.8	0.0	7.0	2.3	0.0	2.3	82.8	53.3
Grey alder	6.9	1.6	74.1	74.3	5.2	2.1	14.7	12.0	0.0	0.0	90.5	81.2
Ash	3.8	15.3	27.4	2.1	1.0	4.6	5.2	4.6	1.4	3.7	36.1	26.1
Oak	2.4	0.0	37.5	31.6	6.3	6.3	5.8	6.3	0.0	0.0	42.7	41.1
Broadleaves	**1.6**	**2.1**	**36.5**	**22.0**	**4.8**	**3.6**	**10.0**	**5.3**	**0.4**	**1.4**	**47.3**	**36.9**
All species	**2.0**	**1.0**	**16.0**	**11.9**	**2.8**	**1.8**	**14.7**	**7.0**	**0.9**	**1.6**	**33.3**	**22.4**
Average in Europe*	**1.8**	**1.2**	**11.7**	**9.3**	**6.0**	**4.6**	**5.2**	**4.9**	**4.8**	**3.4**	**29.8**	**22.6**

* Forest Condition in Europe. Results of the 1993 Survey. 1994. EC-UN/ECE, Brussels, Geneva, 93 p.
Forest Condition in Europe. Results of the 1994 Survey. 1995. EC-UN/ECE, Brussels, Geneva, 106 p.

Table 3. Average defoliation (%) of damaged trees and trees without symptoms of damage (1993-1995)

Species	1993		1995	
	Trees without symptoms of damage	Damaged trees	Trees without symptoms of damage	Damaged trees
Scots pine	22.9±0.3	35.8±1.0	23.3±0.2	30.0±0.9
Norway spruce	19.3±0.4	30.5±0.9	18.5±0.3	52.9±1.6
Conifers	**21.7±0.2**	**33.0±0.7**	**22.1±0.2**	**43.2±1.1**
Oak	35.8±3.2	29.5±2.7	23.8±2.4	29.3±2.3
Ash	14.0±0.9	18.1±1.2	16.1±0.9	20.8±2.3
Birch	20.1±0.8	25.8±1.6	20.1±0.4	24.7±1.0
Black alder	18.0±1.9	17.1±0.8	21.6±1.9	15.8±0.6
Grey alder	23.3±4.1	23.0±1.6	34.4±5.2	24.4±0.9
Aspen	24.7±1.8	25.6±1.5	21.3±1.2	26.8±1.3
Broadleaves	**20.6±0.5**	**23.1±0.6**	**19.2±0.3**	**23.4±0.5**
All species	**21.4±0.2**	**28.4±0.9**	**21.1±0.1**	**34.8±1.1**

decay) cause the moderate defoliation – 30.9%. The foliage damage by insects is not so "important" for the tree defoliation (for example, mean defoliation of damaged trees – 26.0%, undamaged – 21.1%) as well as other damages (game, wiping, direct action of man etc.).

The crown defoliation is influenced not only by various damages but by the number of various factors too: tree age (it is, for example, well-known fact that older trees are more sensitive to the air pollution), biosociological class, crown form (shape), branching habit, fruiting etc.

The influence of the age of trees to their crown defoliation is presented in Fig.1. As seen from it, defoliation of trees becomes higher with the increasing of age. Our data indicate that the average defoliation of trees aged up to 20 years comprises only 14.1±1.0%, that of trees aged 20-39 years – 19.5±0.4%, 40-59 years – 23.9±0.4%, 60-79 years – 25.5±0.4%, more than 80 years – 26.2±0.5% (data of 1994).

