Phenological data concerning the influence of atmosphere pollutants on some species of woody plants

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Abstract: In this paper we have studied nineteen species of woody plants – gymnosperms and angiosperms, spontaneous and cultivated ones – in areas adjacent to industrial platforms: Borzeşti (Bacău county), Bicaz and Taşca (Neamț county), Romania. Our investigations have focused (during the period 2000 – 2007) on observations concerning species of ligneous plants in various phenophases and the state of the leaf surfaces under the influence of the atmosphere pollutants.

Key words: woody plants, atmosphere pollutants, defoliation, foliar surfaces (S.E.M.).

1 Introduction

It is not easy to find generalisations of a phenomenon connected with air pollution; the air pollutants, by their diversity, the particular atmosphere chemistry, the possible combinations with various compounds which result in new pollutants – often unknown ones – the multiple changes they undergo since the moment of their emission in the environment, the final state in which they interact with the vegetation, the way in which the species "respond" by metabolic and structural changes – whether morphologically manifested or not – are only a few of the aspects that we have tried to approach in this study (Il'Kun G.M., 1978; Smejkal G., 1982; Mănescu S. et al., 1994; Yunus M., Iqbal M., 1996; Kerstiens G., 1996; Bäck Jaana et al., 1997; Ivănescu L., C. Toma, 2003; Ivănescu L., M.M. Zamfirache, 2005; Ivănescu L., I. Gostin, 2007; I. Gostin, 2007).

The present study continues the series of investigations concerning the ill – fated effects of air pollutants from the industrialized areas of Moldavia upon the protective vegetation, hoping to make the proper authorities well aware of the importance of keeping, in the investigated areas, the normal natural life conditions.

2 Problem Formulation

We have studied nineteen species of ligneous plants – gymnosperms and angiosperms, spontaneous and cultivated ones – in areas adjacent to industrial platforms: Borzeşti (Bacău county), Bicaz and Taşca (Neamț county), Romania; in the first case, the noxious substances are mainly gaseous (sulphur dioxide, chlorine, ammoniac), but also solid (carbon black, soot); in the other two cases, the noxious substances are mainly solid ones (lime or cement powders prone to sedimentation).

Even if the pollutants involved are different by a chemical point of view, the fact that the three industrial centers are found in depression areas, the presence of the valley corridors and the air circulation along them, the thermic inversions, the precipitations, the considerable percentage of calmness contribute to the stability of the nucleus with the highest concentration over the vegetation along the valley corridors. That is the reason why the strongest impact between the noxious substances and the vegetation occurs in the areas adjacent to these industrial platforms.

2.1 Material and methods

Our investigations have focused (during the period 2000 – 2007) on observations concerning species of ligneous plants in various phenophases and the state of the leaf surfaces under the influence of the above-mentioned atmosphere pollutants.

The observations regarding the ligneous species have allowed us to notice the fact that, in most cases, they react to the pollutants no matter what their chemical nature is. Certainly, the "responses" are conditioned by a multitude of factors (genetic factors, pedo-climatic ones, natural habitat, degree of acclimatization, distance and position with regard

to the source of pollution, age, physiological state etc) and therefore will not be seen as absolute, but will only be reunited as data which will complete the clinical picture of the leaf symptomatology.
To examine the micromorphology of the leaves we have used the scanning electron microscopy methods: the leaf samples were dehydrated using physical methods, silver coated and analysed at the Tesla BS-340 scanning electron microscope. Microphotographs were taken from S.E.M.

