Restoration of Ecosystems Destroyed by the Fly Ash Dump Using Different Plant Species

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Abstract
The leguminous plants was studied at experimental variants on fly ash dump: sown species of *Onobrichys viciifolia* and invasive colonies of Bird's-foot Trefoil (*Lotus corniculatus),* and yellow sweet (*Melilotus officinalis).* Six experimental variants were studied in three replicates each: untreated fly ash, fly ash amended with unmodified/modified volcanic rock and fly ash treated with unmodified/modified volcanic rock (indigenous volcanic tuff) mixed with organic fertilizer, anaerobically stabilized municipal sludge type. The characteristics of topsoil was assessed in toxic metals Cr, Cu, Pb, Ni content and the characteristics of plants was assessed in terms: height, shoot and roots dry weight, root and shoot ratio, root length density, the aspect plant and competitive ability of this species to dominate in sown habitat. Invasive plants *(Lotus corniculatus)* and *Melilotus officinalis* have colonized up to 38 - 43 % and max 5 % respectively, treated experimental variants fly ash with organic fertilizer mixed with unmodified/modified volcanic tuff. The proposed strategy with sown leguminous species led to improved conditions for installation of more and resistant invasive species. Furthermore ecological restoration is increasing with effective fly ash dump stabilization.

Keywords: fly ash dumps stabilization, invasive plant, leguminous species, toxic metals

1. Introduction

The thermal plants that burn up coal are the main sources of energy, all around the world. Coal combustion produces solid residues resulting from the non-combustible fraction. The discharged solid residues consist of small particles of inorganic matter and are transported to fly ash dumps in various ways. Physical and chemical properties of fly ash are given by the nature of the coal used in the combustion, by the process conditions and post combustion conditions. Fly ash can be considered as a resource material with potential application in various domains. Currently many researches are focused on finding new fields of use for fly ash. Alongside these, there are analyzed ways to conserve fly ash dump, without bringing prejudice to the environment. Worldwide current research report phyto-stabilization efficiency with plants suitable for fly ash dumps and destroyed landscape restoration. Limits on the plants induction and growth on the fly ash dump may include: an altered pH, potential toxic elements such as heavy metals, Cu, Cr, Cd, As, etc, excessive hardening properties of topsoil that are induced by the technological process of stabilizing the fly ash layers, lack of nutrients and microbial activity, and more [1-3].
In order to overcome these shortcomings it is relevant the dispersal on the fly ash dump of natural organic fertilizers, manure, compost, biological sludge, etc. materials which provide the necessary nutrients and a required biocenosis the activate biological process into inert soil. By

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incorporating organic fertilizers and inoculating a microbial substrate in the superior layers of the fly ash dump, there can be rapidly formed a vegetation cover resistant to biogeochemical and climatic conditions. Phyto-stabilization studies focus especially on adapting some leguminous species which can subsequently contribute to nitrogen fixation in the soil [4-6].

If this method of fly ash dump vegetation can be economically justified from the price cost – environmental protection, the deposit may be included in a vegetation strategy. The decay of dead vegetation layers determines the forming of a primary layer of humus, which facilitates every year its growth and vegetation preservation. After a long period of time in the crop sown with leguminous plants, invasive plants are installed which are more resistant and end up colonizing increasing areas [7].

The current study was conducted over a three year period on the leguminous plant *Onobrichys viciifolia*, seeded on experimental lots placed on the fly ash dump C.E.T. Timisoara and it sought to evaluate the degree of plant germination, development and perpetuation in time. During the third year there the installation of invasive plants was monitored in addition. Lot of data was the basis of a general strategic program of rapid and efficient reconstruction of the destroyed landscape by vegetation the fly ash dump.