The biosociological class reflects tree "ability" to resist coenotic pressure. According our data the lowest defoliation is

Table 4. Average defoliation of damaged trees

Damage type	Average defoliation, %					
	Scots pine	Norway spruce	Birch	Broadleaves	Conifers	All species
Game	25.0±0.0	20.8±4.6	41.7±9.3	19.0±2.0	20.9±4.5	19.7±2.1
Insects:	41.4±1.8	83.6±1.9	24.0±1.4	22.4±0.6	69.5±1.7	44.1±1.1
dameged foliage	43.4±1.9	22.0±2.3	23.7±1.5	22.5±0.6	42.4±1.8	26.0±0.7
damaged shoots	27.4±2.1	15.8±3.0	-	24.0±3.4	25.6±1.9	25.2±1.7
damaged stems	91.0±4.1	86.2±1.8	40.0±6.3	38.3±9.9	86.8±1.7	85.8±1.8
Fungi and deseases	52.6±6.5	25.8±3.1	27.9±3.0	27.4±1.7	35.2±3.5	30.9±1.8
Wipping	23.4±0.8	27.4±1.3	23.3±2.1	22.6±1.3	25.3±0.7	25.0±0.7
Action of man	22.6±1.7	20.1±1.7	25.7±3.8	19.5±2.2	20.9±1.2	20.6±1.1

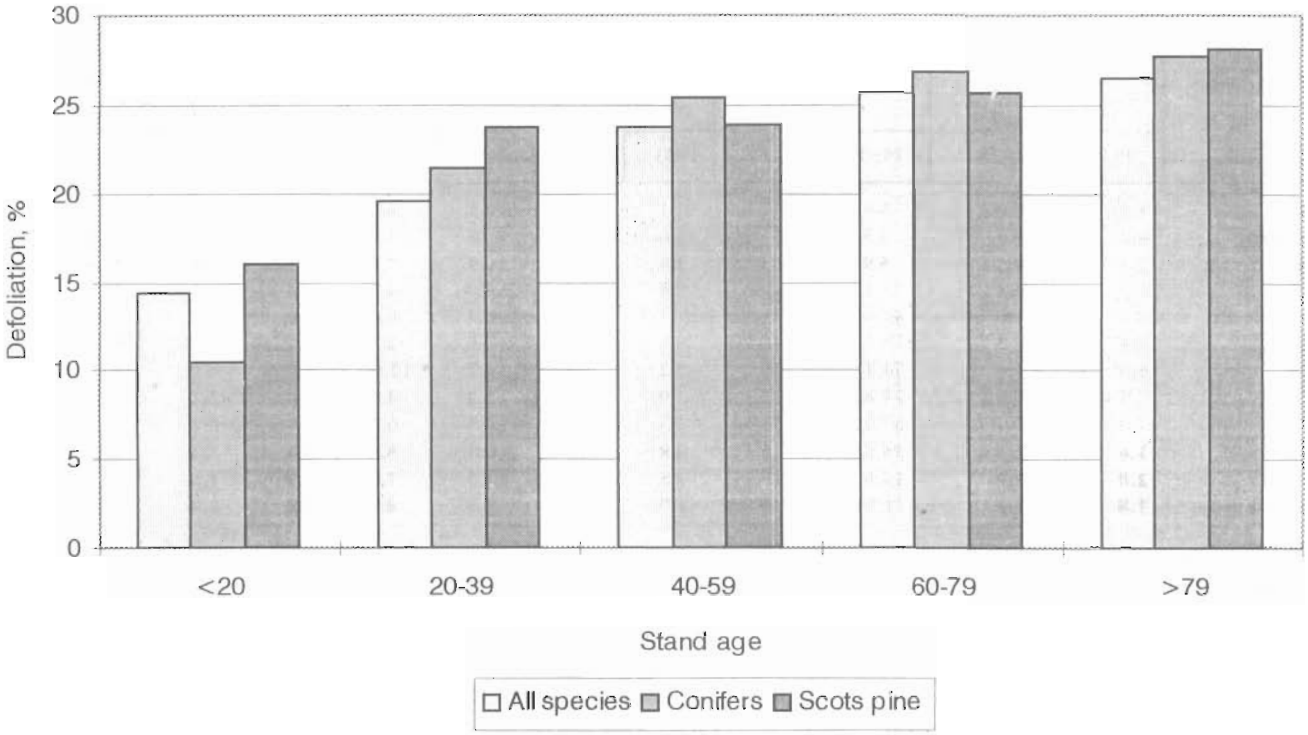

Fig. 1. Mean defoliation and stand age (data of 1993)

