Researches regarding the physiological response induced by atmospheric pollutants on Gymnosperm species in the industrialized areas of Romania

Zenovia Olteanu, Maria-Magdalena Zamfirache and Lacramioara Ivanescu

***Abstract*— In this paper we studied the physiological reaction of the foliar photosynthetic apparatus for four different Gymnospermes species (Pinus nigra Arn., Pinus sylvestris L. Picea abies (L.) Karst. and Abies alba Mill.), coming from the outskirts of the Borzesti (Bacau county), Bicaz and Tasca (Neamt county) industrial platforms. In the studied areas the polluting agents are special from a physic point of view: in the first location are mostly gases (sulfur dioxide, chloride, ammoniac), and solid (black smoke, soot), and in the other two locations, mostly solid (sedimentation lime dust and cement). The placement of the three industrial centers in depression areas, along with other specific geographic characteristics, contribute to the stability of the pollution nucleus with maximal pollution agents concentrations on the vegetation on these platforms; these realities induce the most powerful impact between the pollution agents and vegetation, fact shown by specific functional disturbances of the foliar photosynthetic apparatus (the amount of assimilating pigments)

Keywords— gymnosperms, atmosphere pollutants; gaseous and solids noxious; the assimilating pigments content

I. Introduction

INDUSTRIAL pollution, by its scope and consequences on life, it is considered today one of the most important global problems of humankind. Practical, there is no country that doesn't have at least one industrial air, water or soil pollution source [3, 1]; the human civilization degree is appreciated today by the efforts that are made to protect and restore the surrounding environment, named in an economic, politic and scientific mode a natural capital [10].

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In this paper we try to accomplish a true analysis of the Gymnosperms forests in the areas situated at the outskirts of varied production industrial platforms (Borzeşti –Bacău country, Bicaz and Taşca –Neamț country), were we know the toxic action of some atmospheric polluting agents (sulfur dioxide, chloride, ammoniac, lime and cement dust, black smoke and soot) [4,5].

The observations on the species investigated in different phenophases, as well as laboratory investigations (morpho-anatomical, biochemical and physiological analyses) allowed us to make general remarks regarding the aggressively of different gas and solid pollution agents, the response reactions and their particularities for the Gymnosperms, as a time cumulative effect, as well as possible explications for the partial or total defoliation process and total dry up of the individuals in full vegetation season.

The coniferous plants are considered the principal victim of atmospheric pollution, because of their capability of extracting water from clouds and fog, which they use as a mineral ion source. In conclusion, not only acid rain but also fog, dew and snow represent potential aggression factors that affect mostly the photosynthetic apparatus [6,8].

The specialist literature shows that the modifications induced by atmospheric pollution agents (gases and solid), on the foliar lamina, can have biochemical, physiological and histo-anatomical manifestations, affecting mostly the protective, assimilating tissues (palisade and lacunose), conducting and mechanic. Some leafs have visible affections on all component tissues, and others only partial [2, 9, 4].

Even if the foliar exposed surface for the Gymnosperms is smaller than Angiosperms, the polluting agents modifications are in similar numbers; also gas pollution agents have a higher harming rate on vegetal tissues that the solid ones [5]; so, for example the very fine lime dust can sometimes produce modifications similar to gas pollution agents.

The results obtained by our own researches allows us to consider that the functional modifications induced by the pollution agents interests mostly the assimilating pigments amount, that have a wide variation for conifer plants, on component subtypes, according to the reaction type of each individual, reaction type that is determined genetically, by the nature of the pollution agent, the distance to the source and pedo-climatic conditions.

II. MATERIAL AND METHODS

The biological material we investigated consisted of one or two-year old leaves from four different species: *Pinus nigra* Arn., *Pinus sylvestris* L. *Picea abies* (L.) Karst. and *Abies alba* Mill. found within the surrounding area of Borzeşti (Bacău county), Bicaz and Taşca (Neamț county), Romania; in the first case, the noxious substances are mainly gaseous (sulfur 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). The vegetal material has been collected throughout the period 1996 – 2005, each year from the month of May, up until the end of the month of September, making at the same time site observation, in order to monitor the vegetation state around the polluting sources.

The research was done on fresh material: the dose of the content of foliar assimilating pigments with spectrophotometer method. For each physiological determination there were 3 different samples, processed simultaneous, the final dates representing the average of the results we obtained, expressed as multi annual average values.

