THE TYPES OF ULTRASTRUCTURAL INJURIES IN CONIFER NEEDLES OF NORTHERN INDUSTRIAL ENVIRONMENTS.

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Ultrastructure of mesophyll of second-year green needles of *Picea abies* (L.) Karst. and *Pinus silvestris* L. has been studied in several polluted areas in Finland since 1976 (e.g., Soikkeli and Tuovinen 1979, Soikkeli 1981a). Four different types of injuries have been found. The types differ with the origin of the material:

1) In needles collected from areas polluted by S-communds the type with reduced grana and/or that with lightening of plastogobuli with simultaneous accamulation of lipid-like material are observed.

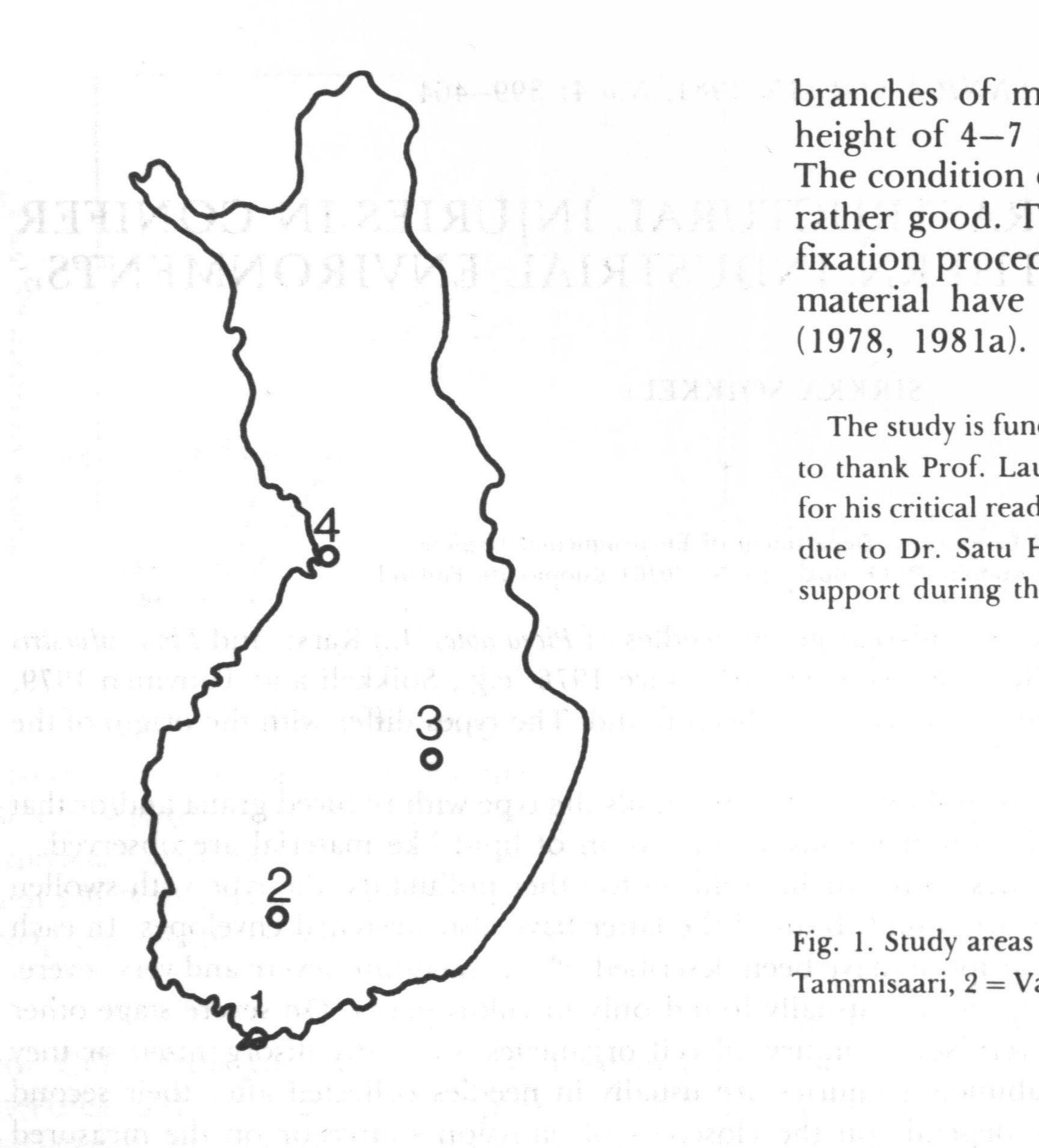
2) In needles exposed to fluorides (alone or in addition to other pollutants) the type with swollen and/or that with curled thylakoids are found. Both of the latter have also stretched envelopes. In each type of injury three stages of cell disruption have been described: slight-medium, severe and very severe. On the slight-medium stage the injuries are usually found only in chloroplasts. On severe stage other organelles show injuries, too. In very severe injury all cell organelles are badly disorganized or they disappear completely. The most abundant injuries are usually in needles collected after their second winter. The severity of cell injury depends on the closeness of emission source or on the measured concentration of SO₂.

