Scand. J. For. Res. 13: 297–305, 1998

Bark Lesions on Beech (*Fagus sylvatica*) and Their Relation to Epiphytes and Site Variables in Scania, South Sweden

ANNA MARIA JÖNSSON

Department of Ecology, Plant Ecology, Lund University, Lund, Sweden

Scandinavian Journal of Forest Research

Jönsson A. M. (Department of Ecology, Plant Ecology, Lund University, Lund, Sweden). *Bark lesions on beech (Fagus sylvatica) and their relation to epiphytes and site variables in Scania, south Sweden.* Received March 18, 1997. Accepted August 13, 1997. Scand. J. For. Res. 13: 297–305, 1998.

Beech bark lesions, (*Cryptococcus fagisuga*), the most common lichen and fungi epiphytes on beech (*Fagus sylvatica*) stems were studied at 48 sites in Scania, south Sweden. Different site variables and the influence of nitrogen deposition were investigated. The field vegetation and lichens were used as biological indicators by calculating indices for nutrition status, toxicity, pH, light and moisture. Two sets of lichen indices, from Hultengren and Ellenberg, respectively, were calculated. Beech bark lesions were found at 25 sites and were more frequent at more polluted sites with much *C. fagisuga* and *Lecanora conizaeoides*, and on largish trees. Algae cover and *C. fagisuga* were positively correlated. Both preferred sites with no direct light exposure, high nitrogen deposition and low pH. The two sets of lichen indices were fairly comparable for toxitolerance, light and pH. In this investigation, *Lepraria incana* was the most frequent of all epiphytes, often determining the value of the lichen indices. *Key words: beech bark disease, biological indicator, Cryptococcus fagisuga, lichen.*

INTRODUCTION

There are many different causes of beech bark lesions; for instance, beech bark disease and temperature damage. Beeches (*Fagus sylvatica, Fagus grandifolia*) affected by wounds in the cambium often exude a discoloured liquid from necrotic spots on the trunk, "slime-flux" (Houston et al. 1979).

The beech bark disease is spread over Europe and North America. It is caused by an interaction between the beech scale *Cryptococcus fagisuga* Lind. and the fungi *Nectria coccinea* var. *faginata* and in North America also by the fungi *Nectria galligena* (Houston 1994). *Cryptococcus fagisuga* is often regarded as a relatively harmless insect, but when large colonies feed in concentrated areas on the beech bark they can kill clusters of parenchyma cells (Ehrlich 1934). Some beeches are relatively resistant to *C. fagisuga* infestation, but the degree of resistance is dependent on the genetics of the infesting population (Wainhouse & Howell 1983). Massive *N. coccinea* infection can appear on stems heavily infested by *C. fagisuga*, stressed by drought, mineral nutrient imbalance or root disease (Lonesdale & Wainhouse 1987). Climatic factors may have some influence, but are generally not considered to be a primary cause (Lonesdale & Wainhouse 1987).

While N and P in excess or deficiency were shown to increase the sensitivity to beech bark disease, K did not seem to affect it. Low bark content of Ca and Mg increased the necrose severity (Perrin & Garbaye 1984). Super optimal concentration of N has been shown to increase the free amino acid concentration in beech leaves (Balsberg Påhlsson 1992), and trees with higher concentrations of amino acids were found to host larger beech scale populations (Wargo 1988).

Several other factors determine the severity of an infestation by *C. fagisuga* and the eventuality of beech bark disease. Positive correlations between tree diameter, percentage of beech infected by *N. coccinea* and the percentage of beech in the stand have been found. Stand position on the slope of a ridge and the steepness of the slope were also positively correlated (Ehrlich 1934). The disease was found to be more severe in stands with a high proportion of hemlock (*Tsuga canadensis*). Winter shading of beech stems (by hemlock) may protect the insect against repeated freezing and thawing (Twery & Patterson 1984). Mosses and lichens might provide shelter for the coccus that is highly exposed on a bare, smooth bark. The presence of *C. fagisuga* has been positively associated with *Lecanora conizaeoides* and negatively associated with *Ascodichaena rugosa* (Houston et al. 1979).

The beech bark is smooth and thin, and overheats early when it is exposed to sunlight (Nicolai 1986). "Slime-flux" has been induced by heating and chilling beech bark artificially. The trees were more temperature sensitive when they were foliated and the bark

Table 1. *A summary of the scales used by Ellenberg et al. (1992) and Hultengren et al. (1991) for lichen and plant indices*

Ellenberg's field layer indices and lichen indices	Range
Toxicity	1 (low toxitolerance)–9 (very high toxitolerance)
Light	1 (deep shadow)–9 (full light exposure)
pH	1 (extremely acid, below 3.4)–9 (basic, above 7)
Moisture	1 (very arid)–9 (very humid)
Field layer N	1 (low N level)–9 (very high N level)
Hultengren's lichen indices	
Pollution sensitivity	0 (highly toxitolerant)–9 (highly pollution sensitive)
Light	1 (shade demanding)–5 (light demanding)
pH	1 (poor wood, low pH)–5 (nutrient rich wood, neutral pH)
Moisture	1 (extremely dry tolerant)–5 (moisture demanding)

lesions were primarily caused by an inadequate water supply in combination with temperature damage (Dimitri 1967, 1968).

