Physiological modifications induced by atmospheric pollutants on Gymnosperm species in the industrialized areas of Romania

Maria-Magdalena Zamfirache, Lacramioara Ivanescu and Zenovia Olteanu

Abstract**—** In this paper we present the critical situation of some species of Gymnosperms (*Pinus nigra* Arn., *Pinus sylvestris* L. *Picea abies* (L.) Karst. and *Abies alba* Mill.) which can be found in areas of industrial zone from Borzesti, Bicaz and Tasca Districts, Romania. The pollutants are in the first location mainly gaseous (sulfur dioxide, chlorine, ammoniac), but also solid (carbon black, soot); in the other two locations, the noxious substances are mainly solid ones (lime or cement powders prone to sedimentation). Our investigation it is about the physiological modifications of the leaves (needles). We want to stress the fact that the large quantity of dry substance from the leaves isn't always related to the distance from the polluting source; moreover, this quantity is not directly related to the necroses which we can see on the leaves and that means that in some cases the changes of physiological functions is quickly followed by defoliations and withering and in other situations the defoliation occurs after the necroses occupy important areas of the foliar surface.

Keywords**—** gymnosperms, atmosphere pollutants, necroses, defoliations, dry matter content, water content

I. Introduction

THE specific literature records that the negative influence of atmospheric pollutants on the vegetation is revealed mainly by total or partial defoliation phenomenon, clorosys, foliar necrosis as well as different teratologic cases, especially in the species situated at the outskirts of different purification sources [3, 7, 2, 9, 8, 4, 6].

In our country, the vegetation pollution with solid agents from the cement, asbo-cement and lime factories, as well as super-phosphoric fertilizers industry, is very well known as a industrialization symptom in the areas of Bicaz, Valea Călugărească, Medgidia, Bârseşti – Tg. Jiu. According to the data published by Barbu N. and Lupaşcu Gh., 1974 [1], the dust eliminated from these factory chimneys contains CaO (42 – 45%), MgO (0,4 – 0,8 %), Si O_2 (12 – 14 %) , Al_2O_3 (3,5 – 4,5 %) and Fe_2O_3 (2 – 3,5 %), with calcinations loses of up to 34%. The authors present in this context the physic and geographical conditions that help the spread and deposit of the dust from these pollution sources, and show that a very important part in this process is played by the terrain configuration, atmospheric circulation and in some part the vegetal cover.

Our investigations were conducted around the functional behavior of the analyzed conifer plants in different phenophases, regarding their foliar surfaces, behavior induced by area specific polluting agents effect. In these research we started out from the idea present in literature [5], that states that beside the particular manifestations determined by different atmospheric polluting agents (gaseous or solid) and vegetation, there is a series of common manifestation for acicular leafs for the Gymnosperm species, as a general response to the stress induced by the pollution aggression, regardless of their chemical nature: partial or total defoliation; partial or total dry up episodes; greater or smaller length, compared to the selected controls; visible foliar chlorosis or necrosis.

Our results allow us to believe that foliar necrosis represent the clear materialization of some deep physiological modifications that affects the average water and dry substance amount; these variations do not necessary correlate to the nature of the polluting agent and/or the distance to the polluting source.

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 areas of Borzeşti (Bacău county), Bicaz and Taşca (Neamț county), Romania; in the first location, the noxious substances are mainly gaseous (sulfur dioxide, chlorine, ammoniac), but also solid (carbon black, soot); in the other two locations, 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.

The research was done on fresh material; the dosage of the water content and dry foliar substance was made with the

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gravimetrical method, of bringing the biologic material to a constant weight by drying up to 105^0C. 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. During this period of time we have conducted phenologic observations on the field, to follow up on the vegetation status around the pollution sources, as well as the new foliar necrosis and chlorosis rate.

III. RESULTS AND DISCUSSION

As a general response of the tested plants to the action of the industrial area specific pollution agents we can enumerate.

The presence of necrosis and chlorosis in the early leaf development stages for the analyzed plants (phenomenon that represents the accumulation of physiological "sufferance" because of different nutrition absence); pollution agents systemic aggression; the existence of different stationer negative factors that influence the development of the photoassimilating apparatus in plants; visible reduction of foliar surface (because of deposits, necrosis and/or chlorosis). All these manifestations represent the basic cause of "chronic starvation" of the individuals which do not grow up any more, do not fruit and use up their own diminishing organic reserves.

On the one year *Pinus sylvestris* leafs the affected portions occupy from 35% (Borzeşti) up to 61% (Bicaz) from the average length; on the 2 years leafs up to 80% (Borzeşti) or 85% (Bicaz).

On the one year *Pinus nigra* leafs, the affected portions occupy up to 55% from the average length (Borzeşti) and are hardly noticeable for the individuals from Bicaz despite the lime and cement deposits; on the 2 years leafs the occupation degree is up to 90% (Borzeşti).

On the 2 years *Abies alba* leafs in the Bicaz area, the affected portions occupy up to 16%; the relatively small percentage of chlorosis or necrosis on the fir trees may be explained by the pectinic displacement of the leafs, fact that allows the rain water to wash off the deposits more easily, preventing the formation of $Ca(OH)_2$ (from the reaction between lime and water), that produce usually severe burns to the leaf.

Foliar necrosis is the clear proof of some profound physiologic alterations that affect the water amount and the dry substance amount.

From the Gimnosperm species we investigated in the Borzesti area (**Table 1**) the most affected is the *Pinus sylvestris* (with over 25% of dry substance amount in the 1 year leafs and over 97% in the 2 years leafs), while in *Pinus nigra* this amount exceeds the control by 6% in the one year leafs and by 23% in the 2 years leafs.