2. Materials and methods

Fly ash dump is situated on fertile soil in Banat. The fly ash dump is formed of solid residues from burning lignite, in C.E.T. Timisoara. The experimental blocks were located on fly ash dump (+45° 47' 3.33", +21° 12' 54.01"). Each experimental variant occupies 10 m^2 (2 m x 5 m dimensions). The experimental variants applied in this study were arranged in a completely randomized block design with three replicates each. Between the experimental variants a 0.5 m corridor was left so that each lot would be personalized. The experimental variants have been prepared with the following characteristics: fly ash variant C, amended fly ash with 5 t/ha^{-1} volcanic rock, native indigenous tuff of Marsid Carrier CT1, amended fly ash with 5 t/ha^{-1} modified indigenous tuff of Marsid CT2, the fly ash fertilized with 25 t/ha^{-1} biosolids (anaerobically stabilized sewage sludge) CB, fertilized fly ash with 25 t/ha^{-1} biosolids mixed with 5 t/ha^{-1} native indigenous tuff CBT1 and fertilized fly ash with 25 t/ha^{-1} biosolids mixed with 5 t/ha^{-1} modified indigenous tuff CBT2. The experimental variants are seeded with the leguminous species *Onobrichys viciifolia*. At experimental block 18 samples of experimental soils variants were analyzed. The modified volcanic tuff (called tuff-Aln) was prepared in the E.C.O.I.N.D. Laboratory patent. Fly ash and soil samples analysis was done to determine the total Fe, Cr, Cu, Ni, Pb, and Zn concentrations according to the analysis method: the heavy metals were extracted from the soil samples by heating with Aqua Regia for 2 h, at reflux. After interrupting the heat, the system was left in stand-by for 16 h. Then the samples were diluted in a flask with distilled water to exactly 50 ml. Plant tissues were thoroughly washed with distilled water to remove any soil particles attached to plant surfaces. The tissues were dried (105°C) to a constant weight. Plant samples with precise weight are then brought to 550 °C; to the residual materials 5ml of concentrated hydrochloric acid are added, samples are maintained 30 minutes on the dry sand bath. After filtering those in a paper filter with small porosity, they were taken to a calibrated flask with hydrochloric acid 1:1 solution. Plant and soil extracts analysis was done using a spectrophotometer, Atomic Absorption Spectrophotometer, GBC Avanta AAS, GBC Scientific Equipment Ltd. Company. From the chemical analysis of the topsoil from the experimental block resulted that it contains Cr 85.5±5.3 g/kg DM, Cu 52.4±3.3 g/kg DM, Fe 4754±52.5 g/kg DM, Ni 34.7±2.5 g/kg DM, Pb 8.8±2.1 g/kg DM, Zn 68.5±3.9 g/kg DM.

The relative abundance and coverage of examined species in relation to time were analyzed from 18 phytocoenological of the plant cover on experimental block. The releve were obtained by Braun Blanquet Releve. The Braun Blanquet Releve approach is based on intentional non random selection of sampling plots typical or representative for plants community type and on visual estimates of abundance and plant cover.

3. Results and discussion

From studies conducted it is revealed that during the seasonal cycles takes place the growth of the plants, their decay and formation of a cover layer of decayed plants which may differ very much from the base layers, of fly ash from which they started. The plants raised during the first year are not harvested; they are allowed to fructify and then are left on the ground in order to contribute to humus formation. It is noticed the fact that the plants grown on the untreated/treated with tuff variants completely dry out. The following year on these variants there will be seeded new quantities of seeds of the same plant. On the experimental variants fertilized in the absence / presence of unmodified or modified volcanic tuff, the plants fructify. The fallen resulted seeds will fill the empty spaces, resulted either by a lack of germination or by the drying out of the plants during a very warm and drought summer. The plants grown in the second year of experiment were harvested, after the fruiting period. The characteristics of *Onobrichys viciifolia* plants resulted in the second year of experiment from variants of untreated/treated soil are given in table 1.

Table 1. The characteristics of *Onobrichys viciifolia* in different fly ash experimental variants after two years of crop. Values are means of three replicates. Total samples analyzed for each parameter was n=18 (3 replicates x 6 treatments)

No.	Parameters	Experimental variants					
		C	CT1	CT2	CB	CBT1	CBT2
1	Plant height (cm)	16±2	18±2	20±5	35±5	33±5	38±4
2	Shoot dry weight (g/kg DM)	19.8	30.1	30.5	33.1	29.1	39.5
3	Roots dry weight (g/kg DM)	32.1	36.1	33.2	42.3	45.4	42.5
4	Root and shoot ratio (g)	1.6	1.2	1.1	1.3	1.6	1.1
5	Root length min. - max. (cm)	9 - 16	10 - 13	12 - 14	12 - 18	12 - 20	20 - 25
6	Plants aspect	Shows chlorosis and drying out	Shows chlorosis, fructify	Shows chlorosis, drying	Green biomass, fructifies	Green biomass, fructifies	Green biomass, fructifies

