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RECULTIVATION OF DEGRADED SOIL DUE TO MINING ACTIVITY WITHOUT ADDING ORGANIC LAYERS OF SOIL USING ALFALFA AND MIXTURES OF GRASS LEGUMES

SUMMARY

The aim of this research was to examine the possibility of reparing the chemical properties of substrate and regenerating the vegetation of degraded soil due to mining activity without adding the fertile soil layer. The research was carried out in the period 2011-2013 on degraded soil of mine and thermal power plant Gacko. The experiment was placed on a landfill located in Srđevići. For these tests, grass-leguminous mixtures were used: I/G (alfalfa 70%, orchard grass 30%); II/G (alfalfa 70%, orchard grass 15%, tall oat-grass 15%); III/G (red clover 50% , italian rye-grass 50%); IV/G (alfalfa 30%, tall fescue 40%, *smooth brome*15%; orchard grass 15%) and alfalfa 100%. The following parameters were monitored and analyzed during the tests: mechanical soil composition, soil chemical properties, microelement content in the soil: Zn, Mn, Fe, Cu; the content of heavy metals in the soil: Pb, Ni, Cr, Cd, Hg, As, plant species presence in the mixture, soil cover with grass, yield of green mass by cuts and years, content of microelements and heavy metals in dry vegetable mass by cuts and influence of nitrate content of individual microelements and heavy metals in soil and dry mass of plants.

Studies of the content of microelements and heavy metals in degraded soil showed that it contained Cd in significantly higher value than the permitted limit value. Other elements were within the limit values permitted for agricultural land. The content of Cd in 2011 was 5.1 mg kg^{-1} of soil, and in 2013 it was 4.5 mg kg^{-1} of soil. By analyzing the composition of the green matter in mixtures I/G, II/G and IV/G, it was found that orchard grass was predominantly present in relation to other constituents of the mixture. The III/G mixture was dominated by Italian rye-grass. The participation of other plant species in the mixture was extremely low. In the green mass of all mixtures, leguminous was represented in a small

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percentage. The largest soil cover with plants was achieved with the mixture IV/G (88.4%), which at the same time achieved the highest average yield of green mass. The determined values of the content of microelements and heavy metals in the dry mass were within the allowed limits. Nitrates influenced the reduction of Cu and Cr content in soil and Cd content in dry plant mass.

Keywords: degraded soil, recultivation, alfalfa, grass-leguminous mixtures

INTRODUCTION

Soil is the basic natural resource which, together with air, water, fauna and flora makes an ecosystem. Changes in the constituent parts of the ecosystem are reflected on the system as a whole. Soil is a resource that is difficult to regenerate. It can be used in many ways. In principle, two basic groups are distinguished: technical and ecological. From the aspect of technical function, the soil can be used for various purposes. The use of land for the purpose of exploitation of raw materials or for mining activities can lead to its permanent or temporary exclusion from production. Mining activities on mine surface lead to degradation and physical destruction of huge land surfaces, the deposit of large quantities of defects and the occurrence of mine waters.

In order to remedy the consequences of the activities on surface mining sites, sanitary measures such as: recultivation, phytomeliotation, decontamination, etc. are performed. The process of recultivation of degraded soil implies technical and biological recultivation. Technical recultivation aims to form the terrain and apply a layer of suitable material to create conditions for the development of vegetation. This part of the recultivation is extremely expensive. Most activities are directed towards transforming degraded soil into a state that is suitable for agricultural and forestry purposes. Biological recultivation is a long-lasting and complex process, which implies the application of a series of appropriate measures to accelerate pedological processes. The implementation of biological recultivation requires a preliminary analysis of the existing situation on the ground and the implementation of the phases, as well as subsequent monitoring of the process and permanent correction (Golubović et al., 2015). Before starting any activity it is necessary to perform chemical analyzes and determine the content of microelements and heavy metals in degraded soil. High concentration of heavy metals reduces soil quality, destroys biological balance and damages all other ecosystem functions (Belanović et al., 2012, Belanović et al., 2013).

Biological measures applied in the final stage of recultivation are also significant from the aspect of area revitalization and the establishment of natural biocenoses. In order to make the process of remediation of degraded soils faster, it is necessary to introduce large quantities of organic and mineral substances to compensate for the lack of basic nutrients. This requires significant financial investment and is often a limiting factor. Therefore, the processes of recultivation of degraded soil in Bosnia and Herzegovina on a large number of similar mines take place slowly and mainly experimentally. In order to accelerate the transformation of mining degraded soils into a state suitable for agricultural use, the studies that were supposed to find the most favorable and economical solution for the revitalization of the area and the establishment of natural biocenoses have begun. Spontaneous renewal of vegetation on surfaces degraded by mining activity with the application of melorative measures proved unsuccessful. Spontaneous restoration of grass cover of varying covering degrees can last from 6 to 23 years (Csecserits et al., 2007; Feng et al., 2007a, b). Grass cover renewal on degraded surfaces is of great importance, because it provides the possibility of reducing the loss of grass surface's biodiversity (Plieninger & Gaertner, 2011). Renewal and putting in use the degraded soil surfaces is of great importance for the community, especially if there is a multicomponent contamination present, and if there are urban or settled areas in the proximity.