INTRODUCTION

The effects of air pollution on the ultrastructure of spruce and pine needles have been studied during 1976-1980 in Finland in several polluted environments. The working group in the Ecological Laboratory of the Department of Environmental Hygiene of University of Kuopio has specialized in the structural approach. The earlier structural studies dealing with air pollutants included those made in fumigation chambers (e.g., WELLBURN et al. 1972) and some made in the field (GODZIK and KNABE 1973). Some of the questions which the structural studies as a whole aimed to answer were e.g., can the injuries be detected without visible symptoms, do the different pollutants cause different injuries, and if so, can these methods be used for diagnostic purposes. This paper summarises the ultrastructural injury types observed in spruce and pine needles growing in polluted environments.

The needles were collected from several polluted environments in Finland (Fig. 1): 1) From the vicinity of a fertilizer factory (emitting e.g., SO₂, NO_X, fluorides) and that of a pulp mill emitting mainly SO₂ (both located near Kuopio, Fig. 1) and near a brick factory emitting SO₂ and fluorides (Tammisaari, Fig. 1). 2) From the environment (1-3 km of the factory) of the fertilizer and chemical factories in Oulu (Fig. 1). 3) From the area of Valkeakoski, which is a heavily industrial town polluted mainly by S-compunds and 4) from the town of Kuopio polluted only slightly by S-compunds. Every study area had several study sites and from every study site at least two spruces and/or two pines were studied. From two areas (SOIKKELI and TUOVINEN 1979) the samples were taken during one year once a month, from other areas at least twice a year.

The needles were collected from the



branches of mature spruces and pines at a height of 4–7 meters, mainly during winter. The condition of the trees varied from bad to rather good. The sampling methods and the fixation procedures as well as analysis of the material have been reported by SOIKKELI (1978, 1981a).

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Fig. 1. Study areas where the needles were collected. 1 = Tammisaari, 2 = Valkeakoski, 3 = Kuopio, and 4 = Oulu.

ULTRASTRUCTURAL INJURY TYPES

At ultrastructural level four different types were observed and they differed with the origin of the material. The injury types were similar in the needles of spruce and pine, and could be observed in green needles. The types which appeared in S-polluted areas can best be characterized by the reduction of grana (Fig. 2) and by the lightening of plastogobuli with simultaneous accumalation of lipid-like material in cytoplasm (Fig. 3). The types in F polluted needles showed stretched envelopes and swollen (Fig. 4) or curled (Fig. 5) lamellae. The curled lamellae injury appeared strongly during the coldest period of winter. When the injuries were slight-medium (the scale is slight-medium, severe, very severe, SOIKKELI 1981a) usually only the injuries in choloplast structure were distinguishable.

