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Tussilago farfara L. — a plant relatively resistant to industrial air pollution

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Abstract

Tussilago farfara L. is a species highly resistant to the fumes emitted by the factory of silicophosphate fertilizers and to other kinds of industrial air pollution. The resistance of this species results from the wide ecological amplitude and characteristic anatomical structure of the leaves of this plant.

INTRODUCTION

Tussilago farfara L. is considered in the flora of Poland as a synanthropic plant of local origin. It is common the country over, particularly on moist sites, on soils rich not only in nitrogen (Motyka, 1962) but also in phosphorus and potassium (Świeboda, 1970). As a pioneer plant it rapidly spreads on fresh landslips, scree-covered tracts, quarries, dumps and roadside escarpments. It also grows on areas devastated by industry, frequently on dumps containing an admixture of toxic components.

In the surroundings of the silicophosphate fertilizers factory, *T. farfara* survives in the zone of high dustfall amounting to about 100 t/km^2 yearly, as shown by observations (Świeboda l.c.). Other more susceptible species disappear from these previously occupied sites.

So far, it has not been explained satisfactorily whether some plants are capable of active defence against the noxious influence of industrial air pollution by producing protective substances or whether their relative resistibility is rather the result of specific features of their morphological and anatomical structure. Certain observations concerning internal adaptive mechanisms in plants are reported by Cvrkal (1960), Materna (1962), Steinhübel (1962) and Levitt (1972).

The present study was undertaken to analyse from the anatomical and chemical point of view specimens of *T. farfara* collected on sites subject for 25 years to the influence of the silicophosphate fertilizers factory fumes, and to compare them with plants not exposed to industrial contamination. The aim was to establish certain properties of *T. farfara* which enable this plant to survive under changed ecological conditions.

MATERIAL AND METHODS

The areas from which the material was collected are situated on both sides of the factory chimneys (Fig. 1) in the zone where dustfall is high, on an open area. Only site 4 is protected by a residential building and a high widely branched tree (a red beech). This experimental site was chosen in order to find out whether, in the same contamination zone, any differences may be noted in the content of the components analysed, in dependence on the situation of the given site (open space or protected place). As control area a freshly levelled plot at the border of the forest was chosen, situated 31 km to the west of the source of contamination.

Soil samples were taken from the surface layer (down to 10 cm) at the beginning of August 1973. Their pH was measured in H_2O and KCl solution, sodium exchangeable ions and the amount of assimilable phosphorus and potassium were determined in a flame photometer and by the method of Enger in Riehm's modification respectively.

Tussilago farfara was taken with the roots and the upper stolons (max. up to 50 cm), simultaneously with the soil samples, 10 specimens from each site. The plants were washed under tap water of soil and industrial dust and next the fresh leaves were separated from the roots and stolons. The material thus prepared was dried at room temperature, When dry, the leaves were pulverised separately, and the roots and stolons ground together. As samples weighed for chemical analysis were burned and the ash was dissolved in 5 ml of 25 per cent hydrochloric acid. Sodium and potassium were determined photometrically and phosphorus by the vanadate method.

The histochemical reactions to sodium were carried out with fresh leaves as well oas stolons and roots of *T. farfara*. As reagent uranyl acetate was used (4 g uranyl acetate in 100 cm^3 of water + 4 drops of acetic acid) which in reaction with sodium forms characteristic crystals in plant cells (Klein, 1932).

The specimens collected were also analyzed as regards their anatomical structure.

