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Investigations on the Vegetal Carpet Developed on Navodari Phosphogypsum Dump After Six Vegetation Cycles (1998-2003)

I. LAZAR, B. A. STERIAN
University of Agronomic Sciences and Veterinary Medicine, Faculty of Biotechnology,
59 Marasti Avenue, 71331, Bucharest, Romania

Abstract

During the period February 1997 – July 1999 an INCO-COPERNICUS PROJECT has been under progress, funded by European Community, with partners from Greece, England, Romania and Bulgaria. The objective of the project was preventing of the Black Sea pollution by heavy metals and radionuclids. There were three case studies for Romania: phosphogypsum dumps and burnt pyrites from Navodari and the dumps resulted after polymetal ore processing from Baia and Somova-Tulcea. After laboratory and glasshouse researches, there was initiated a field experiment on Navodari phosphogypsum dump with a view to developing a vegetal covering carpet which can prevent the environment pollution and even the Black Sea pollution. This paper presents the situation of the evolution of this vegetal covering carpet, after six vegetation cycles (1998-2003).

Keywords*:* vegetal covering carpet, phytoremediation, bioremediation

Introduction

The intensive mining activities during the last 55 years in some regions from the Romanian seaside have generated millions of tones of tailings, stored in dumps, approximately 2-4 millions for each dump and about 5-10 hectares and 30 meters height for each area. The tailings contain high concentrations of heavy metals in mobile forms. For example, the Chemical Combine from Navodari have produced in the last 50-55 years about 4 000 000 m^3 phosphogypsum, stored in 3 dumps.

Under the action of the physical, chemical and biological factors the dumps have represented severe sources of pollution of the environment. This region is important from the viewpoint of ecological and tourist aspects, so starting with 1997 the European Community funded a research project concerning this area.

After a complex geological, mineralogical, climatological, chemical, microbiological, ecological and risk assessment study of the three cases study mentioned above it was established that they are severe pollution sources including for Black Sea. On the base of this complex study the four partners of Project concluded that in the first step investigations for developing a vegetation cover on dumps are needed.

Glasshouse experiments allowed to be selected as tolerant to toxic elements from Navodari phosphogypsum dump at least 6 herbaceous species and 6 bushes/arbors species.

During the first two vegetative cycles (April 1998-November 1999) there were carried out observation concerning plant intensity growth, metallic ions uptake in plant biomass, the chemical evolution of the tailing plus some additives and enzymological and microbiological analyses. The best behavior was noticed for variants 2 and 3, namely those with amendments addition such as dolomite, caoline and fermented sewage sludge.

Agropyron repens, Hierochloe repens, Bromus inermis, Cynodon dactylon (herbaceous species) and *Ailanthus altissima, Acer negundo Robinia pseudacacia, Eleagnus augustifolia* (bushes/arbors) have proved to be the most suitable for development of a vegetative cover on phosphogypsum dumps.

The aim of this work is to find in which measure the species become tolerant and good developed in the previous 2 vegetative cycles continue the good behavior in the next 3-4 vegetative cycles.

Materials and Methods

In (**Figure 1**) There are presented the four experimental variants, with 24 parcels of each variant and the herbaceous and bushes/arbors species planted or seeded. Plantation activity using nursery transplant was made in April 1998 and seeded activity using the seeds more or less of the same planted species has been made in September-October 1998, according to the details mentioned in figure 1.

The research was restarted in 2003, after the personal observations made personal by one of the authors (PhD Professor Ioan Lazar) in 2000, 2001 and 2002. There were made only botanical measurements concerning herbaceous species' height growth and the growth force under the aspect of number of branches, length of branches and height of bushes/arbors.

Results and Discussions

There is presented in (**Table 1**) the evolution of the plants starting from nursery transplant for all variants. In (**Table 2**) it is presented by analogy the evolution of the plants starting from seeds.

