THE RESEARCH FOR THE DEVELOPMENT OF AGRICULTURAL RECOVERY TECHNOLOGY OF STERILE LANDFILLS RESULTING FROM THE CURRENT EXPLOITATION OF LIGNITE

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Abstract
The research was organized on the Balta Unchiașului tailings dump, Rovinari, Gorj county, a dump covered with 30 cm of fertile soil, aiming to establish the effect of fertilization with fertilizers, cattle manure, compost, lignite –based fertilizer and liquid fertilizer based on humates extracted from lignite on sunflower production and followed the effect of fertilization with mineral fertilizers, manure, compost and liquid fertilizers based on humates extracted from lignite, on the sunflower crop). The chemical characteristics of the crop substrate had a large variability and consisted of: pH values between 8.08 and 8.35, so a slightly alkaline reaction, humus values between 2.50 - 3.52%, being valued as a low-medium level of supply, the level of nitrogen total between 0.101 and 1.60%, therefore a low-medium level of supply, mobile phosphorus between 25 and 44 mg/kg, therefore a medium-high level of supply. The most high values is recorded in the variants fertilized with manure and compost, mobile potassium between 152 and 315 mg/kg, so a medium - high supply level, copper between 18 and 23 mg/kg, so normal supply values, nickel between 30 and 37 mg/kg, so an average load, lead between 7 and 12 mg/kg, values that highlight a normal level of load, manganese between 473 and 595 mg/kg, so normal values, zinc between 48 and 66 mg/ kg, showing normal values and cadmium 0.17 AND 0.32 mg/kg so normal values. The sunflower plants can be used as copper hyperaccumulators.

***Key words**: re-cultivation, mine tailings, sunflower, liquid fertilisers*

INTRODUCTION

The concerns regarding the increase of the agricultural and forestry areas, protecting the environment, together with the need for the retrocession of the lands affected by the mining exploitations to the former owners accentuated the activities regarding the reclamation of the areas degraded by the mining exploitation, including them again in the economic cycle.

The law no. 18/1991 on land fund provides in article 101 the following:

(1) Stackholders implied in investment or production activities, who own land that they no longer use in the production process, such as those left after the excavation of raw materials – coal, kaolin, clay, gravel – from abandoned bores and others, are also enforced to take the necessary landscaping and leveling measures, for an agricultural use, and, if this is not possible, for fishery or forestry use, within 2 years after the end of the production process.

(2) Beneficiaries of the works provided for in paragraph 1 will no longer be

approved to remove other lands from agricultural or forestry use, if they have not complied with the provisions of this article.

In these conditions, concerns arose regarding the agricultural or forestry recultivation of these areas (Dumitru et al., 1999; Mocanu et al., 2007; Tatomir et al., 2010; Călinoiu, 2013; Becheritiu, 2003; Blaga, 1981; Ianc, 1999; Munteanu, 1998; Dinucă, 2015).

The legislation stipulates the stripping of the fertile topsoil layer and its use in the recultivation process in order to shorten the period of restoring the agricultural productivity of tailings dumps. The desire to increase labor productivity in the stripping process, which makes the stripped layer sometimes composed of several genetic soil horizons, the thickness differences of the fertile horizon, the temporal distance between stripping and the reuse of the fertile horizon for recultivation, the non-uniformity of the cover thickness, lead to a non-uniformity of the crop substrate characteristics and to the extension of the time period needed to reach a fertility level similar to the zonal soils in the same conditions of economic efficiency.

In these conditions, even if the landfill is covered with 30 cm of fertile soil, its physical, chemical and biological characteristics remain highly variable. By setting up the fertilization system, an attempt is made to improve the chemical characteristics, as well as the biological and physical ones, faster. The yield behaviour is mostly dependent on the fertilization system. For this purpose, several researchers have demonstrated the need for organic and mineral fertilization to ensure the increase of agricultural production and soil humus, nitrogen, phosphorus and potassium contents, considering especially the very low content in these elements in various landfills (Blaga et al., 1986; Călinoiu, 1999; Clapa, 2003; Nastea et al., 1987; Popa, 2007).

MATERIALS AND METHODS

The experiments have been organized in the Balta Unchiașului tailings dump, Rovinari, Gorj county, a tailing dump covered with 30 cm of fertile soil. The aim is to assess the effect of fertilization with fertilizers, cattle manure, compost, lignite–based fertilizer and liquid fertilizer based on humates extracted from lignite on sunflower yield.

