DWARF SHRUBS AS BIOINDICATORS

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INTRODUCTION

Several studies of air polluted forest environments have shown that dwarf shrubs suffer from air pollution. In many cases the disturbances have been attributed to the susceptibility of dwarf shrubs, while in some cases the vegetational competition factor has been discussed (HUTTUNEN 1975, LAAK-SOVIRTA and SILVOLA 1975).

The growth pattern form of dwarf shrubs is very complicated and a single individual can cover large areas due to vegetative reproduction. Since dwarf shrub individuals cannot be transplanted for the purposes of laboratory or field tests, the only possibility is to use small cuttings in bioindication studies. Some preliminary results are discussed.

MATERIAL AND METHODS

To study the special susceptibility of Vaccinium vitis-idaea L. and Empetrum nigrum coll., small cuttings of different provenances of the dwarfs were grown and used for bioindication purposes. Preliminary transplantation experiments were made together with some measurements of natural growing dwarf shrubs in urban and industrial forests (fig. 1).

The cuttings from provenances which started to grow were collected for morphological measurements of the stomata, in order to get some preliminary information on the possibility to have different sensitivities to pollutant sorption. The variability of stomatal frequency was tested with variance analysis. The frequency varies significantly between the provenances (F = 19.31, df = 9, $df_2 = 170$, p < 0.001). The frequency of stomata was 218.8-354.2 per square millimeter. The provenances near the mean values were sampled for transplantations. A typical small cutting of Vaccinium vitis-idaea is presented in figure 2. Natural growing dwarf

shrubs were also studied in the Oulu area. In figure 3 the code numbers 81–87 of the study areas and the transplantation sites A, B and C are presented. A was a transplantation site under air pollution by chemical industry, B a site with traffic caused air pollution and C a clean control site.

The total peroxidase activity was measured by using a modification of the method described by KELLER and SCHWAGER 1971, and buffering capacity was measured by using the method of GRILL and HÄRTEL 1972. The surface erosion and particle accumulation of leaf surfaces were monitored by Scanning electron microscopy, using sputter equipment and thin Au-film.

The air quality in the study areas has been measured by the municipality of Oulu and the Finnish Meteorological Institute (ESTLANDER et al. 1979, VUONONVIRTA pers.comm. 1980). The regional distribution of sulphur compounds and their accumulation in forest trees has been presented by HUTTUNEN et al. 1981.