3 Problem Solution

We shall now present a series of common situations of the investigated species, occurring as a general response to the action of (gaseous and solid) noxious industrial substances:
1. (more or less adherent) deposits of foreign substances – lime and cement dust, carbon black, soot – on the surface of the leaves of most species found in the perimeter of industrial sources.
These deposits change the reactivity of the leaf surfaces, make important photosynthetically active areas inactive, and prevent breathing and perspiration by closing the pore of the stomata. The impossibility of performing the photosynthesis leads to serious metabolic disorders – the absence of nutritious and reserve organic substances from the bodies of plants, leading to a general "starvation" of the individuals, which stop growing, flowering and fructifying.
All these effects, cumulated over time, only weaken the general state of the trees, thus making them more sensitive, more vulnerable to other types of aggression (late spring frost, defoliating insects, or pathogenic fungi).
However, the most obvious solid deposits remain those in the Bicaz and Taşca industrial areas; we mention again the fact that, in the case of some *Abies alba* individuals in the Bicaz area, these deposits cover approximately 80-95% of the leaf surface and also lead to the lowering of the branches and/or the shadowing of the inferior ones; the adherents crusts on the *Quercus robur* leaves in the Bicaz area make them breakable; because of the excessive deposits, the leaves of some *Populus nigra* individuals close to the cement factory at Taşca seem to be "lying" along the branches, so that the non covered portions cannot get light and are therefore photosynthetically inactive; the individuals of *Rosa canina* observed in the Bicaz and Taşca areas are sometimes unrecognizable because of the quantity of lime and cement dust on their surface.
2. episodes of partial defoliation (especially from June to August) noticed in the case of *Pinus sylvestris, Acer negundo, A. pseudoplatanus, Populus tremula, Salix fragilis* in the Borzeşti industrial area; *Pinus sylvestris, P. nigra, Abies alba, Picea abies, Juniperus communis, Quercus petraea, Q. robur* in the Bicaz and Taşca industrial areas.
3. total defoliation in the case of *Pinus sylvestris* – Borzeşti and Bicaz; *P. nigra* – Borzeşti and Bicaz; *Picea abies* – Bicaz; *Populus tremula* – Borzeşti and Taşca; *Aesculus hippocastanum* – Bicaz; *Salix fragilis* – Borzeşti.
The total or partial defoliation phenomena observed in many species in the middle of the vegetation season are the main causes of the slowing down of the growth of the individuals and often of the impossibility of the occurrence of viable fructifications.
We underline two important aspects connected to the general state of the leaves falling off branches: there are leaves which phenotypically present signs of "suffering" – necroses and/or chlorosis of variable sizes – and there are leaves which do not present any morphological symptom which would constitute a warning sign for possible defoliations.
In other words, there are individuals which stop growing and fructifying due to the visible deterioration of the photo-assimilating apparatus and there are individuals which die without ever having shown signs of illness. Such individuals are encountered in areas where the noxious substances are gaseous, but also in those where they are predominantly solid; it is true that the defoliation phenomena are more widespread in the areas where the pollutants are mainly gaseous, where they afflict a larger number of species and individuals, while in areas with solid pollutants, the phenomenon afflicts a smaller number of individuals, but an equal number of species.
Sometimes, the defoliation phenomenon presents particular sings: many needles of *Pinus sylvestris* individuals in the Borzeşti area, covered in a black crust (carbon black) which is non adherent after rain fall off with the microshoots due to a simple mechanical touch; the heavy defoliations observed in some *Juniperus communis* individuals found close to the Bicaz-Chei quarry have also been accompanied by the complete detachment of the branches with leaves from the trunk due to the excessive deposits of solid particles. Sometimes, during not very heavy rain, the crusts are detached together with the leaves.
The electronic microscopy researches (S.E.M) performed on the surfaces of leaves obtained from individuals which presented more or less important defoliations, as well as from individuals with leaf

chlorosis and/or necroses, have highlighted the definitely not negligible role the foreign deposits play in producing these phenomena.

The massive deposits of lime and cement dust on the surfaces of leaves in the gymnosperms (see Photos 1 – 7) investigated in the Bicaz area close the pore of the stomata, change the characteristic cuticular relief by disorganising the model of cuticular striations, change the proportion between the crystallised wax and the amorphous one, in favour of the latter, which may contribute to a certain extent to the closing of the pore, and favour the development of a micro-flora (fungi and algae) which, once in place, covers photosynthetically active and may release a series of toxic substances influencing the general state of the leaf.

Although some authors consider the presence of a micro-flora on the leaf surfaces to be normal, there are also opinions according to which its presence is a warning sign for important physiological disorders, which are not manifest phenotypically in time; therefore, this is another possible answer to the controversial problem of the massive defoliations of trees.

Similar, but less widespread phenomena have been observed on the leaves of ligneous gymnosperms in the Borzeşti industrial area; the soot and carbon black deposits are generally less adherent than those made of lime and cement, but they favour the settlement of a micro-flora made of "colonisers" in permanent competition among themselves.