In the first two vegetative cycles (1998-1999), the herbaceous species from the first variant have a surprising good rise, but beginning on the third cycle the development was slower, especially for *Agropyron repens, Hierochloe repens, Bromus inermis* and *Cynodon dactylon* (for the planted species). The results were average starting with seeds, except *Bromus inermis* and *Bromus tectorum.* Regarding bushes/arbors species, the results are interesting and edifying for: *Ailanthus altissima, Acer negundo* and *Robinia pseudacacia,* but only when it was used the nursery transplant, which is a well-known practice in horticulture. The orchard does not started from the seeds.

Concerning the second variant, the results was excellent for the herbaceous species, because in the two special analyzed years and so in the next four years, the plants have looked vigorously, with a good intensity of development. This situation is only for the 6 herbaceous species, which start from nursery transplant. In the case of seeds' starting the results are good only for *Agropyron repens, Bromus inermis* and *Bromus tectorum. Artemisia absinthium* has a good grown on the parcel of this variant, which have proved to be tolerant at phosphogypsum with some amendments substrate.For arbors, the results are excellent, in the case of nursery transplant for: *Ailanthus altissima, Acer negundo Robinia pseudacacia* and *Eleagnus augustifolia.* They can be used to consolidate the slopes of the dumps. Regarding the parcels starting from seed, the situation is not the same. There are valid the same commentaries from the first variant, respective it has to be used only seedling, brought from the areas where they grow spontaneously or from special organized orchards. As we can see from the table 4, there

were replanted some seedlings, but the results wasn't always very good. That's happened because there wasn't enough irrigations after the second vegetative cycle to compensate the lack of humidity from the slopes of the dumps, which it is necessary to consolidate the roots of the arbors.

As far as the third variant is concerned the results are similar with those from the second variant. A very good development has again *Agropyron repens, Bromus inermis, Hierochloe repens.* These results prove the good development of the plants on the phosphogypsum dump when it was used some amendments (sewage sludge) and when the pH was at least 4.5 and when there was intensive irrigation on the dump.

Finally, concerning the fourth variant the results are almost identical with those established in the case of the second and the third variants. The fourth variant hasn't a good perspective for future, because the costs are at least 2-3 times higher than those for the second and third variants. The prices for the fourth variant are due to obtaining, supply and manipulation of the soil.

Concerning herbaceous species' height growth**,** there were made annual height growth observations in
the first two years (1998-1999) and in the last four years (2000-2003) too. It is presented in (**Table 3**) the growth on an average for the periods mentioned above. Also it is presented the data from the botany literature for each of the six species. From many times the heights of the plants from the experimental field belong to those from the literature. In some cases, the heights are even bigger than those from literature.

In (**Table 4**), there are presented some observations of the plants' growth under the aspect of number of branches, length of branches (cm) and height of bushes/arbors (cm) for three of the most representative species: *Ailanthus altissima, Robinia pseudacacia* and *Eleagnus augustifolia.* The results have proved that the growth force of these three species in the last four years (2000-2003) is better than the growth in the first two years. This finding confirms and sustains the idea that these species have adjusted at phosphogypsum substrate with some additives and have continued to grow better from one year to another.

Conclusions

The herbaceous species and the bushes/arbors from the four variants of the experimental fields have behaved as good as they behaved in the initial period which intensify the idea that the experiment is a success.

Using of some amendments, which can allow the plants' development, have proved to be 2-3 times cheaper than using a coat of soil cap on the whole surface of each parcels.

Among the herbaceous species tested the best development has: *Agropyron repens, Bromus inermis* and *Hierochloe repens* so any of these can be recommended to be used at the scale of the entire surface. The bushes/arbors with the best development are*: Ailanthus altissima, Robinia pseudacacia* and *Eleagnus augustifolia* and can be used at an industrial level. Before taking a decision about the extension of the vegetative cover on whole surface of the dump it is necessary to test some variants with seeds from the sewage sludge, in order to prove the role that this plants can play.

The results provided by this experiment represent a support for the idea that tailings, especially phosphogypsum dumps can be cover with vegetative carpet, which can stop the erosion due to winds and precipitations and offer a pleasant landscape.