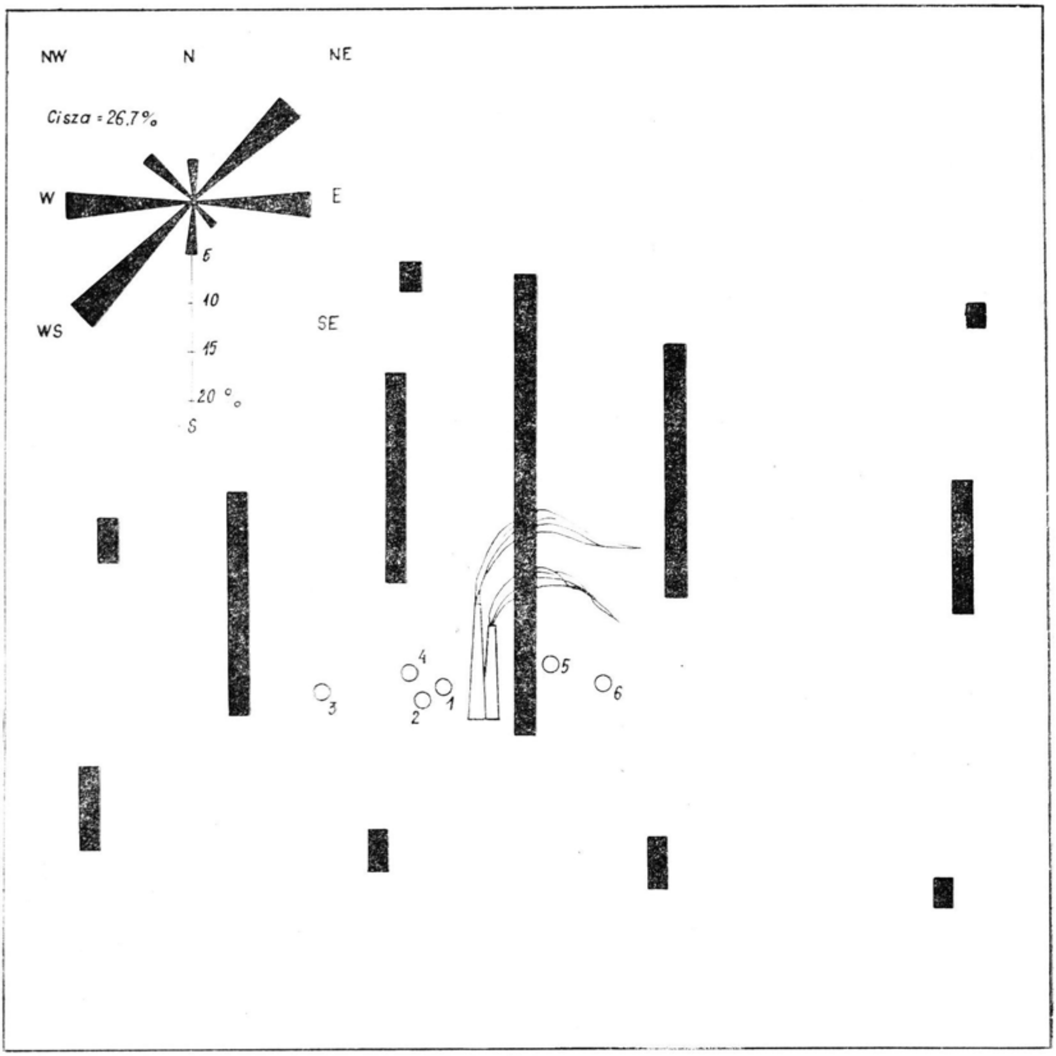

Fig. 1. Mean industrial dustfall in the period Aug. 1, 1970 to July 31, 1971. Circles denote *Tussilago farfara* L. sites in the vicinity of the silicophosphate fertilizers factory. In upper left corner wind rose for territory under study

RESULTS

a) The degree of dust contamination of the areas surrounding the silicophosphate fertilizers factory

In the period 1970—1971 the maximum value of dustfall in this area amounted to about 100 t/km^2. It was highest close to the chimneys and decreased with the distance (Fig. 1). The spatial distribution and range of contamination by dust were under the influence of the wind, its direction and velocity. As seen in Fig. 1, western winds (SW and W) prevail over east winds NE and E with rare north and south winds. Therefore, downfall of dust showed a wider range on the eastern side of the source of fumes.

b) Some properties of soil on the sites examined

The analysed soil samples consisted of clay and clayey sands, only in one case (site 6) there was a humus-mineral layer, developed on limestone (Table 1).

The pH soil in the surroundings of that factory was alkaline and amounted to 7.25—8.75 in H_2O and 7.10—8.20 in KCl solution. The pH was particularly high on sites 1, 5 and 6.

Na_2O content varied between 20 and 410 mg/100 g of soil, sodium accumulation being highest in medium and heavy clay and in the humus-mineral layer. The amount of available phosphorus is very high in all samples and reaches from 124.7 to 781.2 mg/100 g of soil. This is connected with the chemical composition of the emitted dust which contains a considerable per cent of phosphorus pentoxide. In most samples there also is relatively much of available potassium, from 41.7 to 50.9 mg/100 g of soil. Only the samples from sites 4 and 5 are poorer in this component, and contain 13 and 25 mg/100 g of soil respectively.