The compost was produced by aerobic fermentation of a mixture of manure, coal debris, a microbiological bio-product and addition of amide, nitric and ammoniac nitrogen fertilizers, a potassium alkali and salts of iron, copper, zinc, manganese and magnesium.

Chemical characteristics of liquid fertilizers are presented in table 1.

Table 1. Physic - chemical properties of the liquid fertilizer

Physic – chemical properties	Concentrations (g/l)	
	Minimum	Maximum
Nitrogen (total N)	130,00	150,00
Phosphorus (P_2O_5)	30,00	50,00
Potassium (K_2O)	30,00	50,00
Iron (Fe)	0,20	0,30
Copper (Cu)	0,10	0,20
Zinc (Zn)	0,10	0,20
Magnesium (Mg)	0,10	0,20
Manganese (Mn)	0,10	0,30
Molybdenum (Mo)	0,01	0,02
Cobalt (Co)	0,01	0,02
Boron (B)	0,10	0,20
Sulfur (SO_3)	2,00	5,00
Organic substances, of which:	10,00	15,00
-humic compounds	5,00	10,00
-pH (pH units)	6,50	7,50
Density (g/cm^3)	1,18	1,21

The Fundulea 206 sunflower cultivar was used, with the sowing standard of 6 kg/ha, with a distance between rows of 70 cm, resulting in a density of 50.000 plants/ha.

The pH was potentiometric determined in aqueous suspension, total nitrogen by the Kjeldahl method, available phosphorus and potassium extracted into ammonium acetate lactate, humus by wet oxidation, and heavy metals have been extracted into aqua regia according to SR ISO 11047, PTL 27.

RESULTS AND DISCUSSIONS

The chemical characteristics of the culture substrate had a large variability: pH values varies between 8.08 and 8.35 (a slightly alkaline reaction), humus content between 2.50 and 3.52% (low-medium supply level), total nitrogen content between 0.101 and 1.60% (low-medium level of supply), available phosphorus content between 25 and 44 mg/kg (medium-high level of supply), the higher values being recorded in the variants fertilized with manure and compost, available potassium content between 152 and 315 mg/kg (medium - high supply level), copper content between 18 and 23 mg/kg (normal supply values), nickel content between 30 and 37 mg/kg (medium load level), lead content between 7 and 12 mg/kg (normal load level), manganese content between 473 and 595 mg/kg (normal values), zinc content between 48 and 66 mg/ kg (normal values) and cadmium content varies between 0.17 and 0.32 mg/kg (normal values).

On this substrate with very different levels of nutrient supply, sunflower yield varied between 1900 kg/ha in the unfertilized (control) plots and 2922 kg/ha in the plots fertilized with N150P150K150 complex mineral fertilizer. Higher yields were obtained for fertilization with compost dose of 40 t/ha plus mineral fertilizer, where the yield increases with 49-56% compared to the non-fertilized plot. The application of compost doses of 20-60 t/ha gave yield increases of up to 10%, probably due to the lower speed of mineralization. The same doses of manure ensured production increases of up to 17%. Humate liquid fertilizer at N150 dose gave a distinctly significant yield increase. In all experiments and on all crop plants, the best results were obtained with organic + mineral fertilization (Figure 1).

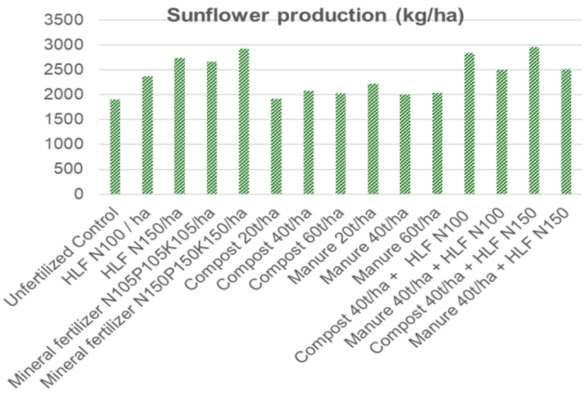

Figure 1.Sunflower production

For sunflowers this is even more important because sunflowers requires a good level of nutrients supply during the growing season.