During the proceeding of the injury (severe injury), often observed in needles collected in late winter or spring, the injuries in chloroplasts became worse. E.g., the reduced

grana lamellae got swollen and the envelopes began to rupture, the plastoglobuli were lightened and their shape changed and their amount and that of lipid-like material in cytoplasm increased. In F-polluted needles the swelling became worse and the lamellae of the other type were heavily curled with simultaneous appearance of hollows in stroma. Also in these two types the envelopes began to rupture.

In addition to the proceeding of the injury in chloroplasts also the other cytoplasmic organelles began to show injuries. E.g., cytoplasm became granulated, mitochondria injured, and the amount of ribosomes decreased (in samples collected during the growing period). In very severely injured cells all of the cell organelles were strongly disorganized and often the cell had an overall granular appearance. The portion of badly injured cells was the highest in nearly two-year-old needles collected during spring.

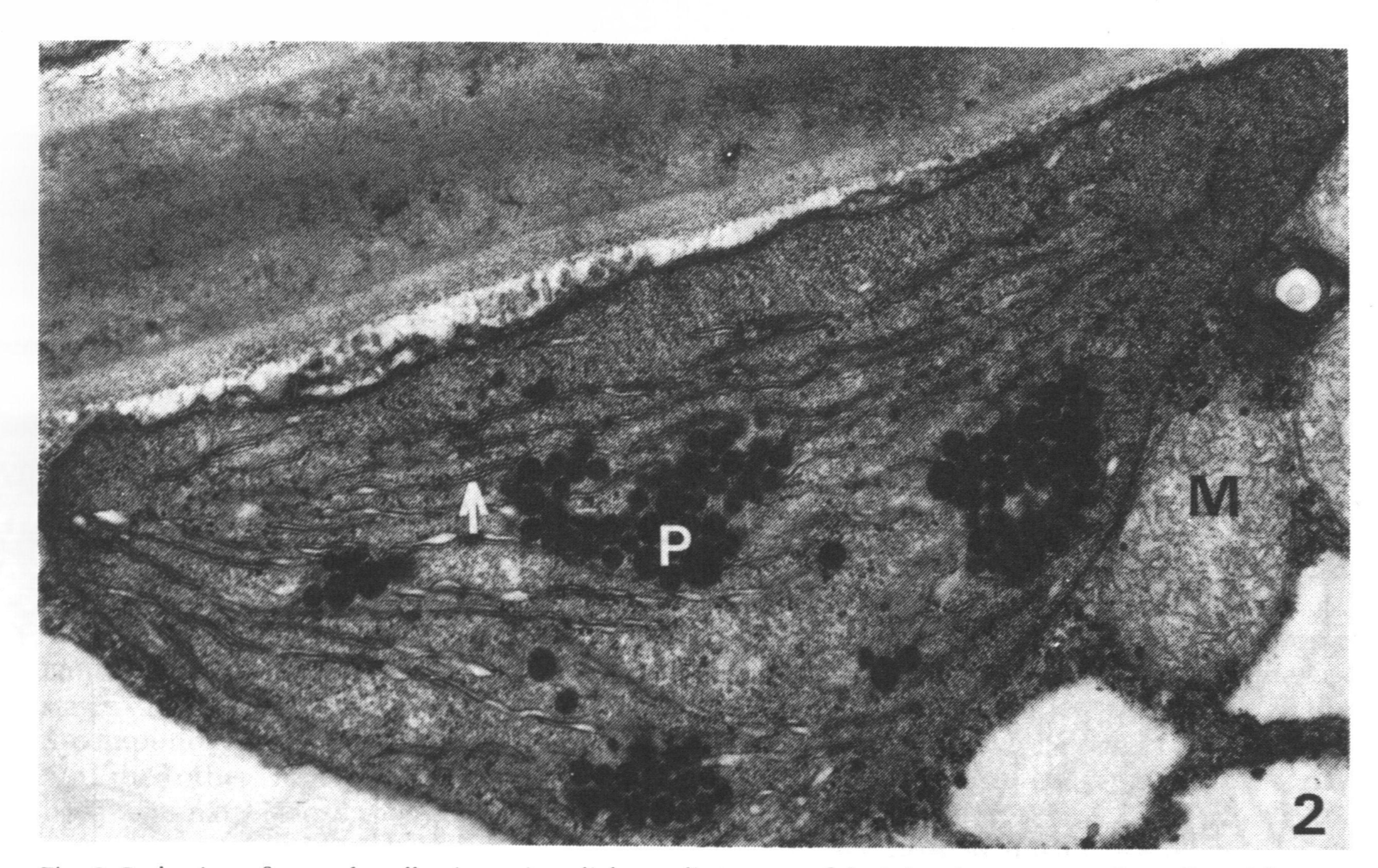


Fig. 2. Reduction of grana lamellae (arrow) at slight-medium stage of the injury in spruce needles collected from S-polluted areas. Mitochondria (M), plastoglobuli (P). Kuopio on May 2, 1979. X 24 000.