The table 1 shows that treating the fly ash layer with volcanic tuff as such or modified determined the forming of a vegetal layer which suffers from chlorosis and partial necrosis of the leaves including in the second year. The plants reach a height of 16 - 20 cm in the aerial part of plants, and the roots have a length of 9 - 16 cm. Root and shoot weight ratio (g) ranged between 1.1 - 1.6. The bigger mass quantity of roots vs. the quantity of the aerial parts explains the fact that these plants resist in the soil without nutrients during long dry periods and excessive heat.

The addition of organic fertilizer in the absence/presence of indigenous volcanic tuff unmodified or modified has determined in the second year, crops of plants that reach a height up to twice as high than the plants grown on the unfertilized variants. More so the quantity of green mass harvested was 1.5-2.3 times bigger vs. the biomass harvested from the unfertilized variants. The roots have developed much better in the presence of the organo-zeolitic fertilizer, being 10 - 15 cm longer. The treatments applied to the fly ash layers have firstly determined the obtaining of some *Onobrichys viciifolia* plants more developed both in the aerial part and in roots. The addition of unmodified / modified amendments mixed with organic fertilizer had a synergetic action determining the development of the aerial parts of plants and of the roots of the seeded plants.

In table 2 are presented the influences of the treatment applied to fly ash deposit on the degree of metals bio-accumulated in *Onobrichys viciifolia* aerial part.

Through treatments effected on the superior layers of the fly ash deposit there can be reduced or increased the quantity of metals accumulated in the aerial tissue of the plants. Fertilizing with anaerobically stabilized sewage sludge in the absence of volcanic tuff increased the degree of Cr, Cu and Pb accumulation in the tissue of the aerial part of the plants compared to the accumulation level of similar tissue parts of plants cultivated on unfertilized variants.

Table 2. Quantities of metals bio-accumulated in the aerial part of *Onobrichys viciifolia* plants in the second year of vegetation

No.	Parameters	Experimental variants					
		C	CT1	CT2	CB	CBT1	CBT2
1	Chromium (g/kg DM)	5.1	4.3	3.9	6.23	3.9	4.0
2	Copper (g/kg DM)	5	3.5	2.4	5.5	2.6	1.5
3	Iron (g/kg D.M.]	700.5	429.2	286	633.3	398.0	350
4	Nickel (g/kg DM)	5.8	2.1	1.96	4.7	3.4	3.5
5	Lead (g/kg DM)	1.5	0.83	0.6	1.6	u.d.l.	u.d.l.
6	Zinc (g/kg DM)	18.4	21.5	20.3	23.1	23.5	25.0

Therefore the adding of indigenous volcanic tuff unmodified/modified mixed with the fertilizer had determined decreases of the Cr toxic metal quantities between 21-23% and Cu between 48-70% vs. accumulation from the aerial tissue of the plants grown on the untreated fly ash variants. The combined fertilizer and tuff treatment has determined the reduction of a Pb toxic metal from the aerial tissue of plants under the detectible limit (u.d.l.), so that the crops can be used as fodder.

In the third year of experiment of the seeded *Onobrichys viciifolia* plant there can be noticed the fact that on some variants there are installed invasive plant species from seeds brought by the wind from the neighboring areas; Bird's-foot Trefoil (*Lotus corniculatus)* and yellow sweet (*Melilotus officinalis).* In table 3 is shown the level of vegetation on the experimental variants expressed through the total vegetation coverage parameter.

Table 3. Total vegetation coverage on the experimental variants

Parameters	Experimental variants					
	C	CT1	CT2	CB	CBT1	CBT2
Total vegetation coverage (%)	10 ± 1	27 ± 2	31 ± 2	47 ± 2	62 ± 2	70 ± 3

Of the invasive plants stands with dominant character the species *Lotus corniculatus*. The plants of yellow sweet (*Melilotus officinalis),* presented a lower share in the invasion process.