The sunflower is a great nutrients consumer. To produce 100 kg of seeds and 300 kg secondary production (stems and leaves), an average of 3.65 kg N, 1.75 kg P_2O_5, 5.0 kg K_2O and 1.8 kg MgO are required.

The good yield results can also be attributed to a good rainfall regime, which allowed a very good development of the plants, even if in July and August there was some rainfall deficit.

Compared to other crops, sunflower is more drought tolerant due to a strong water absorption capacity caused by the efficiency of the root system. When sunflower is grown under stress conditions, yields correlate well with the degree of water limitation. This correlation reflects the sunflower's ability to limit growth and transpiration to available soil water through morphological adjustment to these conditions. Water limitation causes a reduced rate of leaf expansion and therefore a reduced transpiration (Păcureanu and Petcu, 2003).

Nutrient absorption is fast during early growth, so nutrient concentrations are high in young plants and decrease toward maturity. Fortunately, during the period of early growth the soil moisture regime is usually better.

Most of the dry matter accumulates in the period from the appearance of the flower bud to the end of seed filling. As the biomass increases, the relative content of nitrogen, phosphorus and potassium content decrease, due to their migration from the vegetative organs to the reproductive ones (Vrânceanu, 2000). The content of sunflower leaves in heavy metals is presented in Table 2. Vrânceanu (2000) shows that in the seedling stage the sunflower has a nitrogen content of 4.43%. Bergmann (1992) shows that leaf nitrogen levels at the seedling stage range from 3.00 to 5.00%. In the flower bud phase, the nitrogen level is 3.18%, at flowering is 1.69% and at maturity 0.69%. The leaves have been harvested in the flowering phase, and the nitrogen level oscillated between 1.63 and 2.07%, normal values for this phenophase. The measured data do not reveal statistically significant changes in the nitrogen level in the sunflower leaves under the influence of the applied treatments (Figure 2).

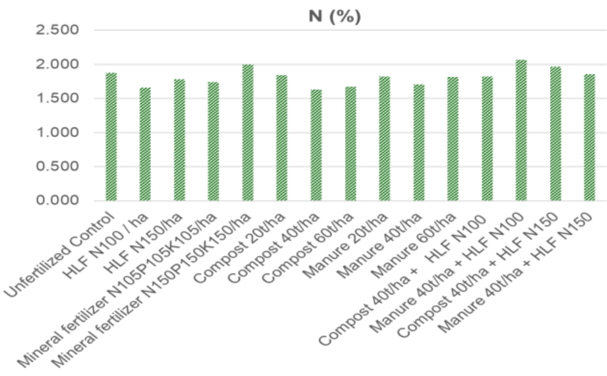

Figure 2. Nitrogen content of sunflower plants

Phosphorus content in sunflower (Figure 3) leaves ranged between 0.31 and 0.48%, being considered normal (0.25-0.50%) (Bergmann, 1992).

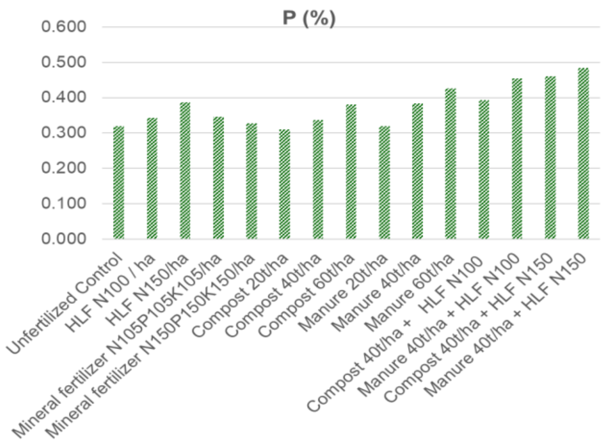

Figure 3. Phosphorus content of sunflower plants

In various stages of development, the P values in the leaves ranged from 0.32% at the seedling stage, 0.36% at the flower bud stage, 0.265 at flowering and 0.14% at maturity (Vrânceanu, 2000).

Potassium content in sunflower (Figure 4) leaves varied between 4.23 and 5.35%, in the normal range (3.0-4.5% according to Bergmann, 2000) – high concentration.