III. RESULTS AND DISCUSSION

Our investigations on the average assimilating pigments amount in some Gymnosperms species, as a response to the pollution agents from the investigated industrial areas showed the following:

For a chlorophyll amount:

In Bicaz industrial area under the influence of solid pollution agents, the a chlorophyll average amount has registered in all situations, regardless of the distance to the pollution source, decreases compared to the control; the smallest values were always obtained for the plants situated the closest to the source.

For the one year leafs a "sensitivity scale" situates *Abies alba* on the first place (53,12% of the control), followed by *Picea abies* (61,42%), *Pinus sylvestris* (65,21%) and *Pinus nigra* (75,03%).

For the 2 years leafs, the smallest amount of a chlorophyll compared to the control is for *Picea abies* (60,86%), followed by *Abies alba* (63,93%), *Pinus nigra* (69,24%) and *Pinus sylvestris* (76,40%).

In Borzesti industrial area (Table 1), under the influence of gas pollution agents in special, the average amount of a chlorophyll is significantly smaller than the control, the most affected plants being, still, the closest to the pollution source.

For the one year leafs the smallest values are for *Pinus sylvestris* (42,63%), followed by *Pinus nigra* (51,73%).

For the 2 years leafs, the same sensitivity order is maintained as for the one year leafs: for *Pinus sylvestris*, with obvious suffering signs (chlorosis, necrosis, defoliation), this amount drops to 27,92%, and for *Pinus nigra* to 42,54%.

We notice the fact that in both cases of solid and gas pollution the amount of a chlorophyll, a pigment involved in photosynthesis drops significantly: this drop that occurs mostly from the first life year becomes more significant in the second one with or without morphological phenotipisation. Gas pollution agents remain the most aggressive ones because of their high solubility, favoring the opening degree of the stomata and the diffusion through cuticle pores. For both pollution agents kinds the impact on the vegetation in helped by adequate environment conditions (temperature, light, air and soil humidity), with the most important damage occurring in the middle of the day, when photosynthesis is maxim [7].

The dramatis drop of a chlorophyll prevents the accumulation of reserve substances in plants; the defoliations that may occur can be the result of some chronic absences of the organic substances, which translate into small dimensions of the photo assimilating organ for the polluted individuals, compared to the control.

For b chlorophyll amount:

Unlike a chlorophyll which constantly drops in the polluted leafs, the b chlorophyll (as the caroteniodic pigments) has extremely varied values compared to the control, values that cannot be always correlated to the distance to the polluting source; these variations consist of:

⊄Values smaller compared to the control: in the 1 year leafs (Bicaz) from *Picea abies* (99,14%), *Pinus nigra* (97,66%), *Pinus sylvestris* (96,54%), *Abies alba* (68,52%); in the 1 year leafs (Borze⬭ti) from *Pinus nigra* (92,63% şi 87,23%) and *Pinus sylvestris* (96,23% and 56,93%); in the 2 years leafs (Bicaz) from *Pinus sylvestris* (96,29%), *Picea abies* (88,69%), *Pinus nigra* (78,90%) and *Abies alba* (74,53%); in the 2 years leafs (Borze⬭ti) from *Pinus nigra* (81,70%) and *Pinus sylvestris* (47,32%).

⊄ Values slightly higher than the control: in the 1 year leafs (Bicaz) from *Pinus nigra* (107,70%), *Pinus sylvestris* (108,47%), *Picea abies* (109,94%), *Abies alba* (110,61%); in the 2 years leafs (Bicaz) from *Abies alba* (104,22%), *Pinus nigra* (105,37%), *Pinus sylvestris* (109,08%) and *Picea abies* (109,16%); in the 2 years leafs (Borze⬭ti) from *Pinus sylvestris* (109,26%).

⊄ Values significantly higher than the control: in the 1 year leafs (Bicaz) from *Abies alba* (143,14%), *Pinus sylvestris* (115,67%), *Picea abies* (114,12%), *Pinus nigra* (112,46%); in the 1 year leafs (Borze⬭ti) from *Pinus nigra* (167,43%), *Pinus sylvestris* (123,64%); in the 2 years leafs (Borze⬭ti) from *Pinus nigra* (153,47%) and *Pinus sylvestris* (142,36%).

We can notice that, except some situations, the Gymnosperms react to the polluting agent, regardless of the nature of the agent, extremely different for b chlorophyll; if we consider that the a chlorophyll has a low level, we can consider that every individual reacts in a personal mode to pollutant aggression, according to its genetic adaptability to extreme stress conditions. The fact that some individuals can respond in different modes, by increasing or decreasing its amount of b chlorophyll, we can conclude that there are numerous photosynthetic cell metabolism adapting possibilities in the presence of stressful factors, by the involving of the neosinthsys enzymes of this pigment.