Ground vegetation and epiphytes on the tree trunk can be used as biological indicators for air pollutants, N level, acidity, light intensity and moisture on a local scale according to Ellenberg et al. (1992) and Hultengren et al. (1991). The algae cover is a good indicator for N (Göransson 1990), and *L. conizaeoides* indicates areas with high amounts of gaseous air pollutants (Hultengren et al. 1991).

The aim of this study was to determine the distribution of *C. fagisuga*, beech bark lesions and epiphytes on *F. sylvatica* in Scania, and to study the influence of site factors (position in the terrain, wind exposure, soil type, texture, aspect of the site, altitude, stand age and proportion of trees other than beech in the stand), tree diameter and exposure to sunlight. The hypothesis was that *C. fagisuga* and beech bark lesions are more abundant in more polluted areas, especially the south-western part of Scania, with a higher deposition of N and S than the north-eastern part (Westling et al. 1992) and that the distribution could be correlated to biological indicators.

MATERIAL AND METHODS

Forty-eight sampling sites were randomly selected from the systematic geographical net of sites used by the Forestry Board of Sweden (SKS) in the monitoring of forest damage on beech and oak (Wijk 1989). The sites taken into account were those in Scania consisting of at least 10 monitored beeches. Scania was divided into four quadrants, and 12 sampling sites were randomly selected for each quadrant. The centre of some sites was poorly situated for the present investigation, in the middle of a dense regeneration forest stand or near the forest edge, so only one or two directions could be used. In these cases the sampling centre was moved 25 or 100 m in a cardinal direction, in order west, north, east or south, from the original plot to obtain an adequate plot.

For each site the following variables were estimated and recorded: the field layer vegetation, stand size, topography, canopy coverage of tree species and recent forest impact. Ten beeches, with a circumference of at least 40 cm, were sampled at each site, two beeches in the centre and two in the west, north, east and south direction, 25 m from the centre trees.

In total, 483 trees were investigated during May 1994. The diameter was measured 1.3 m above ground and eventual direct light exposure of the stem was recorded. A 1 × 1 dm plot was placed on the tree with the lower edge 1.3 m above ground in each of the cardinal directions. The number of *Cryptococcus fagisuga* was counted, and if they were numerous, a 0.25 or 0.1 dm^2 plot was used instead of 1 dm^2. If the sum was less than 10 in the four squares, then every *C. fagisuga* between 0.5 and 2 m above the soil surface was recorded. The cover of algae, *Lecanora conizaeoides* and other trunk epiphytes within the 1 dm^2 plot were estimated on a percentage scale. The number of bark lesions and coverage of trunk epiphytes growing 0.5–2 m above ground, although not in the squares, were also noted. Publications by Krok et al. (1986), Moberg et al. (1990) and Hallingbäck & Holmåsen (1991) were used for species determination.