The soil of the control surface (situated 31 km from the factory chimneys) has an acid pH and its Na_2O, P_2O_5 and K_2O contents are very low as compared with the corresponding data concerning the samples from the close neighbourhood of the factory.

c) The content of sodium, phosphorus and potassium in the leaves and underground parts of *Tussilago farfara*

The amount of sodium in the leaves of this plant is 0.59 to 2.58 per cent (Table 2). The lowest value was recorded on site 4 where the lowest Na_2O content was established. This site is protected from dustfall by the residential house and the high tree. As compared with the soil of the control area, all the samples from the surroundings of the factory are richer in sodium.

Phosphorus content varies between 0.17 and 0.45 per cent. The highest content of this component is found in the leaves collected closest to the source of dust emission. In the leaves from more distant or protected places (site 4) the amount of phosphorus is much lower and close or equal to that in the samples from the control area.

Table 1

Some properties of soil samples taken from *Tussilago farfara* L. sites

Site	Distance from source of contamination	Situation in relation to source of contamination	Kind of soil according to PTG	pH		Na_2O	P_2O_5	K_2O
				H_2O	KCl	mg/100g of soil		
1	150 m	on western side	medium clay	8.65	8.20	410.0	630.0	45.6
2	250 m		clayey sand	7.25	7.10	63.3	417.5	41.7
3	650 m		heavy clay	7.70	7.25	138.6	124.7	48.4
4	300 m		light clay with considerable admixture of sand	7.55	7.30	20.0	143.8	25.0
5	300 m	on eastern side	clayey sand	8.75	7.70	41.4	745.0	13.0
6	500 m		humus-mineral layer	8.25	7.80	372.0	781.2	50.9
7	31 km	control area	light clay	5.60	5.25	0.7	4.0	5.0

Table 2

Na, P and K contents in leaves and underground parts of *Tussilago farfara* in per cent of dry mass

Site	Distance from contamination source	Situation in relation to contamination source	Leaves				Underground parts			
			Na	P	K	K:Na	Na	P	K	K:Na
1	150 m	on western side	1.89	0.37	5.17	2.73	1.67	0.38	2.02	1.21
2	250 m		1.51	0.32	6.44	4.26	1.37	0.38	1.67	1.22
3	650 m		1.77	0.17	3.83	2.16	0.37	0.29	1.35	3.65
4	300 m		0.59	0.20	2.93	4.96	0.39	0.28	1.39	3.56
5	300 m	on eastern side	1.41	0.37	5.10	3.61	0.85	0.52	1.36	1.60
6	500 m		2.58	0.45	2.75	1.06	1.10	0.76	1.24	1.13
7	31 km	control area	0.12	0.20	2.71	22.58	0.07	0.14	0.81	11.57

The potassium content in the material analysed shows a somewhat different state. It is the highest, and amounts to 3.83—6.44 per cent in the leaves of *T. farfara* from sites 1, 2, 3 and 5, while at 4 and 6 the content is similar to that found on the natural site. The low potassium content in sample 6, in which the highest percentual quantities of sodium and phosphorus were found, should be emphasized.

The K : Na ratio in the leaves varies from 1.06 to 4.96, and in the sample from the control area its value is much higher and reaches 22.58.

In the underground parts of *T. farfara* the sodium content lies within the range 0.37—1.67 per cent (site 1) with a very low Na content (barely 0.07%) in the control sample.

As regards phosphorus, the differences are less drastic and vary from 0.28 to 0.76 per cent P (site 6). As compared with the uncontaminated area, in which only 0.14 per cent P was noted, the values for samples 1—6 are in general more than two times higher.

The potassium content varies between 1.24 and 2.02 per cent the largest amounts appearing in the samples from sites 1 and 2. A relatively high K content (0.81%) was also obtained for the control area.

The K : Na ratio in the underground parts for samples 1—6 ranged from 1.13 to 3.65 and in sample 7 it was as high as 11.57. This high K:Na ratio both in the leaves and in the underground parts collected outside the area contaminated by the factory was due to the low sodium content in the analysed *T. farfara* samples.

d) Histochemical analysis

In the biochemical analysis positive reactions were only obtained for *T. farfara* specimens collected on site 1 situated closest to the source of emission.

