Lichen Transplants as Biological Indicators of SO_2 Air Pollution in Copenhagen

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A high degree of parallelism was found between the distribution of epiphytic lichens and the SO_2 air pollution measured with physico-chemical methods (JOHNSEN & SØCHTING, 1973). This parallelism made it possible to establish a monitoring scale of epiphytic lichen species, which has proved most valuable for estimating long-term SO_2 air pollution levels in Danish cities.

In regions where lack of suitable roadside trees limits the use of such a scale, lichen transplants have been used successfully to monitor the extent of SO_2 air pollution (BRODO, 1966; SCHÖNBECK, 1969; KIRSCHBAUM et al., 1971; LEBLANC & RAO, 1973; KROG & BRANDT, 1975). The purpose of this study was to correlate semi-quantitative data on air pollution, using the degree of damage to transplanted lichen thalli as the experimental parameter, with physico-chemical SO_2 air pollution measurements in the Copenhagen area.

MATERIAL AND METHODS

The epiphytic lichen Hypogymnia physodes (L.) Nyl. was selected for transplantation into the Copenhagen area, since this frequently occurring lichen species is known to be semi-tolerant to SO_2 air pollution in this region (JOHNSEN & SØCHTING, 1973). The lichen transplants were collected from an oak tree (Quercus robur L., diam. ca. 40 cm), with Hypogymnia physodes as the dominant epiphytic species.

The oak tree was situated in Asserbo Plantage, North Zealand, which served as the control region, since the air is relatively pure.

Lichen bearing bark discs with a diameter of 6 cm were used as transplants. The discs were cut out of the trunk with a circular saw and were fixed to a wooden board with a two-component epoxy

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glue. Four discs were placed side by side on the board (Fig. 1), which was photographed with infrared film and subsequently fastned to a 2 m long vertical pole.

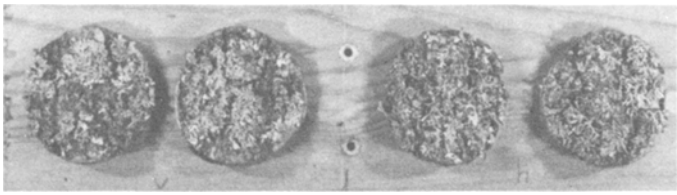

Fig. 1. Board with four transplant discs (x 1/3).

Fourty-six poles, oriented such that the bark discs faced west, were placed at exposed sites (Fig. 2), mainly in private gardens. The frequency of pole sites was highest in the periphery of the town where the gradient of SO_2 levels was most pronounced. The poles were erected at the beginning of December, 1974, and 42 poles were recovered and returned to the laboratory for analysis at the end of May, 1975.

The boards were re-photographed in the laboratory, and for each disc the extent of discolouration of the moist thalli was estimated by eye according to the following scale:

1	ca.	o% discoloured
2	"	1o% "
3.4	"	25% "
5	"	5o% or more discoloured

The growth during the previous 6 months was estimated from the photos in the following way: o: no growth; 1: poor growth; 2: conspicuous growth.

Average discolouration and growth for each board were calculated.

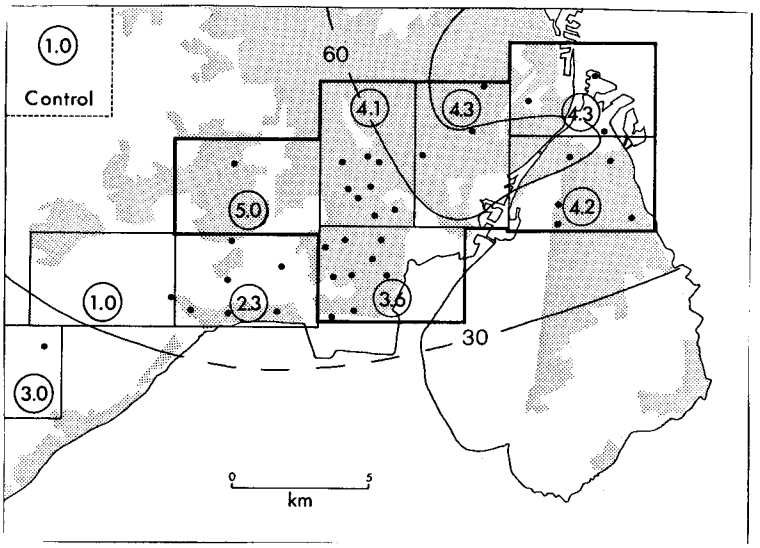

Fig. 2. The Copenhagen built-up area (shaded) and the area under investigation (grid). Dots represent transplantation sites. Encircled figures indicate average extent of thallus damage. Two SO_2 isopleths (μgm^{-3}) are indicated.