The aim of this research was to examine the possibility of reparing the chemical properties of substrate and regenerating the vegetation of degraded soil due to mining activity without adding the fertile soil layer.

MATERIAL AND METHOD

Field research was carried out on the land of the mine and thermal power plant in Gacko from 2011-2013. Analysis of samples of soil and plant material took place in the period 2011-2014 in the laboratories of the Agricultural Institute of Republic of Srpska, Banja Luka. Two-factorial experiment (factor A - years, and factor B - type/mixture) was set in four repetitions at the location Srđevići (949 m. altitude above sea level). The surface of the experiment was 1.240 m^2. For those tests, grass-leguminous mixtures were used: I/G alfalfa 70%, orchard grass 30%; II/G alfalfa 70%, orchard grass 15%, tall oat-grass 15%; III/G red clover 50, Italian rye-grass 50%; IV/G alfalfa 30%, tall fescue 40%, smooth brome 15%, orchard grass 15% and alfalfa 100%. The following seeds were used for sowing: alfalfa in pure culture (100%) 30 kg ha^{-1} of seed; I/G 32 kg ha^{-1}; II/G 40 kg ha^{-1}; III/G 37.5 kg ha^{-1} and IV/G 43.5 kg ha^{-1}.

Before the start of any activity on the experimental surface, the degraded soils were rigged at a depth of 60 cm and fencing was done. After that, soil samples for physical chemical analyzes were taken. On the rigid degraded soil before plowing it was dispersed 30 kg of N, 90 kg P_2O_5 and 40 kg K_2O. The plowing was done at a depth of 20-25 cm, and then 30 kg of N, 90 kg of P_2O_5 and 40 kg of K_2O were dispersed again. The preparation of land for sowing was done by a rotary harrow. The land is aligned with a light harrow. The stones on the test parcel were manually removed. The sowing experiment was carried out in September 2011. After sowing, the entire sown surface was powell with a smooth roller.

Fertilization was done with nitrogen fertilizer KAN 27%N. During the vegetation in the first cut we used 54 kg ha^{-1} N, 40.5 kg ha^{-1} N in the second cut and 27 kg ha^{-1} N in the third cut. The first topdressing was done after the vegetation in the first cut, and the second and third was applied fifteen days after mowing the first and second cut.

The following parameters were monitored and analyzed during the test: mechanical soil composition, soil chemical properties, microelement content: Zn, Mn, Fe, Cu; the content of heavy metals in the soil: Pb, Ni, Cr, Cd, Hg, As, the presence of plant species in the mixture, grass cover on soil, yield of green mass by cuts and years, content of microelements and heavy metals in dry vegetable mass by cuts and influence of the nitrate content on individual microelements and heavy metals in soil and dry mass of plants.

Taking samples on degraded land was carried out before the establishment of the crops in September 2011 and after the removal of III grass leguminous mixture in 2013. The samples were taken at a depth of 0-25 cm. Analyzes of the samples were done in the laboratory for agro-chemistry Agricultural Institute of Republic of Srpska in Banja Luka.

○The active reaction (pH in H_2O) and the potential soil reaction (pH in KCl) were determined by combined electrode on a pH-meter electrometrically.

○The amount of humus was determined by the colorimetric method in a wet burned sample.

○The amount of physiologically active P and K was determined by the ammonium-lactate (AL) method, with the reading of the P concentration on the spectrophotometer and K on the plasma photometer.

Sampling of degraded soil for analysis of chemical properties and total content of microelements and heavy metals was done at a depth of 0-25 cm.

Methods of fractionation by means of a sieve series (for skeleton and larger fractions) and pipette method (sedimentation in calm water) were used to determine the mechanical composition of the soil.

The yield of green mass was obtained by mowing four times per 5 m^2 of plant mass of all mixtures and alfalfa. For the analysis of the chemical composition of dry matter, an average sample of each repetition was taken immediately after mowing. Taken samples of green mass were naturally dried.

During the examination, the composition of the green plant mass was analyzed. The plant mass of grass-leguminous mixtures was separated into components regarding mixtures and other plant species that were not sown. During the survey, the land cover by the crop was determined, i.e. the density of crops. Also, in the dry mass of the first cuts in 2012 and 2013, the content of microelements and heavy metals was examined, and the influence of nitrates on their content was also monitored. Coverage results and yield of green matter were analyzed by variance analysis (ANOVA), and the significance of differences between mean values was determined by LSD-test.