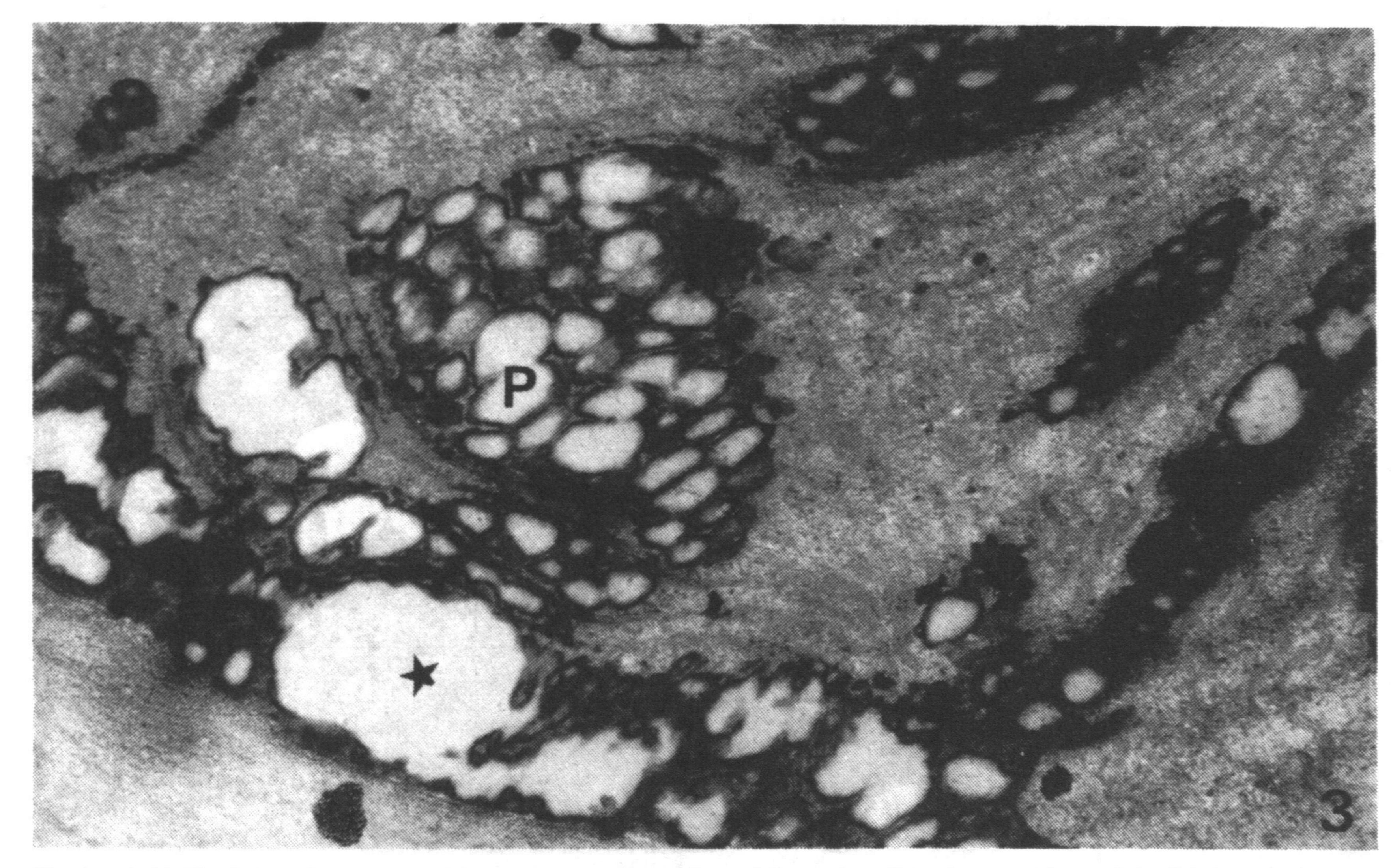


Fig. 3. Lipid-like injury (severe stage) in spruce needles collected from S-polluted areas. Plastoglobuli (P) are lightened and their shape is changed. Lipid-like material (star) in cytoplasm. Valkeakoski on January 31, 1978. X 31 000.