Whatever the chemical nature of the noxious substance is, the settlement of this micro-flora is an indicator of the early senescence of the leaves and a possible cause of the defoliations occurring in the middle of the vegetation season. It is obvious that, the same as the leaf surfaces, this micro-flora is subject to the impact of the industrial noxious substances, which may inhibit or, on the contrary, stimulate its expansion.

The fact that we have only observed the presence of such a micro-flora on the leaf surfaces of individuals with various symptoms of disorders definitely caused by atmosphere pollutants allows us to place our study in the category of those which consider that its settlement on the leaves of individuals on which the noxious substances act systematically is "normal."

4. partial withering phenomena in *Pinus sylvestris*, *P. nigra, Acer pseudoplatanus, Salix fragilis* – Borzeşti; *Picea abies, Aesculus hippocastanum, Quercus petraea – Bicaz; Morus nigra* – Taşca.

5. total withering phenomena in *Pinus sylvestris, Populus tremula* – Borzeşti; *Abies alba, Picea abies* – Bicaz; *Populus tremula, P. nigra* – Taşca.

The partial withering may affect the top of the crown (*Pinus sylvestris, P. nigra, Salix fragilis* – Borzeşti; *Picea abies, Quercus petraea* – Bicaz), the basis of the crown (*Pinus sylvestris, Populus tremula, Acer pseudoplatanus, Salix fragilis* – Borzeşti; *Aesculus hippocastanum, Quercus robur* – Bicaz) or branches found at various levels of the crown (*Salix fragilis* – Borzeşti; *Quercus petraea, Q. robur* – Bicaz; *Morus nigra* – Taşca).

The withering phenomena may be preceded by episodes of defoliation or not; when there are visible signs of disorder (burns, necroses, chlorosis) on the surfaces of leaves, we may expect withering to occur in the near future.

A special situation occurs when individuals whose leaves were – at least apparently – healthy wither suddenly.

Conifers are regarded as the main victims of atmosphere pollution, as they are extremely specialised in extracting water from clouds and fog, out of which they absorb ions. Thus, it is not only acid rain, but also fog, dew and snow that are potential aggression factors.

6. smaller average length of the 1-year-old and 2-year-old acicular leaves of some species of conifers found in the vicinity of the sources of pollution.

7. small average surface of the leaves of some species of deciduous trees found in the vicinity of the sources of pollution.

The appearance of chloroses and necroses in the early stages of the development of leaves, the accumulation of physiological disorders due to nutrition deficiencies, the systematic aggression of the noxious substances, the existence of unfavourable stational factors have repercussions on the degree of development of the photo-assimilating apparatus of plants; the small average surface of the leaf (due to deposits and to necroses and/or chloroses) is the main cause of the "chronic starvation" of the individuals which stop growing, fructify more and more rarely and consume their own smaller and smaller organic reserves.

8. chlorosis, necroses and leaf burns of various sizes, with the aspect of dots, spots or bands, placed especially at the tip of the leaves (in the case of conifers, but also of some deciduous plants), on the brims of the lamina (more seldom at its basis), between the nervures (in the case of deciduous trees), on the adaxial or abaxial face (sometimes, bifacial).

In the case of the species of deciduous plants with leaf burns and necroses (*Aesculus hippocastanum, Acer negundo, A. pseudoplatanus, Populus tremula, Tilia tomentosa*), we have noticed changes of the general shape of the cells by their contraction due to

the absence of the state of turgescence, the quantitative decrease and even the absence of the epicuticular wax, and the presence of algal and fungal "colonisers" in extremely large numbers on the surfaces of leaves showing premature signs of senescence (full yellowing in the month of June).

The existence of partial or total defoliation phenomena with no phenotypisation by necroses and/or chlorosis doubtlessly constitutes a special aspect of the fact that, in the areas where the vegetation is subject to chronic aggressions from atmosphere pollutants, the responses are various, unexpected and cannot always be placed into clear categories, but rather in that of "possible responses." During our observations, it is not seldom that we contested the veracity of the chosen witness due to physiological or histo-anatomical changes observed on the investigated material, without the existence of any suspicion when the "phenological" observations were made.