The characteristic crystals of sodium compounds of tetrahedral structure forming under the influence of the reagent applied, were found in the parenchymal cells of the stolons. These crystals occur either singly, and then they are larger, or in groups of several specimens but of smaller dimensions (Fig. 2). On the other hand, in the leaves and roots of the same specimens such crystals have not been observed.

It should be stressed that on site 1 the soil showed the highest sodium content as compared with the other sites.

e) Anatomical structure of *Tussilago farfara*

The leaf blade of *T. farfara* has a distinctly dorsiventral structure (Metcalfe and Chalk, 1957). It is relatively thick and on the

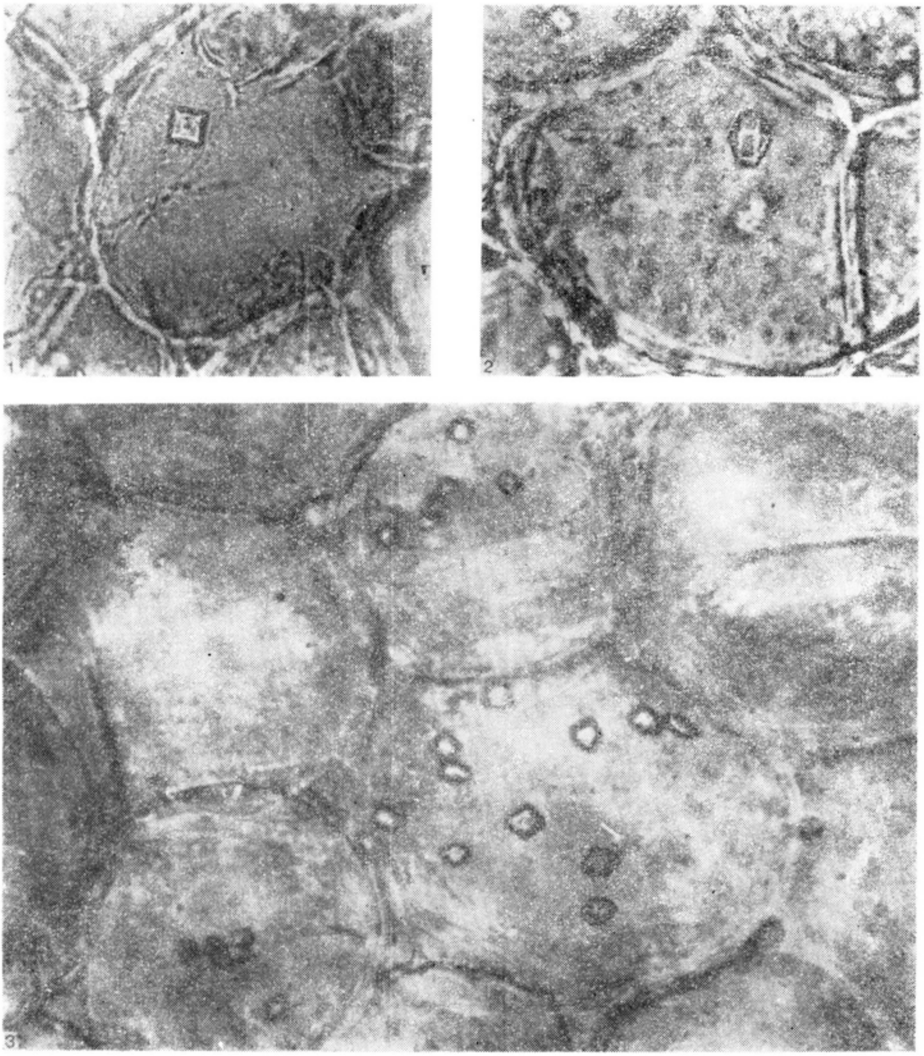

Fig. 2. Tetrahedric crystals formed in reaction of sodium with uranyl acetate in parenchyma cells of *Tussilago farfara* L. rhizomes. × ca. 500 (Photo by Z. Brunarska)

average amounts to ca 500 μ. The walls of upper epidermal cells are straight in outline, while those of the lower epidermal ones are undulated.

Numerous 2—5-cell flagellate clothing hairs grow out of the lower epidermis and form a dense weft. The stomata are distributed on both sides of the leaf blade but more frequently on the lower side.

The palisade parenchyma varies in thickness from 190 to 250 μ and usually consists of 3—4 typically elongated cell layers. The cells of the first layer are, however, distinctly shorter than the remaining ones.