We have a question mark for the "normal" reactions for the 2 years leafs of *Picea abies* with a b chlorophyll amount almost equal to the control (100,83%), the plant being located at 100 m from the pollution source; in the same mode the 1 and 2 years reaction of *Abies alba* (the plant closest to the pollution source), where the amount of b chlorophyll drops by 33% in the 1 year leafs (the control reading a minimal value in this period) and by 26% in the 2 years leafs, when the control reads almost maxim values.

In their turn the carotenoidic pigment responds to stress by:

- Values smaller compared to the control: in the 1 year leafs (Bicaz) from *Pinus nigra* (89,45%), *Abies alba* (80,29%), *Pinus sylvestris* (78,28%), *Picea abies* (80,58%); in the 1 year leafs (Borzeşti) from *Pinus nigra* (97,63%) and *Pinus sylvestris* (62,93%); in 2 years leafs (Bicaz) from *Abies alba* (97,57%), *Pinus sylvestris* (96,07%), *Picea abies* (84,8%) and *Pinus nigra* (76,5%); in the 2 years leafs (Borzeşti) from *Pinus nigra* (97,23%) and *Pinus sylvestris* (54,63%).
- Values slightly higher than the control: in the 1 year leafs (Bicaz) from *Pinus sylvestris* (101,78%), *Pinus nigra* (103,82%) and *Abies alba* (107,16%); in the 1 year leafs (Borzeşti) from *Pinus sylvestris* (101,35%) and *Pinus nigra* (107,11%); in the 2 years leafs (Bicaz) from *Pinus sylvestris* (103,26%), *Abies alba* (107,78%) and *Picea abies* (109,59%); in the 2 years leafs (Borzeşti) from *Pinus nigra* (106,22%) and *Pinus sylvestris* (109,54%).
- Values significantly higher than the control: in the 1 year leafs (Bicaz) from *Pinus sylvestris* (145,01%), *Abies alba* (143,14%) and *Picea abies* (130,04%); in the 1 year leafs (Borzeşti) from *Pinus sylvestris* (123,96%) and *Pinus nigra* (114,62%); in the 2 years leafs (Bicaz) from *Pinus sylvestris* (220,55%), *Picea abies* (198,61%), *Abies alba* (161, 42%) and *Pinus nigra* (147, 26%); in the 2 years leafs (Borzeşti) from *Pinus nigra* (127,93%) and *Pinus sylvestris* (126,36%).

We also mention that in the 2 years leafs of the individuals situated far from the source (Bicaz) of *Pinus nigra* (100,19%) and *Pinus sylvestris* (100,34%) the amount of caroteniodic pigments is almost identical to the level in the control.

The specialist literature shows, on one side the role of the carotenoidic pigments in the protection of the chlorophylls against photo oxidation, and, on the other hand, their resistance to the polluting agents; our investigations show that this resistance has a wide spread area of values from ones really close to the control to ones of great value, as reactions to the extreme conditions in which the analyzed plants are forced to live.

At the investigated material the situations where the distance to the pollution source is not important in the quantity drop pigments are very rare, and the situations where these pigments exceed a lot the control values are very common.

IV. CONCLUSIONS

By our results we confirm the data from the specialist literature [7], that confirm that unlike the gas polluting agents, the cement dust has no rapid toxic effect and does not produce a powerful harm in the vegetal tissues; a powerful harm is produce by the lime dust, which is very fine and has a high basically reaction, exceeding this way the negative action of the cement dust.

Both under the influence of the noxious solids and the gaseous substances the a chlorophyll medium content decreases considerably, in the leaves from the gymnosperms; compared to the values recorded in the control, the phenomena being often correlated to the distance to the polluting source. The most significant valor drops were found in the Borzesti area, fact that allows us to believe the gas pollution agents have a greater destructive effect, compared to the solid ones.

In the leaves of the investigated species, the b chlorophyll medium content reaches, in most cases, lower level against the control value; as far as the carotenoids are concerned, the Bicaz investigated species respond by foliar low values to the present noxious substances.

Additional investigations are necessary that shall deal with the pigments content in the control leaves throughout the entire vegetation period in order to be able to anticipate more accurately the possible ”responses” of the vegetation subject to chronic aggressions due to atmospheric pollutants.