9. rare foliage in *Pinus sylvestris, P. nigra* – Borzeşti, *Aesculus hippocastanum* – Bicaz, *Prunus domestica* – Taşca. The main causes are the defoliations, but also the general critical state of the individuals, which is worse every year, due to the cumulated effects of the action of the noxious substances over time.

10. the second sprouting during the same vegetation season after serious defoliation episodes (*Acer pseudoplatanus, Populus tremula* – Borzeşti).

11.disorders of the inflorescences, which become yellow-brown and fall shortly after they are formed (*Robinia pseudacacia* – Borzeşti) or become brown before the proper flowering and have a mucilaginous consistency (*Syringa vulgaris* – Bicaz).

12. disorders of the fructifications made manifest as large necroses in the shape of dots present on the surfaces of disameres in *Acer negundo* – Borzeşti; small size, brown-reddish colour, rapid deterioration at the mechanical touch (*Rosa canina* – Borzeşti); falling off the branches shortly after being formed (*Morus nigra* – Taşca); the absence of fructifications in successive years (*Robinia pseudacacia* – Borzeşti, *Syringa vulgaris* – Bicaz; most species of fruit-bearing trees).

4 Conclusion

Our investigations have focused (during the period 2000 – 2007) on observations concerning 19 species of woody plants in various phenophases and the state of the leaf surfaces under the influence of the atmosphere pollutants.

Certainly, the "responses" are conditioned by a multitude of factors (genetic factors, pedo-climatic ones, natural habitat, degree of acclimatization, distance and position with regard to the source of pollution, age, physiological state etc) and therefore will not be seen as absolute, but will only be reunited as data which will complete the clinical picture of the leaf symptomatology.

The common situations occurring as a general response to the action of (gaseous and solid) noxious industrial substances are: deposits of foreign substances – lime and cement dust, carbon black, soot – on the surface of the leaves; episodes of partial or total defoliation; partial or total withering phenomena; smaller average length and small average surface of the leaves; chlorosis, necroses and leaf burns of various sizes; rare foliage; the second sprouting during the same vegetation season after serious defoliation episodes; disorders of the inflorescences and disorders of the fructifications.

The electronic microscopy researches (S.E.M) performed on the surfaces of leaves obtained from individuals which presented more or less important defoliations, as well as from individuals with leaf chlorosis and/or necroses, have highlighted the definitely not negligible role the foreign deposits play in producing these phenomena.

References:

[1]Bäck J., Turunen M., Ferm A., Huttunen S., Needle structures and epiphytic microflora of Scots pine (Pinus sylvestris L.) under heavy ammonia deposition from fur farming, Water, Air and, Soil Pollution, vol. 100, 1997, pp. 119-132

[2]Gostin I., Biomarkeri structurali la plante, Ed. Univ. "Al.I.Cuza", Iaşi, 2007

[3]Il'Kun G. M., Zagriaziteli atmosfery i rasteniia. Naukova Dumka, Kiev, 1978

[4]Ionescu AL., Efectele biologice ale poluării mediului. Ed. Acad. R.S.R., Bucureşti, 1978.

[5]Ivanescu L., C. Toma, Influența poluării atmosferice asupra structurii plantelor, Ed. Fundației Andrei Şaguna, Constanța, 2003.

[6]Ivanescu L., M.M. Zamfirache, Some aspects concerning the reply reactions of some Gymnosperms to the action of solid industrial pollutants, in vol. „International Conference of modern management of Mine Producing, Geology and Environmental Protection", Albena, Bulgaria, 13-17 June, 2005, pp. 405-411.

[7]Ivanescu L., Gostin I., Cito-histological changes due to the action of atmosphere pollutants on three species of gymnosperms , International Journal of Energy and Environment, vol. 1, issue 2, 2007, pp. 95-100

[8]Kerstiens G., Plant cuticles, BIOS Scientific Publishers Ltd., Oxford, 1996.

[9]Manescu S., Cucu M., Diaconescu M. L., Chimia sanitară a mediului. Ed. Medicală, Bucureşti, 1994.

[10]Smejkal G., Pădurea şi poluarea industrială. Ed. Ceres, Bucureşti, 1982.