Figure 1 presents the percentage of the occupancy degree of the surfaces on the experimental variants with seeded common sainfoin, and invasive Bird's-foot Trefoil (*Lotus corniculatus),* and yellow sweet (*Melilotus officinalis)* plants.

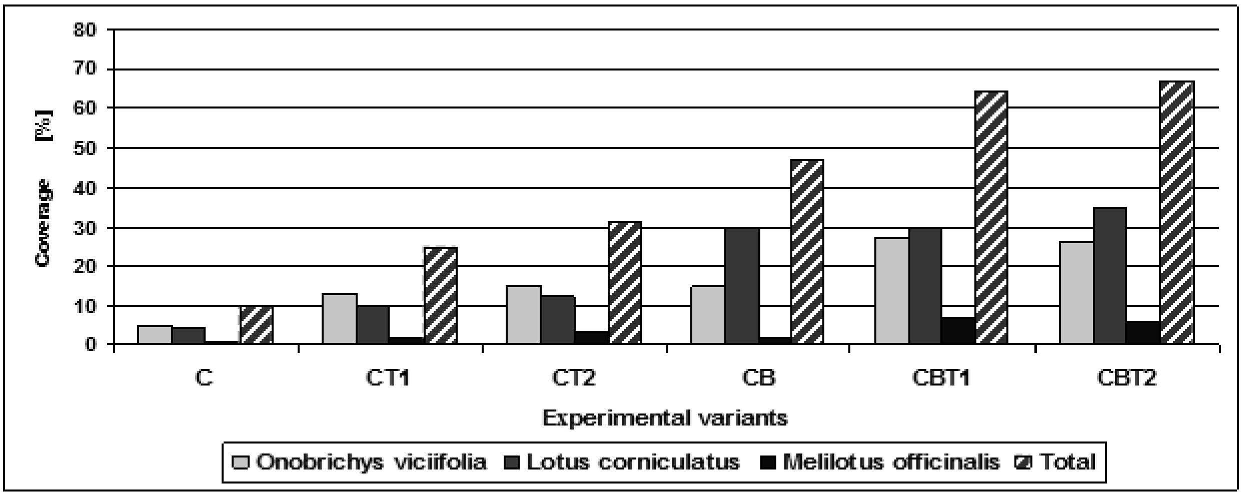

Figure 1. The degree of occupancy of the surfaces on the experimental variants with seeded *Onobrichys viciifolia* plants, and invasive Bird's-foot Trefoil (*Lotus corniculatus),* and yellow sweet (*Melilotus officinalis)* plants

From table 3 and the figure 1 it is shown that the complex treatment of the fly ash layers with organic fertilizer and volcanic tuff has determined a more powerful colonization of the cultivated areas (up to 30 - 35% from the total area with the *Lotus corniculatus* species and 6 - 7% with the *Melilotus officinalis* species), than in the absence of the fertilizer. On these variants it is present the competition between the seeded species *Onobrichys viciifolia* and the invasive species *Lotus corniculatus*, the surfaces occupied by the seeded plant are maintained at 26 – 27% from the total plant covered surfaces. The invasive installed plants increase the habitat quality both from the point of view of the ecological microclimate and esthetically.

4. Conclusions

The vegetal layers successively installed contribute to the isolation of the deposits, their preservation for future use. In the conditions of fertilization of the superficial layers of the fly ash dump with biosolids resulted from municipal wastewater in absence/presence amendments based on volcanic tuff has been initially installed a more stable vegetal layer from seeding *Onobrichys viciifolia* plants vs. unfertilized variants. The plants develop pivot roots at a depth of 20 – 25 cm which stabilize the superior fly ash layers. After a seeded crop that is maintained two years with the *Onobrichys viciifolia* species, there appeared invasive plants of which the predominant species *Lotus corniculatus* which colonizes up to 30 – 35% of the area treated with bio solids and tuff and the species *Melilotus officinalis* with a lower degree of colonization of up to 7%. The proposed strategy for vegetating fly ash dump was by seeding crops of leguminous *Onobrichys viciifolia* species: followed by the installation of some invasive more resistant species, which allow the biological restoration of the fly ash dump in parallel with an effective stabilization against the wind, erosion, washing with precipitation.

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