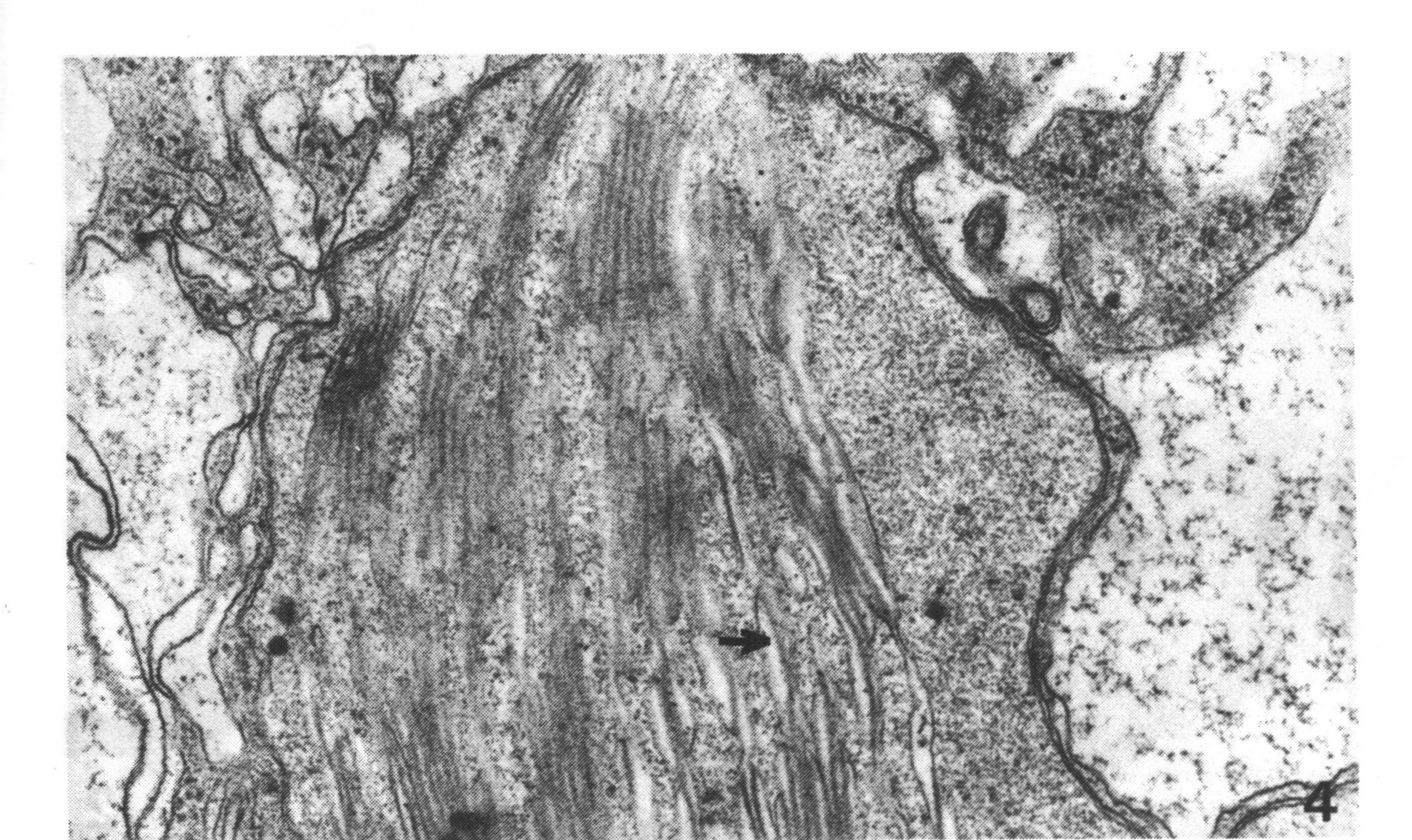


Fig. 4. The injury type with swollen lamellae (arrow; slight-medium stage) typical to F-polluted areas. Spruce needle. A fertilizer factory near Kuopio on January 18, 1977. X 40 000.