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Table 1 The assimilating pigments content in leaves of Gymnosperms from Borzesti industrial area (mg/g fresh matter)

Taxon	Month	Distance from the toxic source	a chlorophyll				b chlorophyll				carotenoidic pigments			
			C.l	%	P.l.	%	C.l.	%	P.l	%	C.l	%	P.l	%
Pinus nigra	May	-250 m	0,3896*	100	0,2270*	58,27	0,1969*	100	0,1717*	87,23	0,2172*	100	0,2326*	107,11
		-700 m			0,2576*	66,14			0,1774*	90,14			0,2092*	96,35
		-000 m			0,3282*	84,25			0,1823*	92,63			0,2124*	97,83
		-250 m	0,7028♦	100	0,3069♦	43,67	0,2641♦	100	0,2157♦	81,70	0,2613♦	100	0,3125♦	119,63
		-700 m			0,5148♦	73,26			0,2198♦	83,26			0,2806♦	107,42
		-1000 m			0,5655♦	80,47			0,2349♦	88,98			0,2563♦	98,11
	Aug.	-250 m	0,5624*	100	0,2958*	52,61	0,1532*	100	0,2100*	137,11	0,1703*	100	0,1917*	112,62
		-700 m			0,3302*	58,73			0,1891*	123,47			0,1770*	103,94
		-1000 m			0,3950*	70,24			0,1718*	112,19			0,1708*	100,32
		-250 m	0,8372♦	100	0,4011♦	47,92	0,1719♦	100	0,2142♦	124,61	0,1940♦	100	0,2481♦	127,93
		-700 m			0,5966♦	71,27			0,2078♦	120,93			0,2117♦	109,15
		-1000 m			0,6626♦	79,15			0,2190♦	127,42			0,1886♦	97,23
	Sept.	-250 m	0,6027*	100	0,3117*	51,73	0,1723*	100	0,2883*	167,36	0,1519*	100	0,1741*	114,62
		-700 m			0,3566*	59,17			0,2307*	133,94			0,1816*	119,61
		-1000 m			0,4317*	71,63			0,1985*	115,23			0,1583*	104,27
		-250 m	0,8743♦	100	0,3719♦	42,54	0,1796♦	100	0,2756♦	153,47	0,2242♦	100	0,3097♦	138,15
		-700 m			0,6754♦	77,26			0,2104♦	117,19			0,2563♦	114,36
		-1000 m			0,6857♦	78,43			0,2180♦	121,39			0,2381♦	106,22
Pinus sylvestris	May	-350 m	0,3046*	100	0,1916*	62,91	0,1746*	100	0,2080*	119,14	0,1497*	100	0,1307*	87,35
		-800 m			0,2228*	73,15			0,2029*	116,23			0,1379*	92,16
		-1000 m			0,2688*	88,26			0,1699*	97,35			0,1418*	94,73
		-350 m	0,6726♦	100	0,2516♦	37,42	0,2486♦	100	0,3539♦	142,36	0,1960♦	100	0,2496♦	127,36
		-800 m			0,4849♦	72,10			0,3049♦	122,65			0,2277♦	116,19
		-1000 m			0,5807♦	86,35			0,2663♦	107,13			0,2052♦	104,72
	Aug.	-350 m	0,6093*	100	0,3145*	51,63	0,1620*	100	0,2002*	123,64	0,1649*	100	0,2044*	123,96
		-800 m			0,3915*	64,27			0,1905*	117,65			0,2063*	125,14
		-1000 m			0,5356*	87,92			0,1614*	99,64			0,1935*	117,36
		-350 m	0,8723♦	100	0,2739♦	31,40	0,1413♦	100	0,1939♦	137,26	0,1810♦	100	0,2273♦	125,62
		-800 m			0,6115♦	70,11			0,1702♦	120,47			0,2464♦	136,14
		-1000 m			0,6216♦	71,26			0,1442♦	102,11			0,1982♦	109,54
	Sept.	-350 m	0,6123*	100	0,2610*	42,63	0,1835*	100	0,1044*	56,93	0,1624*	100	0,1021*	62,93
		-800 m			0,3745*	61,17			0,1443*	78,64			0,1723*	106,14
		-1000 m			0,4921*	80,37			0,1765*	96,23			0,1645*	101,35
		-350 m	0,8865♦	100	0,2475♦	27,92	0,1736♦	100	0,0821♦	47,32	0,2038♦	100	0,1113♦	54,63
		-800 m			0,6318♦	71,27			0,1321♦	76,22			0,2199♦	107,92
		-1000 m			0,6238♦	70,37			0,1896♦	109,26			0,2132♦	104,62

C.l.= control leaves; P.l.= polluted leaves; *= 1 years old leaves; ♦ = 2 years old leaves