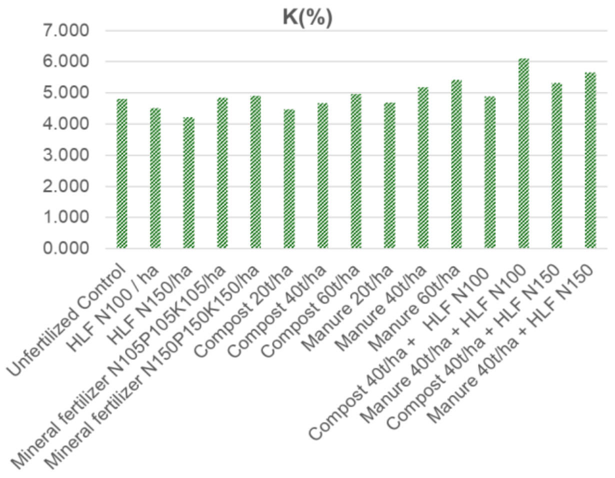

Figure 4. Potassium content of sunflower plants

Potassium is quickly taken up by the root system of the sunflower and acts as a regulator of the water regime of the plant. Root cells well supplied with potassium easily take water from the soil and transfer it to the central cylinder of the root, ensuring a decrease in the transpiration coefficient.

Potassium in the stems and leaves quickly increases until the beginning of flowering and reaches the maximum concentration at full flowering, after which it remains constant in the stem and decreases a lot in the leaves, being translocated to calathids and achenes (Mărin et al., 2020) .

Calcium contents in sunflower (Figure 5) leaves varied between 5.39 and 6.26%, being considered very high (normal values, according to Bergmann, are 0.80 – 2.00%), and magnesium values between 0.98 and 1.34% being considered high (Figure 6) (normal values according to Bergmann (2000) are 0.30-0.80%).

As soil pH increases, calcium and magnesium absorption increases, especially in soils rich in iron and aluminum oxides (Fageria, 2009).

The level of copper in sunflower leaves had values of 25-41 mg/kg, high values compared to the optimal values of 10-20 mg/kg, highlighting the hyperaccumulator characteristic of this plant and the possibility of being used in phytoremediation process for copper loaded soil. For most species, the critical toxicity level of copper in leaves is over 20-30 mg/kg d.m. The largest amount of copper accumulates in the leaves.

The level of iron in sunflower leaves was also highly variable, with values between 95 and 394 mg/kg.

Green plants must absorb iron continuously during growth because it is not transferred from older to younger leaves. In iron deficiency situations, sunflowers can compensate in several ways. The roots develop more root hairs and so-called rhizodermal transfer cells. They also exude more protons (H+ ions) through an ATP-ase efflux pump, phenolic compounds and organic acids, some of which having chelating properties (Bergmann, 1992).

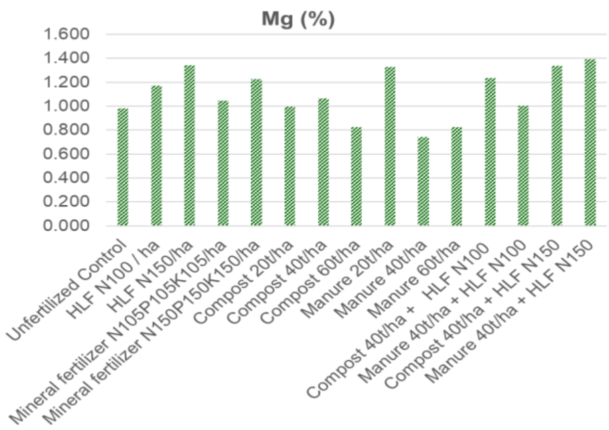

Figure 5. Calcium content of sunflower plants

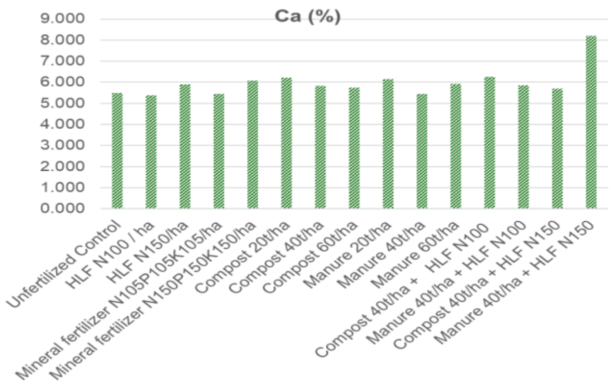

Figure 6. Magnesium content of sunflower plants

The values of nickel in the leaves were 0.89-3.94 mg/kg, being considered as normal values.