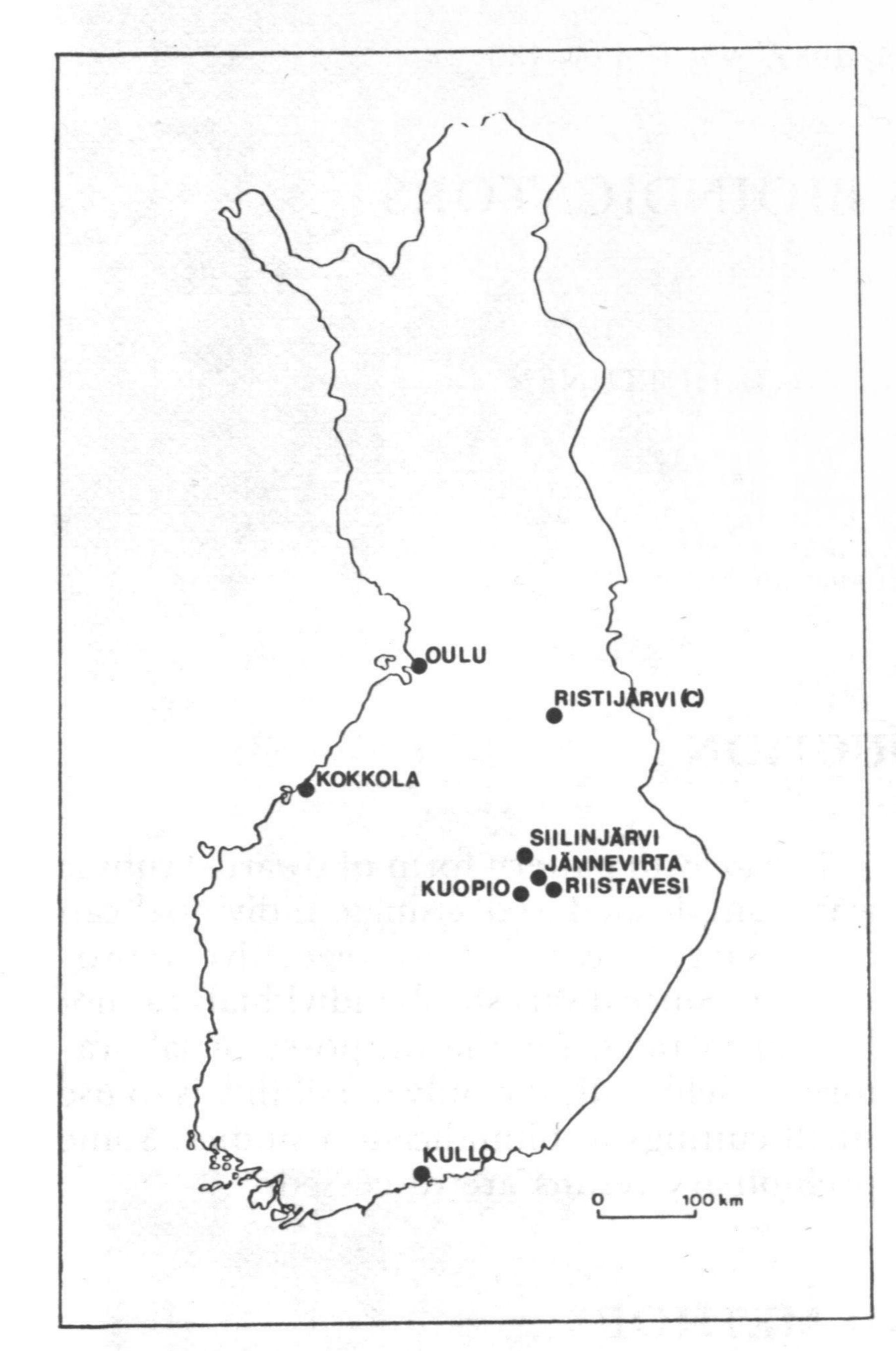


Fig. 1. Location of dwarf shrub provenances tested.



Fig. 2. A typical small cutting of Vaccinium vitis-idaea in a small transplantation pot.