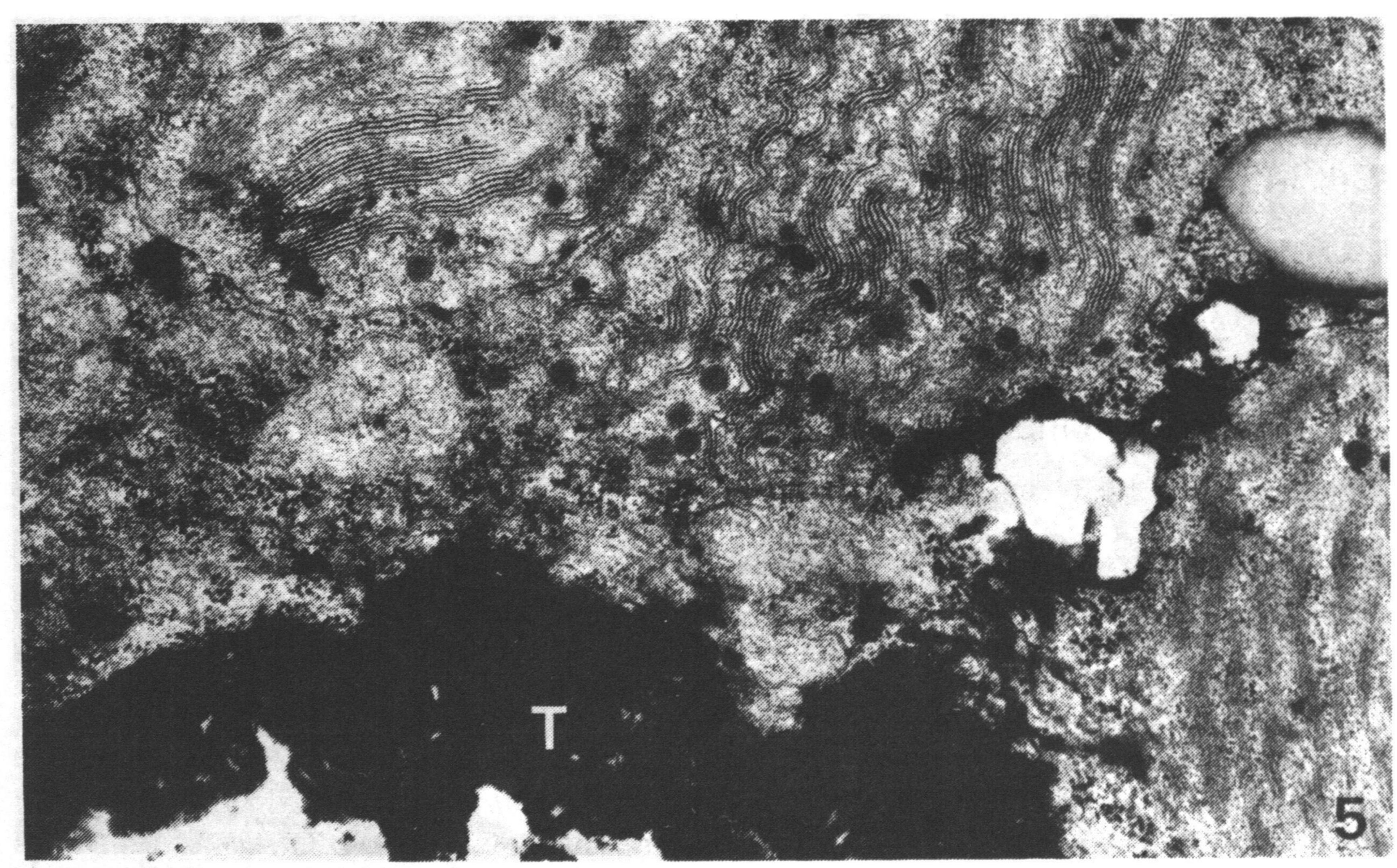


Fig. 5. The injury characterized by curled lamellae (servere injury). Tannin (T) in central vacuole. Pine needle collected from F-polluted area. A brick factory in Tammisaari on February 27, 1978. X 31 000.

Because of their appearance in S-polluted concentrations of which have usually been areas, the injury types with reduced grana and high (e.g., WELLBURN et al. 1972, with the lightening of plastogobuli are MLODZIANOWSKI and BIALOBOK 1977). thought to be caused by sulphur compounds. It is possible that the swelling of the This conclusion is also supported by the thylakoids is not a specific reaction to some observations that in areas with a high level of pollutant. It could better be a sing of an acute SO₂ (e.g., in Valkeakoski) the injuries were injury. On the other hand, the diffetent abundant and the stage of cell injury was species or even the same species under more severe in needles of the same age if different conditions can react differently to compared to areas with a low level of SO₂ the same pollutant. During the structural (Kuopio) (SOIKKELI 1981a, 1981b). The studies it became apparent, however, that the reduction of grana in S-exposed material has both Finnish conifers, Picea abies and Pinus been reported also earlier e.g., by GODZIK silvestris, react similarly in similar pollutant and SASSEN (1974).

lamellae could be the disturbances in SH/SS during the second winter of the needles status of lamellar porteins caused by dissolved (SOIKKELI and TUOVINEN 1979). Also the S-compunds (e.g., SUGHARA et al. 1980). extent of the damage is bigger then than in On the other hand, the accumalation of the younger needles collected during early lipid-like material can refer to disturbances in winter or autumn (SOIKKELI 1981a, 1981b). some stages of lipid metabolism.