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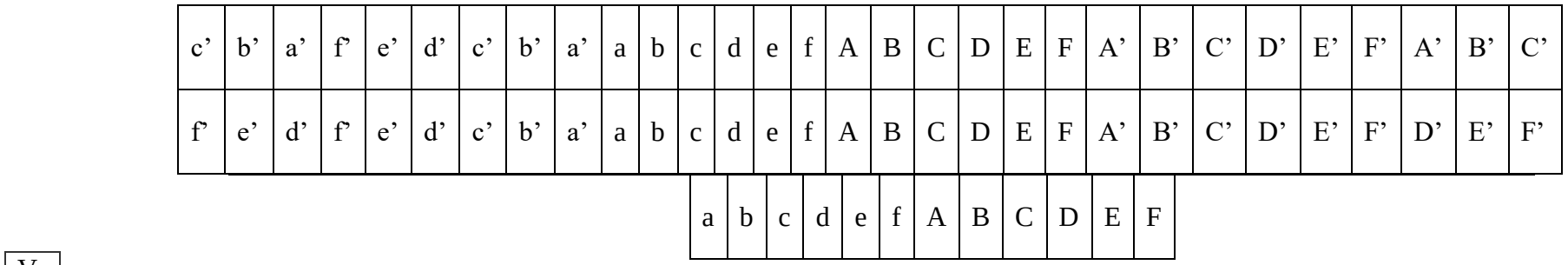

V_1 PG

V_2 PG+D+C+SS

V_3 PG+SS

V_4 PG+SC

a - f herbaceous species planted on April 8 – 9, 1998
A- F bushes / arbors species planted on April 8 –9, 1998
a’- f’ herbaceous species sowed on Oct. 1 –2, 1998
A’- F’ bushes / arbors species sowed on Nov. 12, 1998

PG – Phosphogypsum
D – Dolomite SS – Sewage sludge
C – Caolin SC – Soil cap

a = *Agropyron repens* a’ = *Agropyron repens* A = *Acer negundo* A’ = *Acer negundo*
b = *Hierochloe repens* b’ = *Bromus inermis* B = *Ailanthus altissima* B’ = *Ailanthus altissima*
c = *Bromus inermis* c’ = *Bromus tectorum* C = *Robinia pseudacacia* C’= *Robinia pseudacacia*
d = *Cynodom dactylon* d’ = *Cynodom dactylon* D = *Hippophae rhamnoides* D’ = *Hippophae rhamnoides*
e = *Agropyron repens* (from dump) e’ = *Artemisia absinthium* E = *Populus* (alba, nigra) E’ = *Eleagnus angustifolia* *Ligustrum vulgarae*
f = *Galium humifusum* f’ = *Dichanthium ischaemum* F = *Eleagnus angustifolia* F’ = *Amorpha fructicosa*

Figure 1. *Field experiment – Navodari phosphogypsum dump*

Table 1. The evolution of vegetative carpet in field experiments from phosphogypsum dump (Navodari- Constanta) (starting from nursery transplant and seedlings - April 1998).

Variant*	The year $1^{st} \rightarrow 6^{th}$ vegetative cycle *	Type of plant species *	The species *					
1	1998-2003	I Herbaceous species	a +++ → +++	b +++ → +++	c +++ → +++	d ++++ → +++	e ++++ → +++	f +++ → ++
		II Wooden species	A ++++ → +++	B ++++ → ++	C +++ → +++	D ++ → -	E ++ → ±	F + → -
2	1998-2003	I Herbaceous species	+++++ → ++++	+++++ → +++++	+++++ → +++++	++++ → ++++	+++++ → ++++	++++ → ++++
		II Wooden species	++++ → ++++	++++ → +++++	++++ → ++++	+++ → +++	+++ → +++	++++ → ++++
3	1998-2003	I Herbaceous species	+++++ → +++++	+++++ → +++++	+++++ → +++++	++++ → ++	+++++ → +++++	++++ → ++++
		II Wooden species	+++++ → ++++	++++ → ++++	++++ → ++++	+++ → -	+ → +	+++++ → +++++
4	1998-2003	I Herbaceous species	++++ → ++++	++++ → ++++	+++++ → ++++	++++ → ++	++++ → +++++	++++ → +++++
		II Wooden species	++++ → ++++	++++ → +++++	++++ → +++++	++++ → +	++ → ++++	++++ → +++

Legend: - ± → +++++ = Intensity of growth and vigorousity of plant
- * See the scheme from Fig. 1.