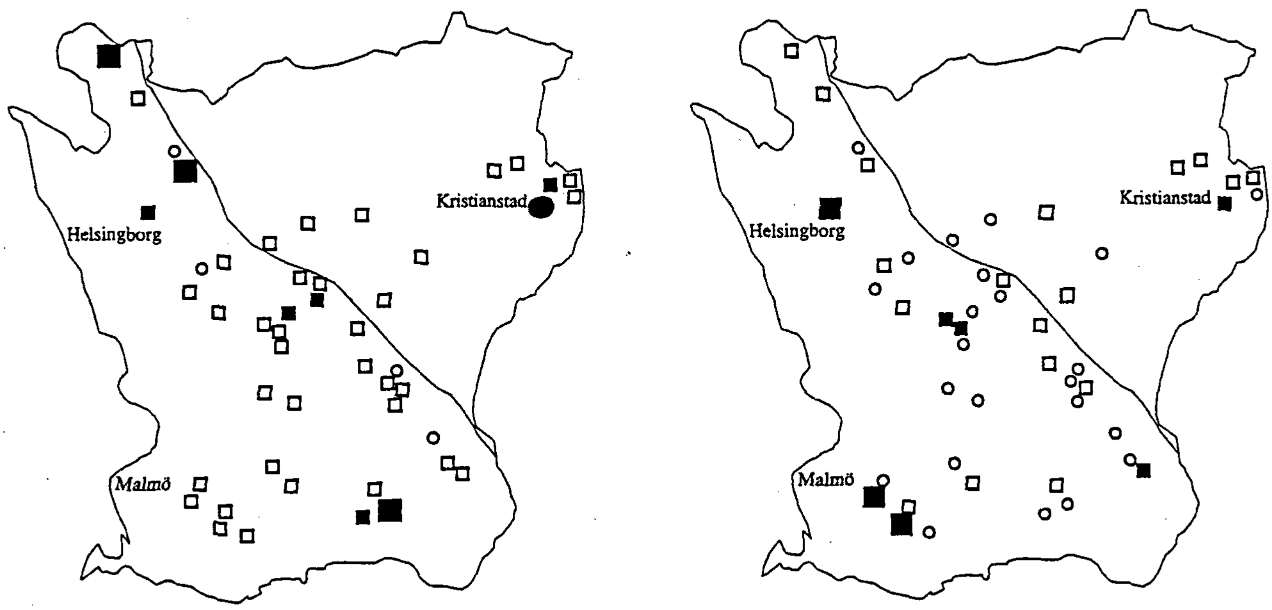

Fig. 1. Distribution of *Cryptococcus fagisuga* (left) and beech bark lesions (right). ○ = without *C. fagisuga* □ = 0.1–10 C. fagisuga dm^{-2} ■ = 10–50 *C. fagisuga* dm^{-2} ■ = 50–100 *C. fagisuga* dm^{-2} ● = 200 *C. fagisuga* dm^{-2} ○ = 0 beech bark lesion $tree^{-1}$ □ < 1 beech bark lesion $tree^{-1}$ ■ = 1–2 beech bark lesions $tree^{-1}$ ■ = 2–3 beech bark lesions $tree^{-1}$.

All cover values, recalculated and expressed per dm^2, were summarized per tree and for all trees per site.

The division of Scania into two parts was based on data of deposition in open fields: for NE Scania 15–20 kg N ha^{-1} $year^{-1}$ and for SW Scania 20–25 kg N ha^{-1} $year^{-1}$ (Westling et al. 1992), which approximately followed the eastern sides of the ridges Söderåsen and Linderödsåsen. Data from the Forestry Board investigation (Wijk 1989) were used to obtain the following terrain parameters: position in terrain, wind exposure, texture, soil type, aspect of the site, altitude and stand age.

"Field layer indices" (F) for N, pH, light and moisture (y) were calculated for each site by taking an average of the index values (Py) given by Ellenberg et al. (1992) for plants present on the site.

$$F_y = \sum_{1}^{n}(Py)/n$$

Different site lichen indices (S_y) were calculated as weighted averages, by multiplying the average of area cover per dm^2 (ac_x) for each lichen on the investigated site by its index value (L_{xy}). The different lichen products were summed ($\Sigma ac_x L_{xy}$) and divided by the sum of area cover (Σac_x). This was made for the values given by Ellenberg et al. (1992) and for those of Hultengren et al. (1991) indicating toxicity or sensitivity, pH, light and moisture (y) (Table 1). The indices related to the sites are called "Ellenberg's" lichen indices and "Hultengren's" lichen indices respectively.

$$S_y = \sum_{1}^{n}(ac_x L_{xy})/\sum_{1}^{n}ac_x$$

Statistics were calculated according to Sokal & Rohlf (1987) and Siegel & Castellan (1988). The beech bark lesions and epiphytes were not normally distributed so non-parametric tests were used. Regression analysis was used for comparison between the indices.

RESULTS

The frequency of *C. fagisuga* (Fig. 1) and cover of algae, lichens and fungi varied considerably among the sites. Beech bark lesions were found on 25 sites (Fig. 1). They were positively correlated to the occurrence of *C. fagisuga* and *Lecanora conizaeoides*, but not to the algae cover. *Cryptococcus fagisuga* was positively correlated to the algae cover and *L. conizaeoides*, and negatively to *Lepraria incana* and *Athelia arachnoidea* (Table 2). *Cryptococcus fagisuga* was negatively related to the amount of lichens (rho = −0.355, $p < 0.05$, Spearman's rank correlation, $n = 48$), and so was the algae cover (rho = −0.637, $p < 0.001$). The diameter distribution of investigated trees ranged from 12 to 120 cm.

The two Scanian regions did not differ regarding stand age, proportion of trees other than beech and

Table 2. *Correlation between beech bark lesions (BBL) and some trunk epiphytes. Spearman rank correlation coefficient (n = 483)*

	BBL		*C. fagisuga*	
Species	*z*	*p*	*z*	*p*
C. fagisuga	4.267	***+	–	
Algae cover	1.276	ns	7.428	***+
L. conizaeoides	3.404	**+	8.277	***+
L. incana	−0.644	ns	−5.417	***−
A. rugosa	−0.404	ns	1.413	ns
A. arachnoidea	−1.507	ns	−3.006	**−

+ Positive correlation, − negative correlation. Significance levels: NS = not significant, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Table 3. *The frequency of C. fagisuga, beech bark lesions, algae cover, L. conizaeoides, A. arachnoidea, A. rugosa and field layer N index were tested against the N level, expressed by three different indicators: Scania SW/NE = Scania divided into two parts, based on data of deposition in open fields, for SW Scania 20–25 kg N* ha^{-1} $year^{-1}$ *and for NE Scania 15–20 kg N* ha^{-1} $year^{-1}$. *Field layer-N-index = A N index calculated as an average of Ellenberg's index values for the present field layer species at each sampling site. Algae cover = The mean coverage of algae on the bark in a 1* dm^2*, 1.3 m above ground at each sampling site. Mann-Whitney U-test was used for the Scania test (n = 48), Spearman rank correlation coefficient for the field layer-N-index (n = 45) and algae cover (n = 48)*