with simultaneous stretching of the envelopes unsuccessful hardening during the preceeding were typical injuries in needles exposed to autumn which is likley to occur in fluorides not depending on the possible environments with nitrogen oxides (HUTTUoccurence of other pollutants. Partly similar NEN et al. 1981), higher concentrations of injuries have also been reported in HF- SO₂ in the air during winters (e.g., fumigated needles of Abies alba by BLIGNY et KARTASTENPÄÄ et al. 1979), accumulated al. (1973). Curled thylakoids occurred during and still accumulating pollutant in the cell, the coldest periods of winter and could be etc. All the harmful effects of pollutants caused together by frost and pollutants. The together with normal winter stresses lead to curling lamellae have earlier been reported in the disorganization of cell metabolism, even some grass species at low temperatures by in the dormant trees (e.g., BÖRTIZ 1967). At KIMBALL and SALISBURY (1973).

many different pollutants in addition to most sensitive organelles such as chloroplasts fluoride, e.g., with SO₂ and NO₂, the spreading later to the entire cell.

One reason to the reduction of grana The injuries become considerably worse The injury process during winter is due to The swelling and curling of the thylakoids many factors functioning together, e.g., the ultrastructural level the events can be seen as Swollen lamellae have been reported with an increasing injury, which begins from the

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