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Taxon	Month	Distance from the toxic source	a chlorophyll				b chlorophyll				carotenoidic pigments			
			C.l.	%	P.l.	%	C.l.	%	P.l.	%	C.l.	%	P.l.	%
Pinus nigra	May	–250 m	0,3896*	100	0,2270*	58,27	0,1969*	100	0,1717*	87,23	0,2172*	100	0,2326*	107,11
		–700 m			0,2576*	66,14			0,1774*	90,14			0,2092*	96,35
		–000 m			0,3282*	84,25			0,1823*	92,63			0,2124*	97,83
		–250 m	0,7028⊄	100	0,3069⊄	43,67	0,2641⊄	100	0,2157⊄	81,70	0,2613⊄	100	0,3125⊄	119,63
		–700 m			0,5148⊄	73,26			0,2198⊄	83,26			0,2806⊄	107,42
		–1000 m			0,5655⊄	80,47			0,2349⊄	88,98			0,2563⊄	98,11
	Aug.	–250 m	0,5624*	100	0,2958*	52,61	0,1532*	100	0,2100*	137,11	0,1703*	100	0,1917*	112,62
		–700 m			0,3302*	58,73			0,1891*	123,47			0,1770*	103,94
		–1000 m			0,3950*	70,24			0,1718*	112,19			0,1708*	100,32
		–250 m	0,8372⊄	100	0,4011⊄	47,92	0,1719⊄	100	0,2142⊄	124,61	0,1940⊄	100	0,2481⊄	127,93
		–700 m			0,5966⊄	71,27			0,2078⊄	120,93			0,2117⊄	109,15
		–1000 m			0,6626⊄	79,15			0,2190⊄	127,42			0,1886⊄	97,23
	Sept.	–250 m	0,6027*	100	0,3117*	51,73	0,1723*	100	0,2883*	167,36	0,1519*	100	0,1741*	114,62
		–700 m			0,3566*	59,17			0,2307*	133,94			0,1816*	119,61
		–1000 m			0,4317*	71,63			0,1985*	115,23			0,1583*	104,27
		–250 m	0,8743⊄	100	0,3719⊄	42,54	0,1796⊄	100	0,2756⊄	153,47	0,2242⊄	100	0,3097⊄	138,15
		–700 m			0,6754⊄	77,26			0,2104⊄	117,19			0,2563⊄	114,36
		–1000 m			0,6857⊄	78,43			0,2180⊄	121,39			0,2381⊄	106,22
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		–800 m			0,2228*	73,15			0,2029*	116,23			0,1379*	92,16
		–1000 m			0,2688*	88,26			0,1699*	97,35			0,1418*	94,73
		–350 m	0,6726⊄	100	0,2516⊄	37,42	0,2486⊄	100	0,3539⊄	142,36	0,1960⊄	100	0,2496⊄	127,36
		–800 m			0,4849⊄	72,10			0,3049⊄	122,65			0,2277⊄	116,19
		–1000 m			0,5807⊄	86,35			0,2663⊄	107,13			0,2052⊄	104,72
	Aug.	–350 m	0,6093*	100	0,3145*	51,63	0,1620*	100	0,2002*	123,64	0,1649*	100	0,2044*	123,96
		–800 m			0,3915*	64,27			0,1905*	117,65			0,2063*	125,14
		–1000 m			0,5356*	87,92			0,1614*	99,64			0,1935*	117,36
		–350 m	0,8723⊄	100	0,2739⊄	31,40	0,1413⊄	100	0,1939⊄	137,26	0,1810⊄	100	0,2273⊄	125,62
		–800 m			0,6115⊄	70,11			0,1702⊄	120,47			0,2464⊄	136,14
		–1000 m			0,6216⊄	71,26			0,1442⊄	102,11			0,1982⊄	109,54
	Sept.	–350 m	0,6123*	100	0,2610*	42,63	0,1835*	100	0,1044*	56,93	0,1624*	100	0,1021*	62,93
		–800 m			0,3745*	61,17			0,1443*	78,64			0,1723*	106,14
		–1000 m			0,4921*	80,37			0,1765*	96,23			0,1645*	101,35
		–350 m	0,8865⊄	100	0,2475⊄	27,92	0,1736⊄	100	0,0821⊄	47,32	0,2038⊄	100	0,1113⊄	54,63
		–800 m			0,6318⊄	71,27			0,1321⊄	76,22			0,2199⊄	107,92
		–1000 m			0,6238⊄	70,37			0,1896⊄	109,26			0,2132⊄	104,62

C.l.= control leaves; P l.= polluted leaves; * = 1 years old leaves; ⊄ = 2 years old leaves