	Scania SW/NE		Field layer-N-index		Algae cover	
	z	*p*	rho	*p*	rho	*p*
C. fagisuga	−1.837	ns	0.363	*+	0.407	*+
Beech bark lesions	−0.278	ns	0.005	ns	0.133	ns
Algae cover	−1.170	ns	0.033	ns	–	–
L. conizaeoides	−2.444	**sw	0.241	ns	0.275	ns
A. rugosa	−1.892	ns	0.192	ns	0.271	ns
A. arachnoidea	−2.318	*sw	0.182	ns	−0.033	ns
Field layer N index	−2.442	*sw	–	–	0.033	ns

Sw = More abundant, or higher in the southwest region; + = positive correlation.
Significance levels: NS = not significant, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

altitude. There were significantly more lichens in the NE part ($z = -1.968$, $p < 0.05$, $n = 48$, Mann-Whitney U-test). The field layer indices indicated that soil pH was higher in the SW part ($z = -3.189$, $p < 0.01$, $n = 45$) and that the forest was lighter in the NE part ($z = -2.274$, $p < 0.05$, $n = 46$). The two lichen indices also found the NE part lighter ("Ellenberg's" $z = -2.767$, $p < 0.01$, $n = 48$; "Hultengren's" $z = -2.668$, $p < 0.01$, $n = 48$). Both lichen indices pointed out that the lichens found in the SW were generally more pollution tolerant ("Ellenberg's" $z = -3.544$, $p < 0.001$, $n = 48$; "Hultengren's" $z = -3.260$, $p < 0.01$, $n = 48$), and "Ellenberg's" pH index was higher in NE ($z = -2.495$, $p < 0.05$, $n = 48$). The SW part of Scania, with a higher deposition of N and other air pollutants (Westling et al. 1992), had more *L. conizaeoides* than the NE part (Table 3). The fungus *A. arachnoidea* was more frequent in the SW part of Scania and the field layer nitrogen index was higher. *Cryptococcus fagisuga* was positively correlated to the field layer N index and to the algae cover.

The beech bark lesions were not correlated to sunlight exposure of the stem. *Cryptococcus fagisuga* was affected negatively in the west and south direction, while *L. conizaeoides* was unaffected by exposure. Exposure to direct sunlight affected the algae cover negatively in all directions (Table 4).

Cryptococcus fagisuga was significantly negatively correlated to the altitude. The beech bark lesions were positively correlated to the diameter of the tree. The algae cover was negatively correlated to the age of the stand and to the diameter of the tree. *Lecanora*

Table 4. *Trees exposed to a higher degree of direct sunlight than the surrounding trees, due to gaps or stand edges, were compared with unexposed trees regarding the abundance of beech bark lesions (BBL), C. fagisuga, algae cover and L. conizaeoides. This was also done taking the cardinal direction of exposure into account. Mann-Whitney U-test (n = 483)*

	Stem exp.		West		North		East		South	
BBL and epiphytes	*z*	*p*	*z*	*p*	*z*	*p*	*z*	*p*	*z*	*p*
Beech bark lesions	−1.006	ns								
C. fagisuga	−3.019	**−	−2.894	**−	−1.478	ns	−0.257	ns	−2.276	*−
Algae cover	−5.168	***−	−5.010	***−	−2.308	*−	−3.113	**−	−4.459	***−
L. conizaeoides	−0.973	ns	−0.323	ns	−0.632	ns	−1.071	ns	−1.226	ns

Significance levels: NS = not significant, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

Table 5. *Correlations between some site variables and C. fagisuga, beech bark lesions (BBL), algae cover and L. conizaeoides. H-values for Kruskal-Wallis (K-W) n = 48, rho values for Spearman rank correlation coefficient (S) n = 48, z-values for diameter of the trees (n = 483)*

Site variables	*C. fagisuga*		BBL		Algae cover		*L. conizaeoides*	
Position in terrain (K-W)	2.142	ns	6.113	ns	1.805	ns	2.566	ns
Wind exposure (K-W)	0.180	ns	2.266	ns	0.031	ns	6.069	ns
Soil texture (K-W)	1.407	ns	4.998	ns	8.039	ns	8.688	ns
Soil type (K-W)	1.531	ns	1.778	ns	2.818	ns	3.132	ns
Aspect of the site (K-W)	4.097	ns	6.166	ns	9.595	ns	8.249	ns
Altitude (S)	−0.367	*−	−0.247	ns	−0.057	ns	−0.560	***−
Stand age (S)	−0.068	ns	0.269	ns	−0.364	*−	0.091	ns
Diameter of the tree (S)	1.105	ns	2.742	**+	−2.535	*−	2.633	**+
Proportion of other trees (S)	−0.053	ns	−0.140	ns	0.029	ns	−0.321	*−

Significance levels: NS = not significant, $*p < 0.05$, $**p < 0.01$, $***p < 0.001$.

conizaeoi-des was positively correlated to the diameter of the tree and to a low proportion of trees other than beech. A negative correlation existed to the altitude (Table 5). There were more lichens in general on sandy soils (H = 13.241, $p < 0.05$, $n = 48$, Kruskal-Wallis) and in old stands ($z = 2.608$, $p < 0.01$, $n = 48$, Spearman's rank correlation). *Athelia arachnoidea* appeared more frequently on trees growing on brown soils (H = 8.603, $p < 0.05$, $n = 48$, Kruskal-Wallis).