The spongy parenchyma is fromed of two parts. The one lying immediately under the palisade parenchyma shows an arrangement and structure typical of the spongy parenchyma, the other situated on the side of the lower epidermis is characterized by very large intercellular spaces. The parenchyma cells are arranged here in rows forming one- and sometimes several-row "chains" joining the middle part of the mesophyll with the lower epidermis (Fig. 3).

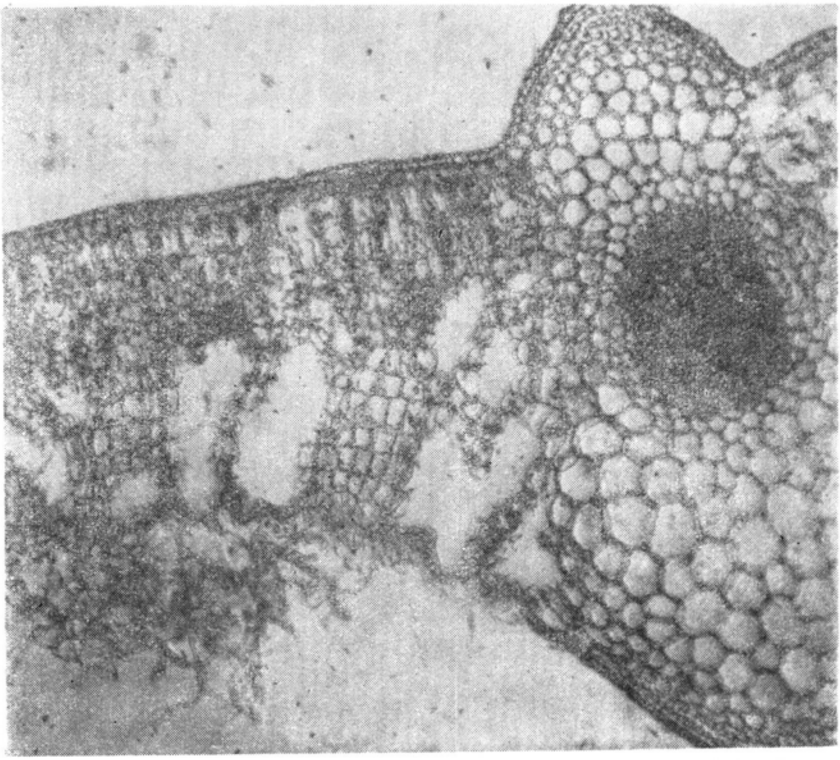

Fig. 3. Fragment of cross section of *Tussilago farfara* L. leaf from the region of the rib. x ca. 100 (Photo by Z. Brunarska)

In the leaf mesophyll, mostly within the rib, sporadic inulin sphero-crystals or single calcium oxalate druses were observed. The young leaves of *T. farfara* still covered with "spidery" hairs, as well as the leaves of the specimens from the control area showed no noticeable damage. The older leaves, however, derived from plants collected in the close vicinity of the silicophosphate fertilizers factory particularly from site 1, had minute brown spots well visible on the upper epidermis. About 80 per cent of these spots did not exceed 1.5 mm in diameter, and spots of larger dimensions were seen only sporadically.

The anatomical analysis of *Tussilago farfara* leaves has proved that necrosis is superficial as a rule, involves several or a dozen or so of the upper epidermal cells, and only in some cases several cells of the first row of the palisade parenchyma (Fig. 4). The dead cells show thickenings and changes in the colour of cell wall into brown.

In the anatomical structure of the petiole, stolons and roots of *T. farfara* no damage was observed nor any essential differences were seen in cell size as compared with the control plants.

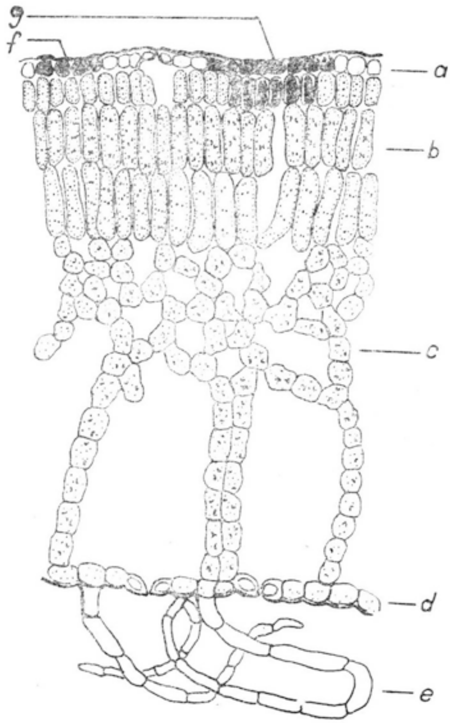

Fig. 4. Scheme of leaf structure of leaf centre of *Tussilago farfara*.