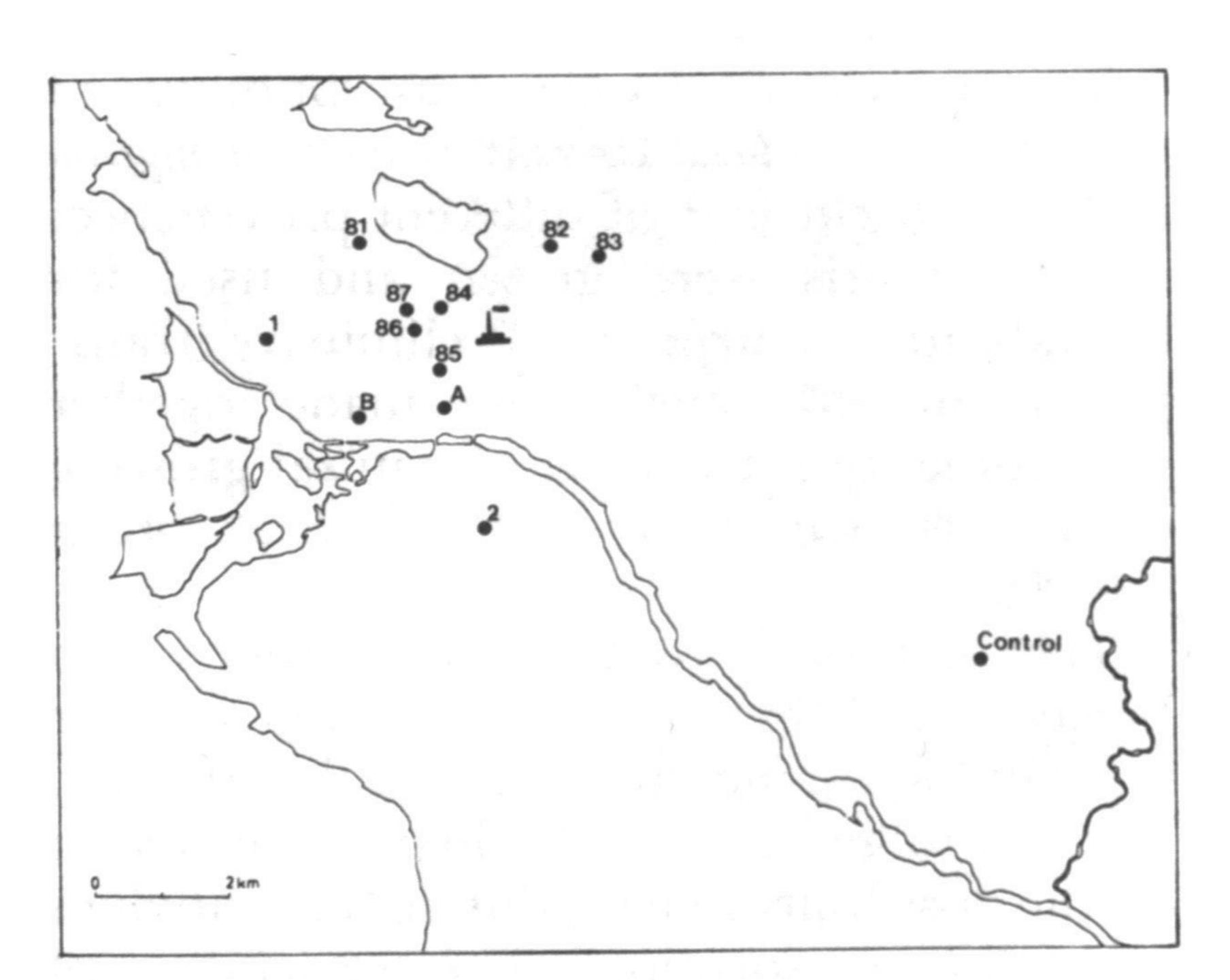


Fig. 3. Map of the industrial and urban study areas numbers 81-87. Location of the transplantation sites A, B and C (control). Other stydy areas 1. Botanical Garden 2. Department of Botany.

RESULTS AND DISCUSSION

Erosion and adsorbed particles

The normal upper surface wax structure of surface wax is mainly amorphous (fig. 4a).

Under traffic caused pollution, typical silicon, metal and soot particle pollution from traffic and roads was observed. Some disturbances Vaccinium vitis-idaea has a wavy shape. The in the normal wavy structure were also observable (fig. 4b and c).