Soil texture and soil type were the two factors that influenced the distribution pattern of the lichen and field layer indices most. There were more toxitolerant lichen species on clay soils than on gravel, silt and loam. The least toxitolerant species composition was found on sites with stone and sand soils ("Ellenberg's" toxitolerance index H = 21.793, $p < 0.001$, $n = 48$, Kruskal-Wallis; "Hultengren's" pollution sensitivity index H = 19.609, $p < 0.01$, $n = 48$). Lichen toxitolerance was thus higher at sites with brown or transition soil than podsol ("Ellenberg's" H = 16.322, $p < 0.01$, $n = 48$; "Hultengren's" H = 15.393, $p < 0.01$, $n = 48$). The field layer pH ranked the soil texture and type in the same order (H = 9.577, $p < 0.05$, $n = 45$).

Sites with gravel, loam or clay were shadier than sites with stone, sand or silt according to the field layer light index (H = 12.335, $p < 0.01$, $n = 46$, Kruskal-Wallis). This corresponds to the order held by the lichen indices, except that they both ranked sites with silt as relatively dark ("Ellenberg's" H = 12.717, $p < 0.05$, $n = 48$; "Hultengren's" H = 14.049, $p < 0.05$, $n = 48$). "Ellenberg's" lichen nutrition indicated lower nutrition values in the upper part of a slope (H = 11.953, $p < 0.05$, $n = 48$).

The field layer pH was negatively correlated to the altitude (rho = 0.412, $p < 0.05$, $n = 45$, Spearman's rank correlation), whereas "Ellenberg's" and "Hultengren's" pH were positively correlated (rho = 0.508 respectively 0.531, $p < 0.001$, $n = 48$). Both lichen indices indicated more pollution-sensitive lichen compositions in old stands ("Ellenberg's" rho = −0.373, $p < 0.05$, $n = 48$; "Hultengren's" rho = 0.393, $p < 0.01$, $n = 48$).

Table 6. *Field layer indices for pH, light and moisture were calculated for each sampling site and correlated to the frequency of C. fagisuga, beech bark lesions, algae cover, L. conizaeoides and A. arachnoidea. Spearman rank correlation coefficient, rho-values are presented*

Field layer indices	*C. fagisuga*	BBL	Algae cover	*L. conizaeoides*	*A. arachnoidea*
pH ($n = 45$)	0.298*+	0.115 ns	0.033 ns	0.287 ns	0.326 *+
Light ($n = 46$)	0.086 ns	0.012 ns	−0.123 ns	0.049 ns	0.079 ns
Moisture ($n = 43$)	−0.198 ns	0.047 ns	−0.134 ns	−0.293 ns	0.117 ns

Significance levels: NS = not significant, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Cryptococcus fagisuga and *A. arachnoidea* preferred less acid conditions according to the field layer pH index. None of the field layer indices were related to the spatial distributions of beech bark lesions, algae cover or *L. conizaeoides* (Table 6).

"Ellenberg's" and "Hultengren's" lichen indices for light were positively correlated to the field layer light index, but pH and moisture indices for lichens and field layer were not correlated (Table 7). "Ellenberg's" toxicity index was negatively correlated to "Hultengren's" lichen sensitivity index, that is, they corresponded. The two pH indices, and the two light indices were positively correlated, and the moisture indices were negatively correlated (Fig. 2).

The results for the two sets of lichen indices were fairly similar (Table 8). *Cryptococcus fagisuga* was negatively correlated to both pH indices. Beech bark lesions were only negatively related to "Hultengren's" pH index. The algae cover was positively related to "Ellenberg's" toxicity index and negatively related to "Hultengren's" pollution sensitivity index. It was also negatively correlated to both pH indices. *Athelia arachnoidea* could stand pollution, and was mostly found in shade according to both "Hultengren's" and "Ellenberg's" indices. It was negatively correlated to "Ellenberg's" moisture index only.

DISCUSSION

"Slime-flux" is a general symptom of wounds in the cambium (Houston et al. 1979), and thus it was difficult to see whether the investigated beeches were affected by beech bark disease or not; however, the positive correlation between bark lesions and *C. fagisuga* and no correlation to stem exposure indicated so. Site factors seemed not to have any influence on the distribution pattern of beech bark lesions. The result supported the hypothesis that beech bark lesions are associated with polluted areas, since there were more bark lesions near the industrial regions; in SW Malmö, Lund, in NW Helsingborg, in W Eslöv, and in NE Kristianstad (Fig. 1). High N deposition might lead to nutritional imbalances and lower the frost resistance of the beeches (Ågren & Bosatta 1988, Skeffington et al. 1988), and thus increase the frequency of beech bark lesions. Beech bark lesions, however, were not obviously related to any of the N indices in this study.