[11]Yunus M., Iqbal M., Plant response to air pollution, John Wiley & Sons, Chichester · New York · Brisbane · Toronto · Singapore, 1996

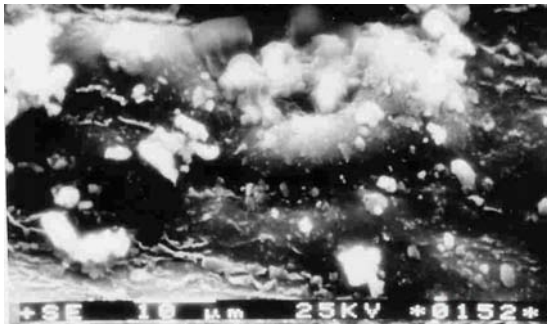
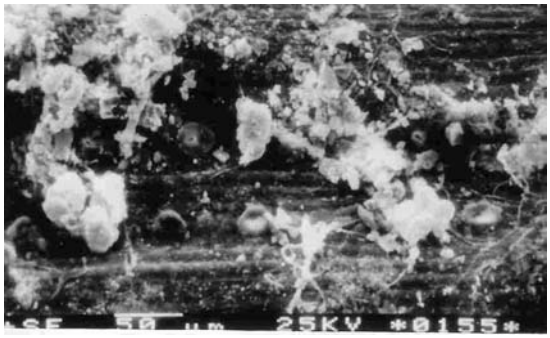


Photo 1. *Pinus sylvestris* – adaxial surface of the polluted needle



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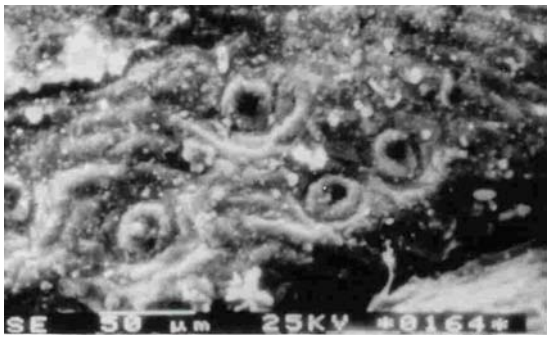

Photo 3. *Pinus sylvestris* – abaxial surface of the polluted needle

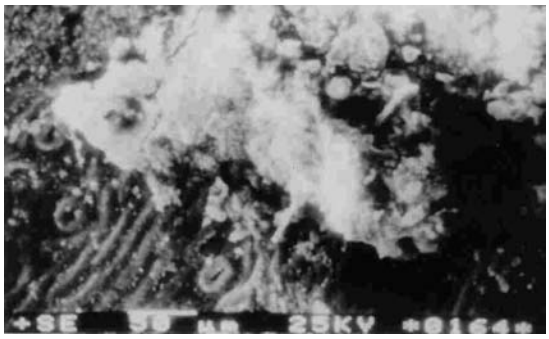

Photo 4. *Pinus sylvestris* – abaxial surface of the polluted needle

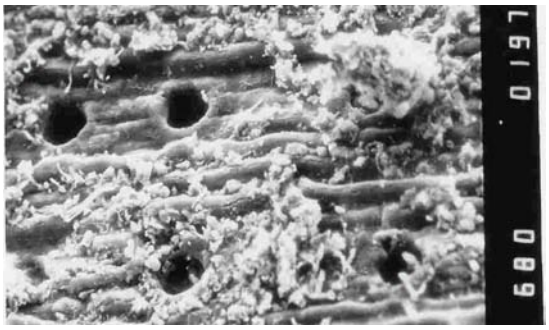

Photo 5. *Pinus nigra* – adaxial surface of the polluted needle

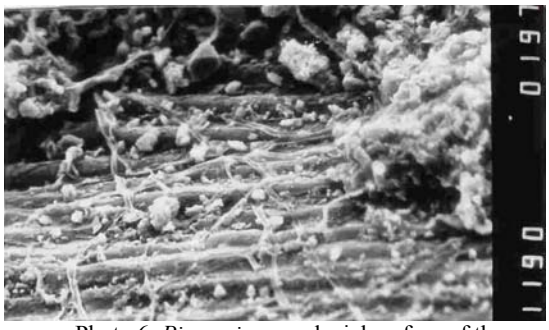

Photo 6. *Pinus nigra* – adaxial surface of the polluted needle

Photo 7. *Pinus nigra* – abaxial surface of the polluted needle