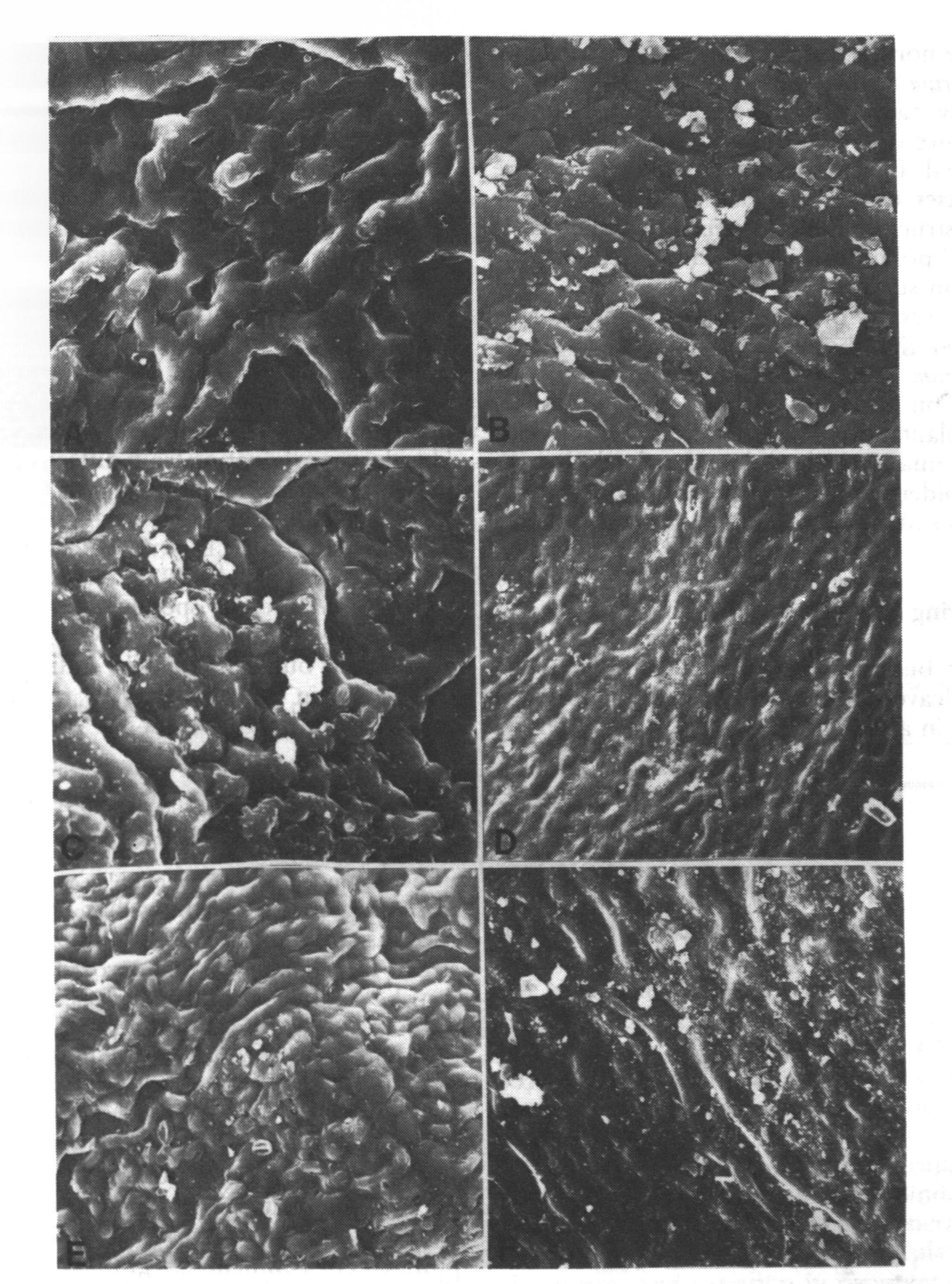


Fig. 4. Scanning electron micrographs (SEM) of the surfare wax structure of Vaccinium vitis-idaea and Empertrum nigrum coll. on Sept. 15, 1980 after a 5-week transplantation period.

Fig. 4A. The upper wax surface of Vaccinium-vitis-idaea leaves. Transplantation from a slightly polluted control area at Sanginjoki near Oulu (provenance Kullo) 2000x.

Fig. 4B. The upper wax surface of transplanted Vaccinium vitis-idaea in a traffic polluted area (provenance Kullo). Typical urban particle pollution with Si, metal and soot particles, 2000 X.

Fig. 4C. The upper wax surface of transplanted Vaccinium vitis-idaea in a traffic polluted area (provenance Kokkola) 2000x.

Fig. 4D. The upper wax surface of Empetrum nigrum coll. A slightly polluted control area (provenance Oulu) 540x. Fig. 4E. The upper wax surface of Empetrum nigrum coll. under chemical industry pollution (provenance Oulu). The epidermal cells have lost their normal outer appearance and the surface structure seems curled 1000x.

Fig. 4F. The upper was surface of Empetrum nigrum coll. under traffic caused pollution. A slightly curled surface structure with Si and metal particle deposition (provenance Oulu) 1000x.