Low amounts of lead were found in the leaves: 0.50-3.38 mg/kg.

Manganese values between 20 and 42 mg/kg fall within the optimal range (25-100 mg/kg, Bergmann, 2000).

pH is one of the main factors determining Mn availability to crop plants. The effect of pH > 6.0 in lowering free metal ion activities in soils has been attributed to the increase in pH-dependent surface charge on oxides of Fe, Al, and Mn, chelation by organic matter, or precipitation of metal hydroxides (Fageria , 2009).

Table 2. Influence of fertilization on sunflower yield and plant chemical composition.

	Cu	Fe	Ni	Pb	Mn	Zn
Agrofond	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**	**mg/kg**
Unfertilized (Control) plot	30	228	2,14	1,36	20	66
Humate liquid fertilizer (HLF) N_{100} / ha	36	144	1,85	1,89	21	64
HLF N_{150}/ha	41	155	1,91	0,93	26	57
Complex mineral fertilizer $N_{105}P_{105}K_{105}$/ha	33	171	1,67	2,55	26	62
Complex mineral fertilizer $N_{150}P_{150}K_{150}$/ha	41	105	1,39	1,65	24	54
Compost 20t/ha	31	104	1,29	1,50	29	56
Compost 40t/ha	25	95	1,66	1,21	33	70
Compost 60t/ha	29	163	1,38	2,18	32	56
Manure 20t/ha	35	130	0,89	0,50	33	69
Manure 40t/ha	34	144	0,93	1,85	40	69
Manure 60t/ha	30	153	1,49	2,16	42	58
Compost 40t/ha + HLF N_{100}	40	142	2,12	2,72	35	60
Manure 40t/ha + HLF N_{100}	38	144	1,31	2,86	34	63
Compost 40t/ha + HLF N_{150}	40	140	1,53	0,82	22	63
Manure 40t/ha + HLF N_{150}	37	394	3,94	3,38	24	60
HSD 5%=	**11**	**50**	**1,38**	**1,50**	**11**	**17**
HSD 1%=	**15**	**68**	**1,87**	**2,03**	**15**	**23**
HSD 0.1%=	**20**	**90**	**2,48**	**2,69**	**20**	**31**

The climatic conditions influence the mobility of Mn. Low temperatures also decrease Mn uptake, severe Mn deficiency in some plants being more frequent in spring or early summer, when temperature drops occur, followed by favorable growth conditions (Băjescu and Chiriac, 1984).

Zinc content had values between 54 and 70 mg/kg, falling within the optimal range presented by Bergmann (30-80 mg/kg).

Zinc uptake by plants is influenced mainly by the pH value and phosphate concentration of the nutrient medium. Uptake decreases as the pH value rises.

CONCLUSIONS

The research carried out on the Balta Unchiașului tailings dump from Rovinari with the aim of agricultural use of the degraded surfaces due to the strip mining lignite led to the following conclusions:

1. Covering with 30 cm of fertile soil creates the necessary conditions for obtaining yield

values close to those obtained on undisturbed regional soils. It is required that only the fertile horizon be removed when uncovering and that it be used as quickly as possible when covering the dump. Incorrect stripping leads to large non-uniformities in cover characteristics and production.

2. The fertile soil cover is medium supplied with nutrients and has a normal content of heavy metals.

3. The best sunflower yield results are obtained by organic + mineral fertilization.

4. Treatment with liquid fertilizers based on humates extracted from lignite, complex mineral fertilizers with NPK, cattle manure and compost (obtained by aerobic fermentation of manure with coal dust, microbiological biopreparations and addition of mineral fertilizers with amide nitrogen, nitric and ammoniacal, potassium hydroxide and iron, copper, manganese and magnesium salts) led to crop yields similar to those obtained on undisturbed zonal lands, with production increases reaching values of 56%.

5. The fertilization system did not lead to statistically significant changes in the macroelements, some microelements and some heavy metals content of sunflower leaves.

6. Sunflower plants can be used as copper hyperaccumulators.

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