Cryptococcus fagisuga and algae cover were more frequent at sites indicated as more acidified and having a higher N deposition, supporting the hypothesis. The spread pattern and cyclical population behaviour of *C. fagisuga* were probably the causes of its non-normal distribution. Houston et al. (1979) found a negative association of *A. rugosa* and *C. fagisuga*, but no such correlation was found in this investigation. Algae cover was more abundant in young and dense stands, which might influence its value as N indicator.

The results supported the idea that *L. conizaeoides* is more frequent in the most polluted areas (the SW part of Scania). *Lecanora conizaeoides* is not directly favoured by N, but is insensitive to gaseous pollutants and acid conditions. It becomes more abundant when other, competitive lichens are killed by high pollution levels. *Lepraria incana* responds in the same way (Hultengren et al. 1991).

Athelia arachnoidea is a parasitic fungus on lichens and green algae, especially in heavily polluted environments. It attacks weak populations (Arvidsson 1978), and lichens in low lands are often weak due to unfavourable trapping of air pollutants (Hultengren et al. 1991). The positive correlations of *A. arachnoidea* to the field layer pH index and to brown soils are probably due to the fertile soil of the Scanian low lands.

Differences in bark epiphytes between the SW and NE part of Scania indicate that the deposition gradient due to the ridges Söderåsen and Linderödsåsen has a major influence. The indication of higher soil pH in SW Scania is due to more clay soil, whereas the lichen distribution indicated lower pH and more pollution.

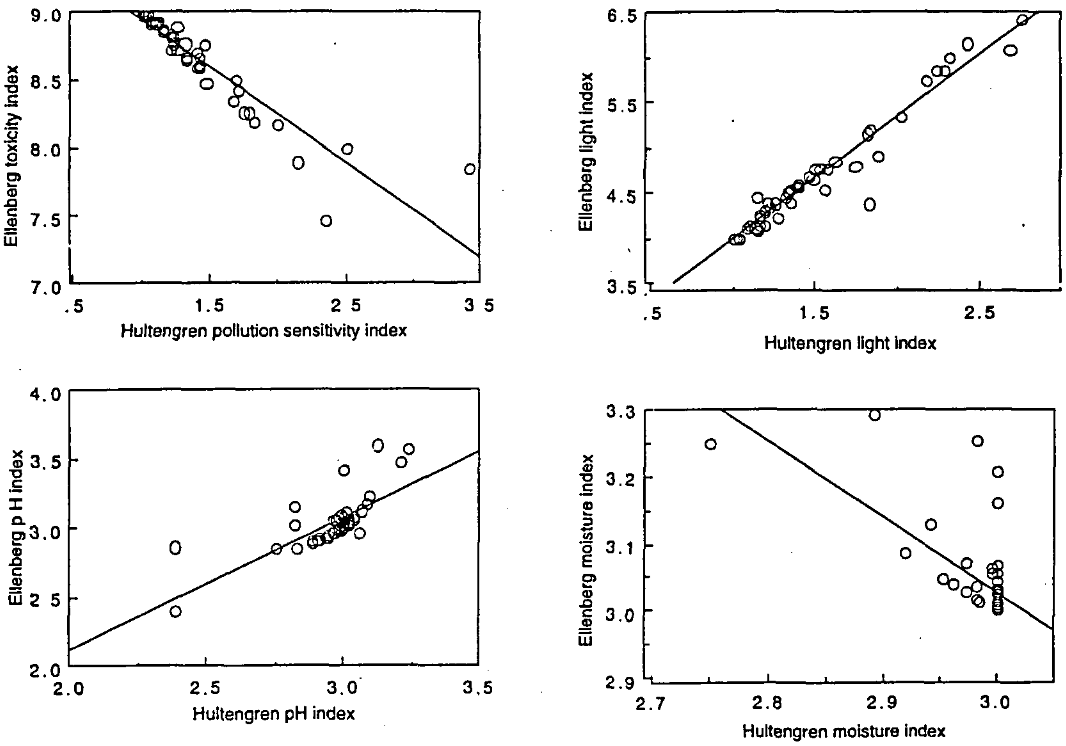

Fig. 2. Correlation between "Ellenberg's" and "Hultengren's" lichen indices for toxitolerance ($z = -10.677$, $p = 0.0001$, $R^2 = -0.92$, $n = 48$), light ($z = 6.380$, $p = 0.0001$, $R^2 = 0.74$), pH ($z = 14.056$, $p = 0.0001$, $R^2 = 0.97$) and moisture ($z = -5.184$, $p = 0.0001$, $R^2 = -0.65$).

This could be due to the large industries and big cities in the SW–W part and to the prevailing winds coming from these directions. There is also a region in the NE–E part of Scania with large industries, and this was reflected by a higher frequency of beech bark lesions and *C. fagisuga*. The distribution of beech bark lesions and *C. fagisuga* coincides with the deposition pattern of S and N according to Åkesson (1994). The distribution of algae cover was geographically even, and *L. conizaeoides* had many similarities in distribution with beech bark lesions and *C. fagisuga*, apart from a high frequency in the central western stands of Scania.