The normal upper surface wax structure of *Empetrum nigrum* coll. is slightly wavy with a mainly amorphous, but partly tubular structure (fig. 4d). Under acute air pollution induced injury the wavy surface structure increases due to cell damage (fig. 4e). The wavy structure is also observable under traffic caused pollution with typical particle suspension on surfaces (fig. 4f).

The results of morphological monitoring showed that both *Vaccinium vitis-idaea* and *Empetrum nigrum* coll. suffered from air pollution on the urban and industrial transplantation sites after 5 weeks' tranplantation. The injury involved changes in epidermal cell structure rather than erosion of waxes.

Buffering capacity

The buffering capacity of Vaccinium vitisidaea leaves from different provenances was tested in a standardized glass house environ-

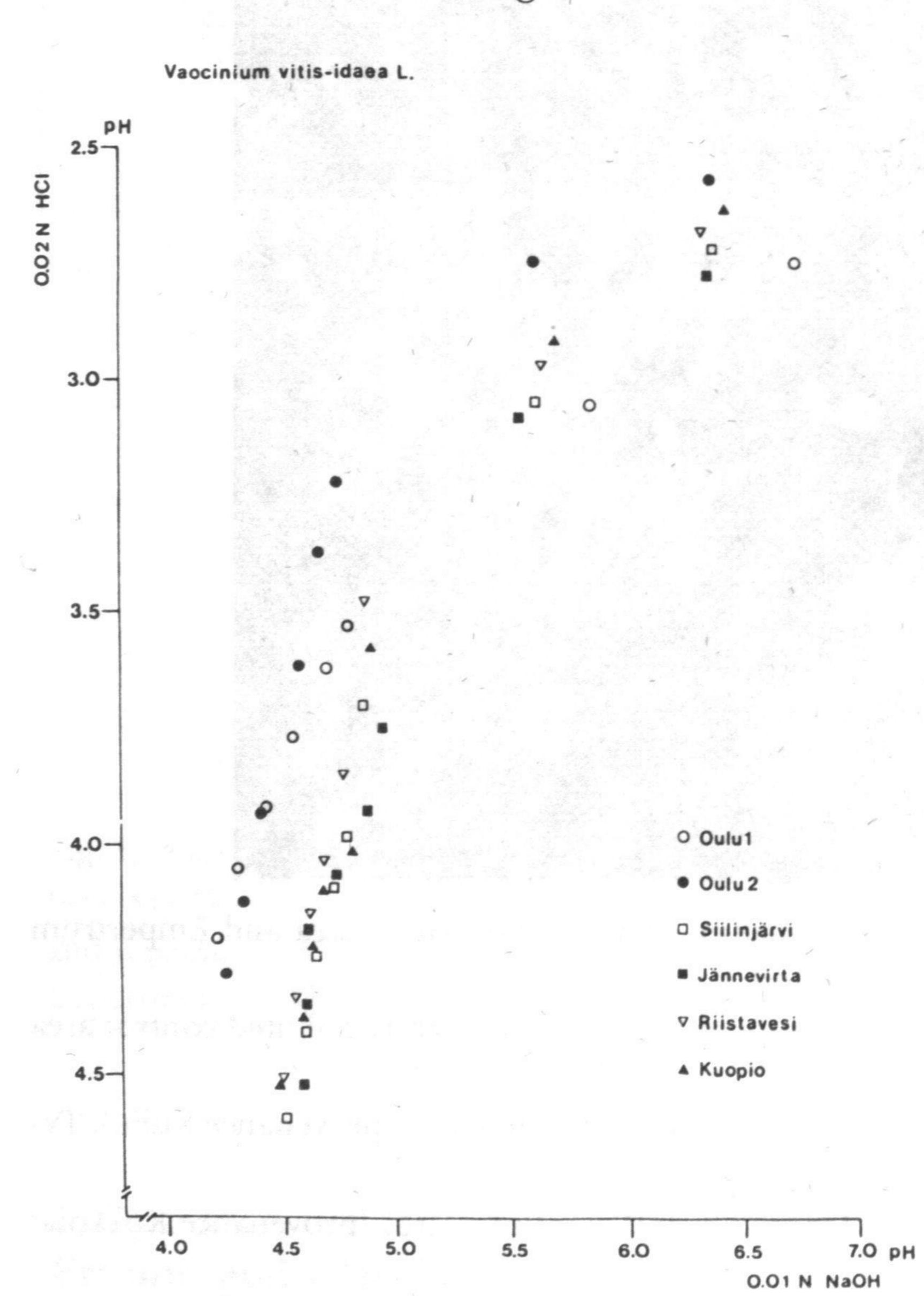


Fig. 5. The buffering capacity of Vaccinium vitis-idaea in standardized environmental and soil conditions. The pH changes measured in the buffering range of 0.1 ml to 3 ml of added acid or basic substances.

ment in the Botanical Garden on April 20. 1978. The buffering capacity of the leaves of the northern provenances was found to be weaker at the acid end of the buffering range. In the eastern provenances the buffering capacity of the basic end of the range was more easily affected. Some differences between the samples of polluted urban and unpolluted clean area provenances could also be observed (see provenances of Oulu in figure 5).