On the analyzed material we can conclude that *Pinus sylvestris* is sensitive especially to gas pollution (SO_2, chloride, ammoniac) and in some part to sod pollutions (lime dust and cement). The one year leafs are more sensitive to gas pollution, while the 2 years leafs are sensitive to both gas and solid pollution agents (we believe because of the chronic exposure to polluting factors).

At the Bicaz investigated Gymnosperms plants (**Table 2**) the highest amount of dry substance in the one year leafs is at the *Picea abies* (over 76% compared to the control), than is *Pinus nigra* (over 28%), *Abies alba* (over 18%) and *Pinus sylvestris* (over 12%).

In the 2 years leafs the highest amount of dry substance is still at the *Picea abies* (over 68% compared to the control), followed by *Pinus sylvestris* (over 46,4%), *Pinus nigra* (over 31%) and *Abies alba* (over 17%).

We underline the fact that not always the dry substance amount is related to the distance to the pollution source; also this amount is not always related to the macroscopic visible necrosis, which means that in some cases that the alteration of some physiological functions is followed by defoliation and drying, and in other cases the defoliations occur after the phenotipizant necrosis occupy important surfaces that they restrict from photosynthetic activity.

The decrease of the water amount, combined with the increase of dry substance amount, can be correlated to the close-open stomat mechanism gaming; in our electronic microscopy investigations (S.E.M.) we evidenced ostiols obliterated with solid deposits or amorphous wax, or wide open ostiols. In other words, beside the alteration of the metabolism, we noticed that one of the most important ways for the plant to lose water by perspiration is affected. The solid deposits, especially lime and cement affect the cuticle perspiration, ant this associated with foliar surface "microscopic colonizing individuals" affects perspiration, respiration, and photosynthesis.

The presence of partial or total defoliation processes, without fenotipization by necrosis or chlorosis, is a clear demonstration of the fact that in the areas were the vegetation in constantly subjected to chronic aggression from atmospheric pollution agents, the responses are different, unexpected, and cannot be always included in the precise response category but in the "probable response" one. In this context we inform the throughout our investigations we have frequently contested the accuracy of the control, because of physiologic or hysto-anatomic changes that took place in the investigated material, with no suspicion in the moment when the phenologic observations took place.

IV. CONCLUSIONS

At a pollution agent aggression, regardless of their nature, the responses can be very different but also alike. If initially, the physiological and biochemical modifications are not profound and disappear when the agent is eliminated, after a chronic exposure, these modifications become irreversible, preceding the following hysto-anatomic alterations.

The foliar chloroses and the necroses represent the distinctive materialization of deep physiological alterations that affect the water and dry substance medium content. We outline the fact that not always the high dry substance content in the leaves is correlated with the distance to the polluting source. At the same time, not always this content is directly correlated to the microscopically visible necroses, which means that in certain cases the disturbance of some physiological functions is straightly followed by defoliation and drying and in other situations the defoliation appear after the phonotypical necroses have occupied important portions within the foliar surface.

In the analysis of the plant response reactions to pollution agents we cannot generalize any of the observed reaction; there is no uniformity not even for individuals from the same specie, not to mention individuals from different species, or families. The responses are individual; because of that the pollution impact studies on the vegetation should consist of a large range of investigations for each individual in an investigated perimeter.

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Table 1 - The water content and dry matter from leaves of Gymnosperms from Borzesti industrial area (g%)

Month	Taxon	Control leaves (C) 1	Control leaves (C) 2	Distance from the toxic source	Polluted leaves 1	Polluted leaves %C	Polluted leaves 2	Polluted leaves %C
May	*Pinus nigra*	68,26°	31,74°	-250 m	66,30°	97,12	33,70°	106,17
				-1000 m	68,14°	99,82	31,86°	100,37
		65,08*	34,92*	-250m	65,74*	101,01	34,26*	98,10
				-1000m	64,93*	99,76	35,07*	100,42
	Pinus sylvestris	63,84°	36,16°	-350m	61,39°	96,16	38,61°	106,77
				-1000m	62,81°	98,38	37,19°	102,84
		62,48*	37,52*	-350m	60,36*	96,60	39,64*	105,65
				-1000m	59,89*	95,85	40,11*	106,90
Aug.	*Pinus nigra*	66,26°	33,74°	-250m	69,38°	104,70	30,62°	90,75
				-1000m	68,53°	103,42	31,47°	93,27
		63,09*	36,91*	-250m	62,84*	99,60	37,16*	100,67
				-1000m	60,37*	95,68	39,63*	107,36
	Pinus sylvestris	64,53°	35,47°	-350m	56,14°	86,99	43,86°	123,65
				-1000m	60,46°	93,69	39,54°	111,47
		63,22*	36,78*	-350m	33,73*	53,35	66,27*	180,17
				-1000m	58,83*	93,05	41,17*	111,93
Sept.	*Pinus nigra*	65,93°	34,07°	-250m	65,22°	98,92	34,78°	102,08
				-1000m	64,32°	97,55	35,68°	104,72
		64,27*	35,73*	-250m	55,74*	86,72	44,26*	123,87
				-1000m	58,46*	90,96	41,54*	116,26
	Pinus sylvestris	64,84°	35,16°	-350m	55,91°	86,22	44,09°	125,39
				-1000m	59,36°	91,54	40,64°	115,58
		65,74*	34,26*	-350m	32,17*	48,93	67,83*	197,98
				-1000m	57,39*	88,11	42,61*	124,37

1 = watter content; 2 = dry matter content (105° C);
*= 1- years old leaves; *=2- years old leaves

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				–1000m	57,39$^{\not\subset}$	88,11	42,61$^{\not\subset}$	124,37

1 = watter content; 2 = dry matter content (105EC);

* = 1- years old leaves; $^{\not\subset}$=2- years old leaves