Table 2. The evolution of vegetative carpet in field experiments from phosphogypsum dump (Navodari- Constanta) (starting from seeds - October 1998).

Variant *	The year $1^{st} \rightarrow 6^{th}$ vegetative cycle *	Type of plant species *	The species *					
1	1998-2003	I Herbaceous species	a′ + → +	b′ +++ → ++	c′ +++ → ++	d′ - → -	e′ + → ±	f′ + → -
		II Wooden species	A′ +++ → ++	B′ ++ → -	C′ +++ → -	D′ - → -	E′ - → -	F′ + → -
2	1998-2003	I Herbaceous species	+++ → ++	++++ → ++++	++++ → +++	++ → +	++ → +	+ → +
		II Wooden species	+ → ++	+ → +	+ → +++	+++ → +	- → +	+++ → +++
3	1998-2003	I Herbaceous species	+++ → ++	++++ → +++	++++ → ++++	++ → ++	++ → -	- → -
		II Wooden species	+++ → +++	+++ → +++	+++ → +++	- → -	- → -	+++ → +++
4	1998-2003	I Herbaceous species	++ → ++	+ → +	+++++ → +++++	- → -	- → -	- → -
		II Wooden species	+ → +	- → -	- → -	- → -	- → -	- → -

Legend: - ± → +++++ = Intensity of growth and vigorousity of plant
- * See the scheme from Fig. 1

Table 3. Herbaceous species' height growth in 1998-2003

The variant	The period (on an average)	Height growth (cm) from some species (on an average)					
		Agropyron repens	*Hierochloe repens*	*Bromus inermis*	*Cynodon dactylon*	*Artemisia absinthium*	*Galium humifusum*
V1	1998-1999	30 – 40	25 – 35	30 – 50	24 – 30	50 – 55	25 – 38
	2000-2003	40 – 49	30 – 35	41 – 65	30 – 35	56 – 60	30 – 48
V2	1998-1999	40 – 63	40 – 44	50 – 70	38 – 40	65 – 75	40 – 55
	2000-2003	60 – 81	43 – 85	70 – 98	42 – 45	70 – 98	60 – 85
V3	1998-1999	37 – 65	50 – 75	70 – 86	35 – 45	62 – 72	32 – 46
	2000-2003	60 – 72	56 – 87	85 – 96	37 – 51	70 – 95	36 – 51
V4	1998-1999	55 – 70	40 – 45	65 – 75	38 – 43	60 – 65	29 – 38
	2000-2003	66 – 89	45 – 56	75 – 115	40 – 47	70 – 90	34 – 48
Dimensions (in normal conditions)	Dimensions (from the botany literature)	20 –150	20 – 60	30 – 150	10 –50	20 – 40	30 – 60

Table 4. Growth force under the aspect of number of branches, length of branches and height of bushes/arbors, that have proved to be tolerant on the phosphogypsum substrate with some additives

The variant	The period (on an average)	Species and number of branches, length of branches (cm) and height of bushes/arbors (cm)		
		Ailanthus altissima	*Robinia pseudacacia*	*Eleagnus augustifolia*
V1	1998-1999	2 / 12 / 155	5 / 6 / 41	10 / 6 / 42
	2000-2003	3 / 12 / 160	8 / 8 / 40	13 / 10 / 47
V2	1998-1999	2 / 25 / 175	13 / 22 / 88	16 / 13 / 66
	2000-2003	7 / 36 / 190	15 / 30 / 110	20 / 31 / 73
V3	1998-1999	2 / 10 / 170	11 / 30 / 115	19 / 30 / 70
	2000-2003	6 / 20 / 195	14 / 39 / 125	23 / 33 / 92
V4	1998-1999	2 / 40 / 155	10 / 23 / 155	18 / 29 / 65
	2000-2003	5 / 50 / 185	13 / 27 / 117	22 / 32 / 85