a — upper epidermis, *b* — palisade parenchyma
c — spongy parenchyma, *d* — lower epidermis, *e* — clothing hairs, *f* — upper epidermis damaged, *g* — damage reaching to first palisade parenchyma layer

T. farfara specimens from sites 1—6 did not show any inhibition of growth in spite of numerous minute necroses on the leaf blade, some of them, e.g. those from site 6, were even unusually spectacular. In this case, the vigorous growth of the plants was, among others, due to the large amount of P_2O_5 in the soil (781.2 mg/100 g of soil).

DISCUSSION OF RESULTS

The sites with *Tussilago farfara* in the surroundings of the silico-phosphate fertilizers factory lie in the zone of high industrial dustfall. The latter is not, however, evenly distributed. There are places protected by a building and depressions of the territory in which the effect of dustfall is much less marked, although they are situated close to the stacks. Hence, at a detailed soil and plant analysis the differences in the content of the main components of dust (sodium, phosphorus and potassium) depend not only on the distance from the stack, but also on the position of the site (open or protected).

The dust deposit on the area surrounding the factory changes the chemical properties of the soil increasing its alkalinity. The accumulation of sodium, phosphorus and potassium in the soil surface layer depends on the kind of soil. It is higher in clayey soil and in the root layer than in sand or light sandy clay.

The higher sodium and phosphorus content in the plant material analysed is usually connected with a high amount of these mineral components in the soil. In the case of potassium, however, such a dependence is not observed. Sodium and potassium are accumulated in *T. farfara* predominantly in the leaves and phosphorus in the underground parts.

As compared with the control area, the content of the components analysed is much higher in soil and plants which indicates a marked influence of the emission from the silicophosphate fertilizers factory.

The mean value of the K : Na ratio for the samples collected in the vicinity of the factory discussed was 3.23 and was lower than for instance in *Agropyron repens* analyses carried out on the same sites (Świeboda, Dąbrowska, 1975). In general, the K : Na ratio is greater in the salt-tolerant species than in the more sensitive ones. Norkrans and Kylin (1969) conclude that the resistance to a high salt content also depends on the ability of the given species to mobilize energy for dislodging sodium and taking up potassium ions.

The establishment of crystals of sodium compounds only in the stolons of *T. farfara* specimens collected on site 1 is associated with the highest content of sodium in the soil, i.e. with the high accumulation of this component in the plant organs studied.

Most sodium ions taken up by the plant roots return to them and are accumulated in cell vacuoles (Soloviev, 1967). According to this author, the mechanism regulating salt translocation in the plant is localized in the roots.

Thus, the presence of crystals of sodium compounds established only in specimens of *T. farfara* collected on site 1 would indicate that in this case, owing to the high amount of this component in the soil and its high concentration in the stolons, the regulating mechanisms failed and therefore the accumulated component crystallized under the action of the reagent applied.

The damage of older leaves which occurred in 1972, and was observed previously (Świeboda, 1970) was probably caused by the prolonged summer droughts owing to which large quantities of dust settled on the surface of leaf blades mostly oriented in horizontal plane. It also might have been caused by a short-lasting high emission of contaminants while dust collectors failed to operate.

The mosaic pattern of the necroses on leaves is due in general to the uneven dust and gas dispersion in the surroundings of the industrial plant. It may also be caused by an uneven uptake and transfer of nutrient components and noxious substances by the particular parts of the leaf, or by a non-uniform intensity of the physiological processes.

The necrotic spots observed on *T. farfara* leaves were not only limited to the surface layer of the leaf blade, which would indicate that they were caused by a chemical reaction occurring after the settling of dust particles containing soda, while gaseous substances mainly produce damage in the cells adjacent to the stomata (Brandt, 1962; Jamrich, 1964; Hajdúk, 1969).