Table 7. *Field layer indices correlated with corresponding "Ellenberg's" and "Hultengren's" lichen indices*

	"Ellenberg"		"Hultengren"	
Field layer indices	z	p	z	p
pH ($n = 45$)	−1.224	ns	0.712	ns
Light ($n = 46$)	2.546	*+	2.242	*+
Moisture ($n = 43$)	−0.103	ns	0.473	ns

Significance levels: NS = not significant, *$p < 0.05$, **$p < 0.01$, ***$p < 0.001$.

Differences in the distribution of epiphytes could be due to a number of site factors that influence the exposure of beech to acidification, pollution and perhaps also nutritional imbalances. Soil texture and type were decisive for species composition at the beech sites. An important variable seemed to be the altitude. Discharged air pollutants can be trapped within an area due to the topography. One could expect less effects on the lichen flora in those areas most remote from local emission sources, which in this case would be on the Scanian ridges in the central part of the landscape.

The field layer and lichen indices were similarly influenced by different site variables. The soil has a higher buffering capacity to acid deposition than the bark, and this caused different pH indices for the field vegetation and the lichens. The moisture indices were generally higher for the vascular plants than for the lichens, which might be due to wind and sun that dries the stem, while the soil prevents desiccation. The field vegetation and the epiphytes on the stems are exposed to the same light intensities, regulated by the tree crown shadows and light gaps.

"Ellenberg's" and "Hultengren's" lichen indices

Table 8. *Correlations between different lichen indices and C. fagisuga, beech bark lesions, algae cover and A. arachnoidea. Indices were calculated using values from Ellenberg et al. (1991) and Hultengren et al. (1991) respectively. Rho-values from Spearman rank correlation coefficient (n = 48)*

"Ellenberg" lichen indices	*C. fagisuga*	BBL	Algae cover	*A. arachnoidea*
Lichen nutrition	0.248 ns	0.068 ns	0.242 ns	0.100 ns
Toxicity	0.219 ns	−0.031 ns	0.389 **+	0.319 *+
pH	−0.430 **−	−0.115 ns	−0.334 *−	−0.128 ns
Light	−0.105 ns	0.058 ns	−0.218 ns	−0.311 *−
Moisture	−0.091 ns	0.200 ns	−0.200 ns	−0.309 *−
"Hultengren" lichen indices	***C. fagisuga***	**BBL**	**Algae cover**	***A. arachnoidea***
Pollution sensitivity	−0.234 ns	−0.016 ns	−0.404 **−	−0.294 *−
pH	−0.568 ***−	−0.324 *−	−0.368 *−	−0.007 ns
Light	−0.051 ns	0.082 ns	−0.153 ns	−0.308 *−
Moisture	0.130 ns	−0.114 ns	0.129 ns	0.188 ns

Significance levels: NS = not significant, $^{*}p < 0.05$, $^{**}p < 0.01$, $^{***}p < 0.001$.

and the field layer indices partly differed in their results. The lichen indices are calculated from quantitative data, and the ground vegetation data are qualitative. It is considered to be more statistically correct to calculate averages from qualitative data, but in species-poor habitats a quantitative measure might be a better choice (Ellenberg et al. 1991). In general there were less than 10 different lichen species at each site. Diekmann (1995) investigated some properties of Ellenberg's indices applied to Swedish conditions, finding that qualitative data gave better results for vascular plants, and quantitative data gave better results for bryophytes. Within forests, better results were obtained when calculating from quantitative than from qualitative data.

Generally, lichen indices should be better indicators for conditions on tree stems than field layer indices. *Lepraria incana*, the most frequent of all epiphytes, often determined the lichen indices. Differences between Ellenberg's and Hultengren's scales could cause differences between the indices, especially since Ellenberg's scales refer to the distribution of species in central Europe and Hultengren's to species in Sweden. Diekmann (1995) found that Ellenberg's moisture indices were the least good for describing conditions in Sweden. This was also found in the present investigation, with a negative correlation between "Ellenberg's" and "Hultengren's" moisture index.

In conclusion, the correlation results obtained in this study do not prove any real cause and effect relations, but they do support the hypothesis that pollution favours the appearance of *C. fagisuga* and beech bark lesions. Bark lesions were more frequent at sites with large amounts of *C. fagisuga* and *L. conizaeoides*, and on larger trees. The algae cover and *C. fagisuga* were positively correlated. They both preferred sites with a high nitrogen deposition and low pH indices. The two sets of lichen indices (weighted averages) were most influenced by *L. incana*, and showed similarities for toxitolerance, light and pH. Generally, lichen indices should be better indicators for conditions on tree stems than field vegetation indices.

ACKNOWLEDGEMENTS

I am grateful to B. Nihlgård and everybody else who helped me during this project. Thanks to M. Sykes for revising the language.

REFERENCES

Ågren, G. I. & Bosatta, E. 1988. Nitrogen saturation of terrestrial ecosystems. Environ. Pollut. 54: 184–197.

Åkesson, A. 1994. Underlagsrapport LUFT, Miljövårdsrapport för Skåne, Del M, Remissrapport 1994. 39 pp. The County Administrative Board in Malmöhus län. (In Swedish.)

Arvidsson, L. 1978. Svampangrepp—en orsak till lavöken. Svensk Bot. Tidskr. 72: 285–291. (In Swedish.)