The results of the buffering capacity measurements indicate some differences in the eliminating capacity of *Vaccinium vitisidaea* leaves originating from different parts of the country. Similar observations have been made on conifer needles and some broadleaved trees (GRILL and HÄRTEL 1972, HUTTUNEN et al. 1981). The buffering capacity of different species has normally a wide range of variation (WIND 1979). The variation of buffering capacity indicates some differences in the physiological processes as well as some differences of the stage of metabolism.

Total peroxidase activity

Total peroxidase activity has been widely used as an indicator of pollution induced stress. The changes in total peroxidase activity can be related to disturbances in photosynthesis and respiration and to the amount of toxic substances accumulated (KELLER 1974, HUTTUNEN et al. 1981).

The total peroxidase activities of transplanted *Empetrum nigrum* cuttings were somewhat higher in the polluted environment than on the control sites, *Vaccinium vitis-idaea* cuttings had more variable values in the polluted environment. No gradual increase of the activity values towards autumn was observable in the measurements. The higher values of the control transplantations may also be caused by the normal environmental provenance stress due to the long range transplantation site (fig. 6).

Monitoring of the total peroxidase activity of dwarf shrubs in natural growing forests showed that the stress effect was greatest under the prevailing winds and varied along with the wind conditions. This indicates that most of the stress effects were caused by