RESULTS AND DISCUSSION

Mechanical composition. The percentage distribution of skeletal fractions of different dimensions after analysis of the skeletal base of degraded soil is shown in Table 1. Based on skeletal fractions, the soil is classified as skeletal medium stony. The skeleton was 62.2% in relation to total porosity. The stone fractions, separated on sieves with an aperture of 2-20 cm, were represented by 68.3%. This fraction consists of 61.0% of the particles sizing from 20 to 5 cm and 7.3% of the particles sizing 5-2 cm. The gravel fraction was separated on sieves with openings of 0.2-2.0 cm, and it was represented with 31.7%. This fraction consisted of 13.8% of the particles sizing 1-2 cm, 8.9% of the particle sizing 0.5-1 cm and 9% of fine gravel particles sizing 0.2-0.5 cm.

Table 1. Analysis of the skeletal base - degraded land according to Gračanin (1947)

Depth (cm)	Skeleton in relation to total porosity, %	Skeletal fractions (cm)								Class
		Stones, %				Gravel, %				
		>20	20-5	5-2	Total	2-1	1-0.5	0.5-0.2	Total	
0 – 60	62.2	0	61.0	7.3	68.3	13.8	8.9	9.0	31.7	Skeletal, medium stony

Chemical properties of the degraded soil According to the results of chemical analyzes of the layer of degraded soil, alkaline reaction (pH in H_2O 8.4) was found at the depth of 0-25 cm. There was no humus in the analyzed layer.

Table 2. Chemical properties of the degraded land

Year	Depth (cm)	pH		Humus (%)	N (%)	$CaCO_3$ (%)	P_2O_5 (mg/100g)	K_2O (mg/100g)
		H_2O	KCl					
2011	0-25	8.4	8.3	-	0.01	98.3	1.1	1.3

The content of easily accessible phosphorus was very low (1.1 mg/100 g of soil). The provision of potassium was also low (1.3 mg/100 g of soil). Based on the content of CaCO3 (98.3%), the degraded soil was classified into highly carbonate soils.

The content of microelements and heavy metals in degraded soil The content of microelements and heavy metals in a layer of 0-25 cm of degraded soil is shown in Table 3.

Table 3. Total content of microelements and heavy metals in degraded soil

Year	Depth (cm)	The content of elements (mg kg^{-1})									
		Mn	Fe	Zn	Cu	Pb	Cd	Ni	Cr	As	Hg
2011	0-25	0.01	0.1	5.4	5.7	7.3	5.1	21	30	0.4	<0.1
2013	0-25	0.01	0.1	6.1	5.1	6.8	4.5	22	27	0.6	<0.1
Permitted values in agricultural land*		1	4	200	120	150	2	75	100	20	1.5

* Rulebook (2016)

The total content of the microelements Mn and Fe was within the allowed limits. The content of the investigated heavy metals, except Cd, was below the permitted limit value in agricultural land. The content of Cd in the degraded soil varied from 4.5 mg kg^{-1} (2013) to 5.1 mg kg^{-1} (2011) and was higher than allowed values in both years of testing.

The representation of plant species in the mixture In order to gain insight into the representation of individual components in grass-leguminous mixtures, analyzes of the composition of the planted mass in the first cuts in 2012 and 2013 were performed during the experiments. The results of the analysis of the composition of herbaceous grass-leguminous mixtures of first cut in 2012 are shown in Figure 1-4.