Balsberg Påhlsson, A.-M. 1992. Influence of nitrogen fertilization on the minerals, carbohydrates, amino acids and phenolic compounds in beech (*Fagus sylvatica* L.) leaves. Tree Phys. 10: 101–110.

Diekmann, M. 1995. Use and improvement of Ellenberg's indicator values in deciduous forests of the Boreo-nemoral zone in Sweden. Ecography 18-2: 178-189.

Dimitri, L. 1967. Untersuchungen über die Ätiologie des "Rindensterbens" der Buche. Forstwissenschaftliches Centralblatt 86: 257-276. (In German.)

Dimitri, L. 1968. Untersuchungen über den Einfluß des Wassergehaltes, der Rindendicke und der Darrdichte auf die Wärmeleitung der Buchenrinde. Holz als Roh- und Werkstoff 26: 95-100. (In German.)

Ehrlich, J. 1934. The beech bark disease—a *Nectria* disease of *Fagus*, following *Cryptococcus fagi* (Baer.). Can. J. For. Res. 10: 595-691.

Ellenberg, H., Weber, H. E., Düll, R., Wirth, V., Werner, W. & Paulißen, D. 1992. Zeigerwerte von Pflanzen in Mitteleuropa. 2ed. Scripta Geobotanica XVIII. 258 pp. Erich Goltze KG Gsttingen. ISBN 3-88452-518-2. (In German.)

Göransson, A. 1990. Alger, lavar och barruppsättning hos unggranar längs en gradient från Sverige till Holland—en pilotstudie. Swedish Environmental Protection Agency, 39 pp. ISSN 0282-7298 3741. (In Swedish.)

Hallingbäck, T. & Holmåsen, I. 1991. Mossor—en fälthandbok. 2nd ed. 288 pp. Interpublishing, Stockholm. ISBN 91-86448-11-0. (In Swedish.)

Houston, D. R. 1994. Major new tree disease epidemics: beech bark disease. Annu. Rev. Phytopathol. 32: 75-87.

Houston, D. R., Parker, E. J. & Lonsdale, D. 1979. Beech bark disease: patterns of spread and development of the initiating agent *Cryptococcus fagisuga*. Can. J. For. Res. 9: 336-344.

Hultengren, S., Martinsson, P.-O. & Stenström, J. 1991. Lichens and Air—Sensitivity classification and index calculation. 58 pp. Swedish Environmental Protection Agency. ISSN 0282-7298 3967.

Krok, Th. O. B. N. & Almquist S. 1986. Svensk Flora. Fanerogamer och ormbunksväxter. 26 ed. 570 pp. Esselte Herzogs Uppsala. ISBN 91-24-32019-6. (In Swedish.)

Lonsdale, D. & Wainhouse, D. 1987. Beech bark disease. For. Comm. Bull. 69: 5-15.

Moberg, R. & Holmåsen, I. 1990. Lavar—en fälthandbok. 3 ed., 240 pp. Interpublishing, Stockholm. ISBN 91-86448-25-0. (In Swedish.)

Nicolai, V. 1986. The bark of trees: thermal properties, microclimate and fauna. Oecologia 69: 148-160.

Perrin, R. & Garbaye, J. 1984. Influence de la nutrition de hêtre (*Fagus sylvatica* L.) sur la sensibilité au chancre provoqué par *Nectria ditissima* Tul. Ann. Sci. For. 41: 449-460. (In French.)

Siegel, S. & Castellan, N. J. Jr. 1988. Nonparametric statistics for the behavioral sciences, 2nd ed., 399 pp. McGraw-Hill, Singapore. ISBN 0-07-100326-6.

Skeffington, R. A. & Wilson E. J. 1988. Excess nitrogen deposition: issues for consideration. Environ. Pollut. 54: 159-184.

Sokal, R. R. & Rohlf, F. J. 1987. Introduction to biostatistics, 2nd ed., 363 pp. W. H. Freeman, USA. ISBN 0-716-71805-7.

Twery, M. J. & Patterson, W. A. 1984. Variations in beech bark disease and its effects on species composition and structure of northern hardwood stands in central New England. Can. J. For. Res. 14: 565-573.

Wainhouse, D. & Howell, R. S. 1983. Intraspecific variation in beech scale populations and in susceptibility of their host *Fagus sylvatica*. Ecol. Entomol. 8: 351-359.

Wargo, P. M. 1988. Amino nitrogen and phenolic constituents of bark of American beech (*Fagus grandifolia*) and infestation by beech scale (*Cryptococcus fagisuga*). Eur. J. For. Pathol. 18: 279-290.

Westling, O., Hallgren Larsson, E., Sjöblad, K. & Lövblad, G. 1992. Deposition och effekter av luftföroreningar i södra och mellersta Sverige. 109 pp. IVL rapport B 0283-877x 1079. Institutet för vatten och luftvårdsforskning, Gothenburg. (In Swedish.)

Wijk, S. 1989. Skånelänens samrådsgrupp mot skogsskador. Skogsskadeinventering av bok och ek i Skåne, Blekinge och Halland. Rapport 7. The County Administrative Board in Kristianstad län. (In Swedish.)