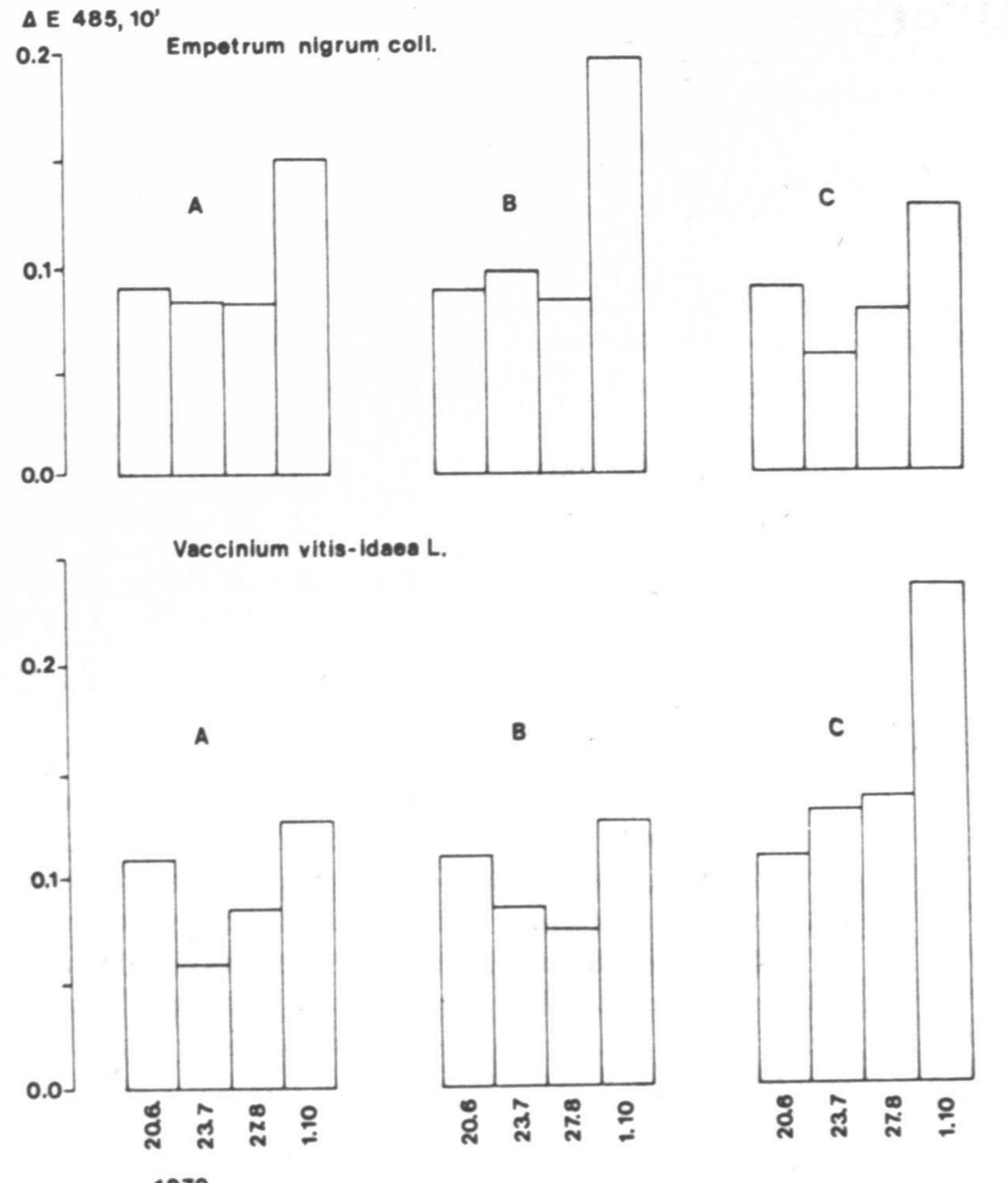


Fig. 6. The total peroxidase activity of transplanted Vaccinium vitis-idaea (provenance Kokkola, Kvikant) and Empertum nigrum coll. (Provenance Oulu, Pyykösjärvi) during the monitoring summer 1979. The air pollution induced stress is observable particularly in the Empetrum nigrum coll. transplantations. A. A transplantation site in a traffic pollution area. C. Control transplantation in a clean area.

short-term concentrations of air pollutants. The greatest stress effects were measured during July. Several test areas had relative stress values over 150 %. The stress effect again increased in October (fig. 7).

Peroxidase activity has been found to increase in dwarf shrub leaves due to herbicide treatments and air pollution, as is indicated by the preliminary results of SCHULZ (1979). Total peroxidase activity has been found to be one of the best indicators of air pollution effects in many field and laboratory experiments (HORS-MAN and WELLBRUN 1975, 1977).

Bioindication

The bioindicative value of surface structure monitoring can be explained by the changes in the physico-chemical properties of leaf effects are present. Long can determined, and end changes can be observed.