typical of dominant trees (Kraft class I) (Table 5). For example, mean defoliation of dominant trees (Kraft class I) comprises 20.6±0.6%, codominant (Kraft class 2) – 22.6±0.3%, intermediate (Kraft class 3) – 26.6±0.5%, overtoped (Kraft class 4) – 30.5±2.9%. The biggest differences between mean defoliation of dominant and intermediate trees were noticed in aspen and alder stands – 10-15%. The corresponding differences comprise 6-8% in conifers stands.

Defoliation of the whole crown accumulates the coenotic influence to some extent while that of the upper part of the crown (1/3 from the top) reflects more the global environmental changes (for example, air pollution etc.). In some Scandinavian countries this index rather widely applied in the forest health monitoring studies (Jukola-Sulonen 1990). Our data indicate that the defoliation of one third of the upper part of the crown is 3% less than the defoliation of the whole crown. However

Table 5. Crown defoliation by biosociological class

Species	Class according to Kraft							
	1		2		3		4	
	Number of trees	Defoliation, %	Number of trees	Defoliation, %	Number of trees	Defoliation, %	Number of trees	Defoliation, %
Scots pine	128	22.7±0.9	1705	24.3±0.3	501	28.9±0.7	24	32.3±5.4
Norway spruce	102	18.8±1.2	939	22.0±0.5	400	26.8±0.8	19	23.4±2.7
Conifers	**230**	**21.0±0.8**	**2648**	**23.4±0.3**	**904**	**27.9±0.6**	**43**	**28.4±3.3**
Birch	68	21.7±1.6	473	20.0±0.7	129	21.3±1.5	4	50.0±12
Aspen	39	19.1±1.8	166	24.3±1.3	39	36.0±3.5	1	40.0±0.0
Black alder	9	11.1±2.2	180	16.2±0.9	62	20.2±1.5	4	33.3±2.1
Grey alder	7	14.3±2.1	73	20.9±1.8	35	26.9±2.8	1	30.0±0.0
Oak	14	32.9±5.0	69	35.1±2.7	13	22.7±4.5	0	-
Ash	21	10.7±1.2	140	14.7±0.9	47	19.7±2.0	0	-
Broadleaves	**171**	**20.2±1.1**	**1271**	**20.9±0.5**	**423**	**23.8±0.9**	**11**	**38.6±5.3**
All species	**402**	**20.6±0.6**	**3922**	**22.6±0.3**	**1327**	**26.6±0.5**	**54**	**30.5±2.9**

analogical trend remains: the slight defoliation of the upper part of a crown is typical of dominant and codominant trees, i.e. Kraft class 1 and 2, and it is becoming higher in crowns of intermediate and overtoped trees, i.e. Kraft class 3 and 4. For example, mean defoliation dominant trees comprises 17.3±0.7% and the same index of overtoped trees – 30.5±2.9%.

Trees with different crown shape – narrow, normal or wide – have different defoliation too (Table 6). For example, mean defoliation of relatively narrow crowns is equal 28.5±0.6%, while wide and normal one – 22.2±0.8% and 21.5±0.2% respectively.