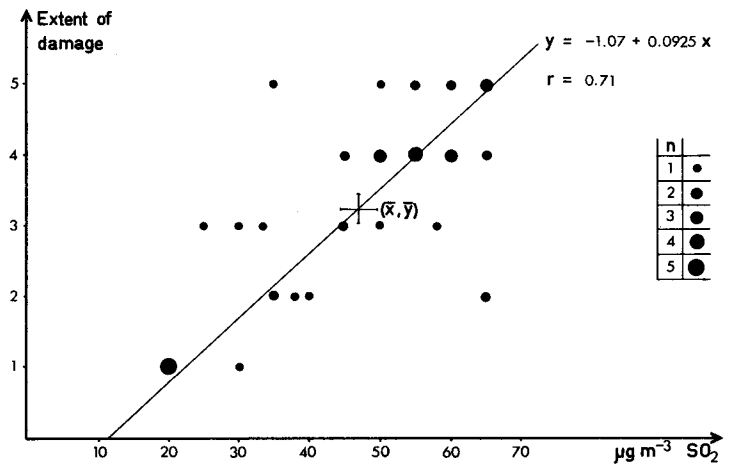

Fig. 3. The correlation between SO_2 levels at transplantation sites and the extent of transplant thallus damage. $r \neq o$ at $p = o.ol$. n: number of coinciding dots.

RESULTS AND DISCUSSION

The grid shown in Fig. 2 was used as an arbitrary regional division of the southwestern part of the Copenhagen area (KRAK, 1974). The figures encircled represent the average damage values obtained from the subgrids, the figures 5.0, 1.0 and 3.0 being based on single values only.

By statistical analysis it was found that the observed damage averages provided a basis for distinction among only three damage regions: the control region, the outer peripheral region and the central region of Copenhagen, the last region being circumscribed by a heavy line in Fig. 2.

SO_2 air pollution data, calculated as a winter average, Dec. 1974 - May 1975, were provided by the Greater Copenhagen Air Pollution Committee. That these data permitted distinction among only three zones as regards immission was shown by statistical analysis (according to HARRIS et al., 1948; KEAGY, 1961; and JOHNSEN, 1974). The statistical parameters used were the number of monitoring stations for SO_2, the standard deviation of the measurements within each zone, and the difference between the zonal SO_2 means and the selected isopleth values. The SO_2 levels of the 3 immission zones were greater than 60 μgm^{-3}, between 30 and 60 μgm^{-3} and less than 30 μgm^{-3}, respectively. The three zones indicated by two isopleths are shown in Fig. 2.

The correlation between estimated SO_2 levels at the pole sites, calculated from the data provided by Greater Copenhagen Air Pollution Committee, and the average damage values for each pole, obtained in this study, is shown in Fig. 3. The correlation coefficient was 0.71, significant at the $p = 0.01$ level of confidence. Growth of thallus lobes was not correlated with SO_2 levels, in accordance with GILBERT (1971).

The limiting levels of SO_2 for epiphytic *in situ* *Hypogymnia physodes* were 1oo µgm^{-3} in Copenhagen (JOHNSEN & SØCHTING, 1973) and 6o-7o µgm in England and Wales (HAWKSWORTH & ROSE, 197o). Both levels represent arithmetic winter averages (Oct. - March incl.), the value from Copenhagen being the mean of the winters 197o-71 and 1971-72.

Due to the unusually mild winter 1974-75 (Table 1) and consequently reduced combustion of fuel for heating, the SO_2 levels shown in Figs. 2 and 3 are 4o% lower than the winter average levels of 197o-72 in Copenhagen.

TABLE 1

Climate of Copenhagen during the year of investigation compared with a 3o-year average (Normal)

	Normal	Sept.1974-Aug.1975
Annual mean temperature	8.5°C	9.8°C
Annual precipitation	6o2 mm	62o mm

Nonetheless, the transplants showed conspicuous signs of damage even in areas where *in situ* *Hypogymnia physodes* grew well on roadside trees. The extent of damage to *Hypogymnia physodes* transplants occurring at SO_2 levels lower than the above critical values, reflects the difficulties in direct comparison between *in situ* vegetation and transplants. Following transplantation, the lichens fail to adapt to the higher SO_2 air pollution levels and are consequently damaged at relatively low levels. The transplantation procedure itself has no harmful effect, as indicated by the undamaged controls (Fig. 2).

CONCLUSION

It is concluded from the high correlation between visible transplant damage and SO_2 levels, that SO_2 pollution gradients can be sufficiently described by means of the lichen transplantation method. The transplanted lichen species should be chosen on the basis of its SO_2 sensitivity, this being neither too high nor too low in relation to the average SO_2 level of the area under investigation. A de-

scription of the existing lichen vegetation or a knowledge of the SO_2 variation in the area should thus precede any transplantation experiments. Hypogymnia physodes, which was also used successfully in transplantation experiments in Oslo (KROG & BRANDTH, 1975), showed sufficient variation in degree of damage after 6 months of transplantation in the Copenhagen area to be a useful indicator of SO_2 air pollution levels. Thus, our data suggest that Hypogymnia physodes is a suitable organism for use in future transplantation experiments on air pollution levels in metropolitan areas in southern Scandinavia.

ACKNOWLEDGEMENTS

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