The surface damage of the leaf blade observed in *T. farfara* affected only part of the cells of the upper epidermis and the first palisade parenchyma layer. The two deeper palisade cell layers and the spongy parenchyma responsible for photosynthesis functioned normally. Due to the thick mesophyll and characteristic leaf structure of *T. farfara*, damage of that type does not impede the process of assimilation, because light penetration is only slightly weakened. Thus, the anatomy of the leaf is one of the characters of this species which enables it to resist to the noxious influence of industrial dustfall.

A protective role is also played by the weft of clothing hairs densely distributed on the lower side of the leaf blade and the spidery hair covering both sides of young *T. farfara* leaves, which above all protect the stomata.

T. farfara is relatively much resistant to the fumes of the silicophosphate fertilizers factory. Nevertheless, on site 1, where a high pH of soil (pH in HCl solution = 8.2) and a high Na_2O content of 410 mg/100 g was found with simultaneous high phosphorus and potassium quantities in the soil, *T. farfara* appears in single specimens. On the other sites it still forms smaller or larger patches. Thus, the factor eliminating *T. farfara* from the site most exposed to contamination by factory dust is the high salt content in the soil.

T. farfara has been classified to the group of plants resistant to other kinds of industrial air pollution (Hajdúk, 1966; Niklfeld, 1967; Kaleta, 1970). Up till now, however, this was based on the lack of noticeable damage, whereas the internal properties of the plant were not considered. Therefore, it seems advisable to perform detailed investigations in the internal structure of plants, which could help to determine the ability of this species to survive under the changed ecological conditions of industrial areas. The knowledge of the adaptive mechanisms would allow a more correct choice of species for recultivation of these territories.

The present investigations lead to the following conclusions:

1. When taking soil and vegetation samples for investigation of the influence of industrial air pollution, not only the distance from the source of contamination should be taken into account, but also the situation of the locality. There are, namely, marked differences in the content of the noxious components in the soil and plants depending on whether the given site lies on an open space or is protected against noxious contamination.

2. *Tussilago farfara* in the vicinity of the silicophosphate fertilizers factory behaves like some facultative halophytes. However, if compared, for instance, with *Agropyron repens* it takes up much more sodium. Owing to this property the resistance of *T. farfara* is more limited and dependent on the level of sodium ion concentration in the edaphic environment and in the plant tissues.

3. A positive feature of *Tussilago farfara* influencing largely its resistance lies in the anatomical structure of the leaf blade ensuring protection to the assimilating parenchyma layer against damage caused by industrial dust and gases.

4. The use of histochemical analysis to detect sodium compounds in plant tissue gives good results only in the case of high concentration of these compounds. A lower sodium content cannot be revealed in plant material by this method.

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Podbiał pospolity Tussilago farfara L. jako roślina względnie odporna na przemysłowe zanieczyszczenia powietrza

Streszczenie

Badania przeprowadzono na okazach *Tussilago farfara* zebranych w otoczeniu fabryki supertomasyny oraz na stanowisku nie zagrożonym wpływem emisji tej fabryki.

Uzyskane dane, zestawione w tabelach wskazują, że na stanowiskach znajdujących się pod wpływem wysokiego opadu pyłów przemysłowych wzrasta zawartość sodu, fosforu oraz potasu w glebie i roślinach w porównaniu do powierzchni kontrolnej.

W wyniku zastosowania analizy histochemicznej stwierdzono w tkankach roślinnych obecność tetraedrycznych kryształów powstałych w reakcji sodu

z octanem uranylu. Kryształy związków sodu występują w komórkach miękiszowych kłączy okazów podbiału pospolitego zebranych ze stanowiska 1-go, najbardziej narażonego na wpływ emisji omawianej fabryki.

Analiza anatomiczna blaszki liściowej wykazała, że *Tussilago farfara* posiada charakterystyczną budowę wewnętrzną liścia. Warstwa miękiszu gąbczastego, w której przebiega proces fotosyntezy, zabezpieczona jest od góry trzema rzędami wydłużonych komórek miękiszu palisadowego, a od dołu warstwą parenchymy o dużych przestworach powietrznych. Ponadto spodnią stronę blaszki liściowej zabezpieczają liczne, kutnerowate włoski okrywające.

Tussilago farfara w otoczeniu fabryki supertomasyny wykazuje dużą żywotność i odporność na wpływ emisji przemysłowych, a zaobserwowane nekrozy na liściach starszych miały tylko charakter powierzchniowy. Uszkodzenie części komórek skórki górnej i pierwszej warstwy miękiszu palisadowego nie powodowało widocznych zakłóceń w rozwoju tej rośliny.