Table 6. Crown form (shape) and defoliation

Species	Crown form (shape)					
	Narrow		Normal		Wide	
	Number of tree	Defoliation, %	Number of tree	Defoliation, %	Number of tree	Defoliation, %
Scots pine	422	29.8±0.9	1530	22.9±0.3	131	23.7±1.2
Norway spruce	323	27.3±0.8	935	21.2±0.5	57	22.6±1.6
Birch	104	26.3±2.2	724	20.5±0.6	74	20.7±1.7
All species	**955**	**28.5±0.6**	**3899**	**21.5±0.2**	**339**	**22.2±0.8**

Tree fruiting was assessed by scores: 0-no fruiting; 3-very abundant. According to our data tree fruiting influences crown defoliation also. For example, mean defoliation of Scots pine trees without fruiting (cones) – 27.3±1.0% (38.2% of all trees observed), while fruiting estimated by 1 – 23.8±0.5% (48.4%), 2 – 20.6±0.9% (13.1%), 3 – 20.6±7.1% (0.3%).

Branching habit – pure comb, irregular comb, plate and brush – was assessed just for Norway spruce. Data show that the highest defoliation is typical of pure comb and plate branching – 32.7% (2.6% of all spruces observed) and 30.5±1.6% (9.8%) respectively.

Crown damage of trees can be classified in to the following types: base type – the most considerable needle loss in the lower part of crown (the defoliation of the rest crown must be at least 20% less, other wise the injury type is characterized as uniform); window type – in some parts of crown defoliation is higher at least 20%; uniform – crown density is more or less uniform in the whole crown; top type – the loss of needles in the upper part of a crown must be at least 20% higher than that in the lower one; peripheral – the apical shoots of about 25% of all branches are dying; below the top – similar to window type (fixed location); inner type – the highest defoliation is in the inner part of crown (close to stem) (Innes 1990; Lesinski 1992). The data indicate that the base and uniform injury types are the most widespread. The uniform crown injury type was recorded for 71.3% of all trees observed. The highest defoliation is typical of the peripheral injury type (56.4±2.0%). The other injury types can be ranked according the mean defoliation decrease as follows: top (mean defoliation 34.1±1.1%), below the top (30.2±3.8%), window (29.3±1.7%), inner (27.3±2.9%), base (26.8±0.4%), uniform (24.7±0.3%).

"Ecological background" (soil fertility, moisture etc.) effects tree defoliation also. This kind of influence is not direct. In some cases ecological conditions just helps tree to be more resistance to various stress factors. It was determined, for example, that defoliation of trees growing on infertile sites (a,b) is slight higher (3-4%) than that on fertile sites (c,d,f). The slight lower defoliation (3-5%) was recorded in wet (humidity index U) hydrotops as well as on hydrotops of temporal excess of moisture (L). Such trend being revealed every year allows us to make an assumption that trees growing on infertile sites of normal moisture (Na) and swamps (Pa) are less resistant against adverse environmental factors.

Discussions

As it seen from the number of publications (Houston 1973, Manion 1991, Tichy 1991 etc.), it is very complicated to reveal pure influence of individual factor to tree crown defoliation because sometimes the same factor can act as predisposing, inciting or contributing one. Nevertheless it is quite evident that various tree species have different resistance to external impact (environmental changes). For example, investigation close to sourses of industrial emissions show that conifers are more sensitive to air pollution (Vaičys 1991). So it means that if we want to reveal the influence of various factors to crown defoliation first of all we must separate trees by species. By our opinion, Scots pine is the best indicator of that (the most widespread species).

We used following index for the assessment of the degree of defoliation changes under various factors:

D_{max} – mean defoliation of damaged trees (or influenced in highest degree),

$$I = \frac{D_{max} - D_{min}}{D_{min}}$$

D_{min} – mean defoliation of undamaged trees (or influenced in lowest degree).

Assessment of defoliation changes due to various factors influence is presented in Table 7.

Symptoms of so-called direct damage have the greatest influence to the crown defoliation. Among them damages by insects (particularly stem damages), fungi and diseases are the most significant. For example, Scots pine trees which stems were damaged by insects "have" index 2.91 (all tree species – 3.06), trees damaged by fungi and diseases – 1.26 (all tree species – 0.46), while trees damaged by game, wipping or direct action of man – just 0.07, 0.00 and 0.03 respectively. In older stands crown defoliation is higher than in younger ones.