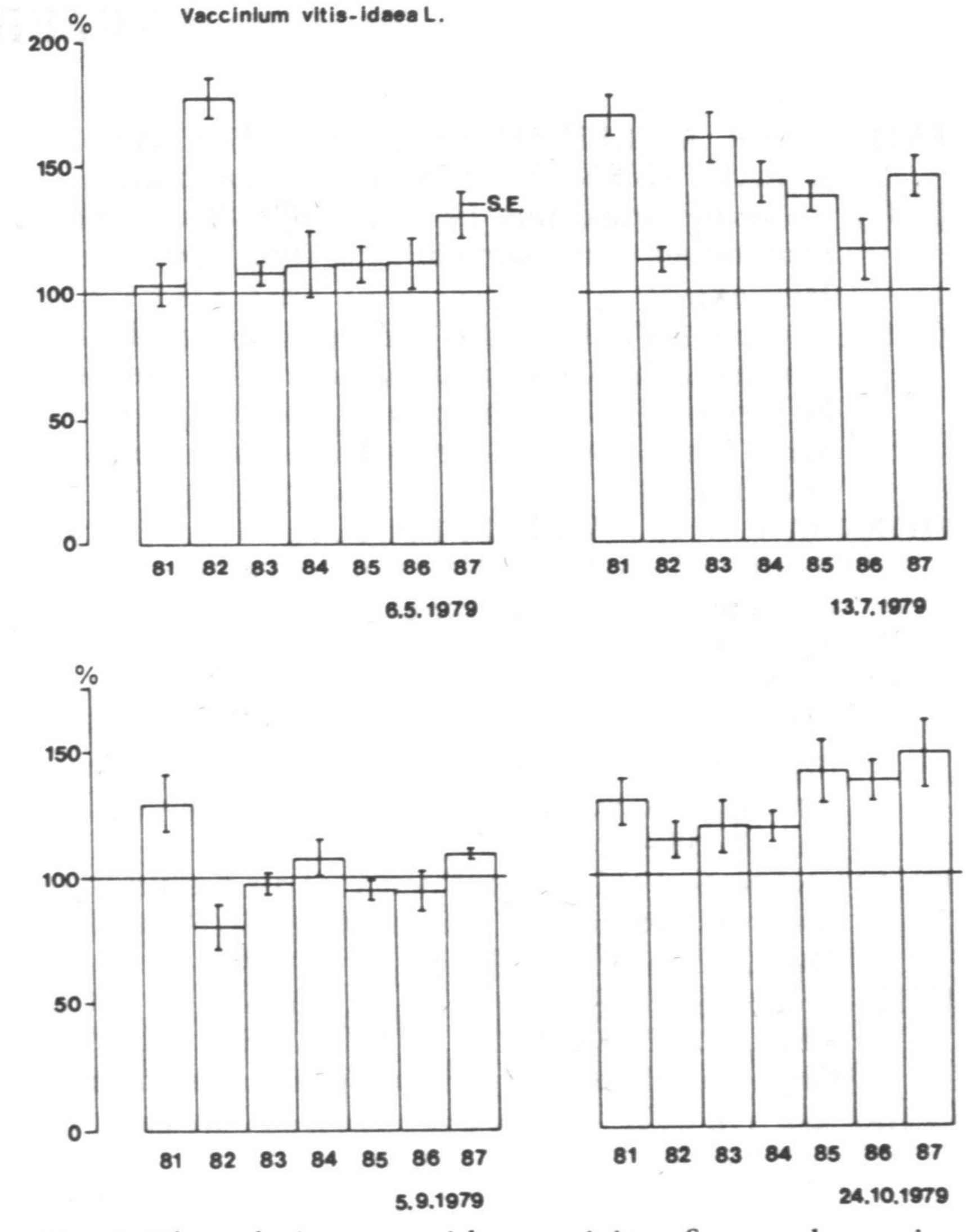


Fig. 7. The relative peroxidase activity of natural growing Vaccinium vitis-idaea on test sites in urban forest areas. The control area is located in a slightly polluted forest area Sanginjoki.

surface, which can be related to the resistance against air pollutants and secondary injuries due to plant diseases and insects. The epidermal changes due to air pollution can be related to the acute injury effects of short-term high concentrations. The possibility of water economy distrubances is one of the most obvious.

The indicative value of buffering capacity is one of the most suitable for bioindication purposes. Buffering capacity is a general indicator of the physiological stage of a plant. The differences and variation in provenances can also be determined with the buffering capacity measurements.

The indicative value of stress enzymes, like peroxidases, has been discussed in many studies. In the transplanted cuttings the indication was not regular due to the acute effects of air pollution. The indicative value of enzyme assays is most obvious when no acute effects are present. Long-term stress effects can determined, and even the seasonal changes can be observed.

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