Table 7. Assessment of defoliation changes due to various agent influence

Agent	Scots pine		All species	
	$D_{max}-D_{min}$	I	$D_{max}-D_{min}$	I
SYMPTOMS OF DAMAGE*:	6.7	0.29	13.7	0.65
Game	1.7	0.07	-1.4	-0.07
Insects:	18.1	0.77	23.0	1.09
foliage	20.1	0.86	4.9	0.23
shoots	4.1	0.18	4.1	0.19
stems	67.7	2.91	64.7	3.06
Fungi and deseases	29.3	1.26	9.8	0.46
Wipping	0.1	0.00	3.9	0.18
Action of man	-0.7	-0.03	-0.5	-0.02
TREE AGE	2.0	0.10	10.8	0.90
BIOSOCIOLOGICAL CLASS	9.6	0.42	9.9	0.48
CROWN SHAPE	6.8	0.30	7.0	0.33
SOIL FERTILITY	6.8	0.30	7.7	0.37
SOIL HUMIDITY	4.2	0.20	6.1	0.31

* visually recorded damages

This holds for all tree species. For example, mean defoliation in younger than 20 years stands comprises 11.8±1.2%, and in older than 80 – 22.4±0.3% (index I=0.90). It means that younger trees are more resistant (sustainable) at the some level of ecological conditions.

Comparatively significant influence of biosociological class to the crown defoliation was recorded (I=0.42-0.48). During crown defoliation assessment especially great attention must be focused on intermediate trees (Kraft class 3) because, as it seen from the Table 5, mean their crown defoliation is higher than defoliation of dominant (Kraft class 1) and codominant (Kraft class 2) trees (there is not significant differences between defoliation of dominant and codominant trees). According to the European manual of forest monitoring (Manual..., 1994) overtoped trees (Kraft class 4) must be replaced.

The influence of crown shape, soil fertility and humidity is not very high (I=0.20-0.37) – the differences of mean defoliation comprise 4-7%.

The defoliation of trees without symptoms of damages remains about 20%. It means that "direct" damage does not explain all reasons of crown defoliation in Lithuania. Global environmental changes (including air pollution) are supposed to be crucial factors determining forest condition.

Conclusions

1. During period investigated (1989-1995) the mean defoliation of conifers was higher than the corresponding index of broadleaves. According to the mean defoliation increase tree species can be rankhed as follows: ash – 16.1%, black alder – 17.4%, birch – 20.5%, grey alder – 22.9%, aspen – 23.6%, Scots pine – 24.0%, oak – 25.5%, Norway spruce – 28.6%.

2. About 25-30% of all trees observed have symptoms of visually assessable damage. The highest defoliation is typical of trees which have been damaged by stem insects – 85.8%. Fungi (wood decay) cause the moderate defoliation – 30.9%. Foliage damage by insects is not so significant (mean defoliation of damaged trees – 26.6%, undamaged – 21.1%) as well as other damages – wipping, direct action of man etc.

3. Defoliation becomes higher with the increasing of tree age.

4. The lowest defoliation is typical of dominant and codominant trees (Kraft class 1 and 2).

5. Crown shape, tree fruiting, branching habit, soil fertility and humidity can influence crown defoliation also, but this impact is not very significant (it can effect mean defoliation by 3-5%).

6. The defoliation of trees without symptoms of visuable damages remains about 20%. It means that "direct" damage does not explain all causes of crown defoliation.

References

Hanisch B., Kilz E. 1990. Monitoring of forest damage. Stuttgart: Ulmer; London: Helm, 317 p.

Houston D.R. 1973. Diebacks and declines: diseases initiated by stress, including defoliation. Proc. Int. Shade Tree Conf., 49, p. 73-76.

Innes L.J. 1990. Assessment of tree condition. Forestry Commission. London: HMSO. 96 p.

Jukola-Sulonen E., Mikkola K., Salemaa M. 1990. The vitality of conifers in Finland, 1986-1988. Acidification in Finland (Ed.Kaupi et all). Springer-Verlay. Berlin. Heidelberg, p. 523-560.

Kandler O. 1992. Historical declines and diebacks of Central European forests and present conditions. Environmental Toxicology and Chemistry, 11, p. 1077-1093.

Lesinski J.A. Armolaitis K. 1992. Papildomi pušies ir eglės pažeidimų požymiai miškų monitoringe.(Contributory symptoms of injury in pine and spruce for forest monitoring) Umeå, 24 p.

Manion P.D. 1991. Tree disease concepts. Prentice Hall, Englewood Cliffs, N.I. 409 p.

Manual on methods and criteria for harmonized sampling, assessment, monitoring, and analysis of the effects of air pollution on forests (Ed. Programme Coordinating Centers in Hamburg and Prague). 1994, 177 p.

Mueller-Dombois D. 1986. Perspectives for an etiology of stand-level dieback. Ann. Rev. Ecol. Syst. 17, p. 221-243.

Tichy J. 1991. Considerations of recent methods of assessment of damage of forest stands. IUFRO Workshop on Monitoring Air Pollution Impact on Permanent Sample Plots, Data Processing and Results Interpretation. Prahatice, p. 102-106.

Tree crown photos 1990. Swiss Fed. Inst. for Forest, Snow and Landscape Res., p. 129.

Vaičys M., Armolaitis K. 1991. Gas resistance and regeneration of forests damaged by industrial emission. *Forest Plants and Forest Protection*. 18th IUFRO World Congress (div.2) v.1. p. 360-367.

Дефолиация крон деревьев: влияющие факторы

Р. Озолинчюс, В. Стакенас

Резюме

Все факторы, влияющие на дефолиацию дерева, можно подразделить на прямо (ветер, снег, лед, холод, болезни и т.д.) и косвенно (повышение кислотности почвы, недостаток питательных веществ, засуха) действующих. Биологические свойства (порода, форма кроны, тип ветвления), индивидуальные особенности (возраст, противостояние ценотическому воздействию) деревьев и "экологический фон" (плодородие почвы, ее влажность) оказывают влияние лишь на "остроту" воздействия вышеперечисленных факторов.

Использованы данные лесного мониторинга (1988-95). Визуальные повреждения отмечены у 25-30% всех обследованных деревьев. Особенно высокая дефолиация у деревьев, поврежденных вредителями стволов (*Ips typographus*) и грибами (древесной гнилью).

Дефолиация дерева также обусловлена биологическими и индивидуальными особенностями дерева. Например, наивысшая дефолиация отмечена у сосны обыкновенной и ели европейской; с увеличением возраста дерева дефолиация его кроны увеличивается; ель европейская, имеющая гребенчатую и плосковетвистую форму ветвления, отличается наивысшей дефолиацией и т.д.

"Экологический фон" тоже оказывает влияние на дефолиацию дерева – наивысшая дефолиация отмечена у деревьев на сухих почвах и на болотах. Определено семь типов повреждения. Наивысшая дефолиация свойственна периферийному типу.

Для оценки степени изменения дефолиации под воздействием различных факторов использован следующий индекс: $I=(D_{max}-D_{min})/D_{min}$, где D_{max} и D_{min} – соответственно средняя дефолиация поврежденных (или подвергнутых определенному воздействию) и здоровых (или неподвергнутых воздействию) деревьев. Деревья, имеющие симптомы так называемых прямодействующих факторов, отличаются и наибольшим индексом (I=0,46-3,06).

Дефолиация деревьев без симптомов повреждений остается существенной – около 20%. Делается предпосылка, что глобальные изменения в окружающей среде (включая загрязнение воздуха) являются факторами, определяющими дефолиацию крон.

Ключевые слова: дефолиация, повреждение, местопроизрастание, возраст, тип повреждения.