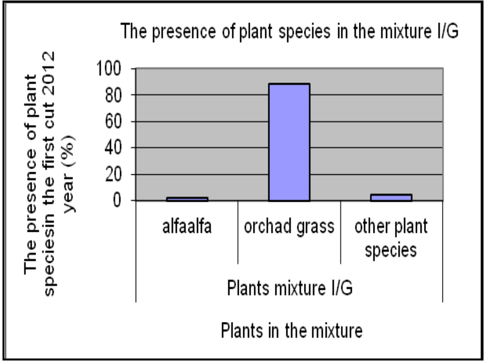

Fig. 1. The presence of plant species in the mixture I/G

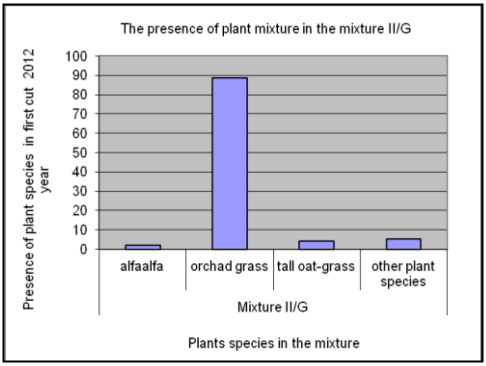

Fig. 2. The presence of plant species in the mixture II/G

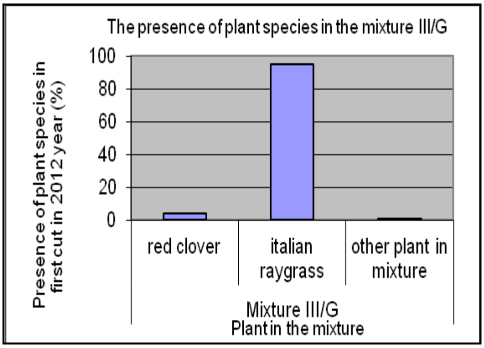

Fig. 3. The presence of plant species in the mixture III/G

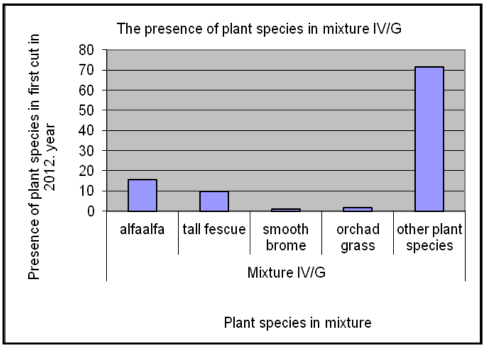

Fig. 4. The presence of plant species in the mixture IV/G

Analyzing I cut of the grass-leguminous green mass of mixtures in 2012, a slight share of other plant species in I/G, II/G and III/G (1.1% to 5.2%) was found. The participation of other plant species in IV/G mixture was dominant (71.5%). Other plant species in the mixtures were represented by 28.5%. In I/G and II/G mixtures the dominant plant was Orchard grass, while the participation of the other components in the mixture was insignificant (Charts 1 and 2). In green mass of III/G mixture, the most common plant species was the Italian rye-grass.

The results of the analysis of herbaceous mass in grass-leguminous mixtures of I cut in 2013 are shown in Figure 5-8.

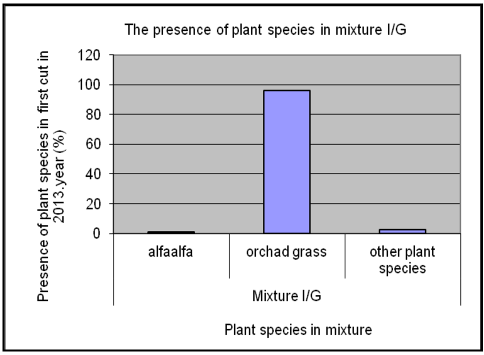

Fig. 5. The presence of plant species in the mixture I/G

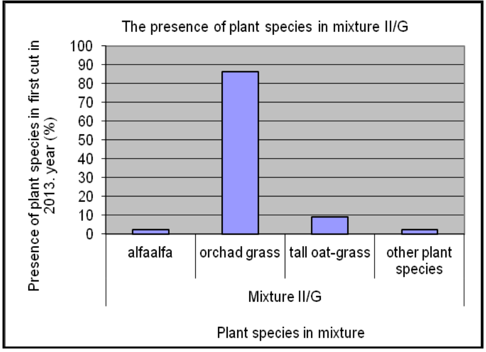

Fig. 6. The presence of plant species in the mixture II/G

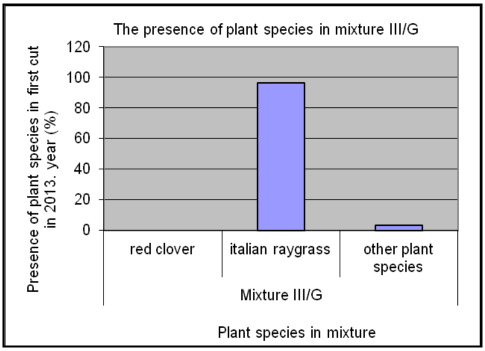

Fig. 7. The presence of plant species in the mixture III/G

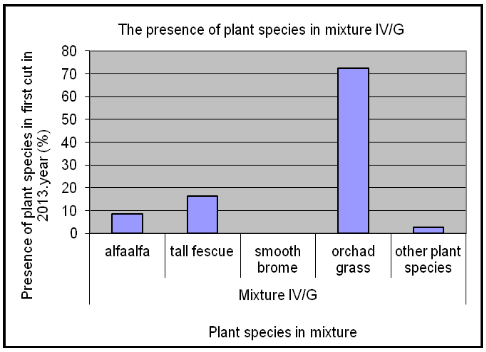

Fig. 8. The presence of plant species in the mixture IV/G

During the second year of experiment, the green mass of I cut was dominated by grass in all mixtures. Orchard grass was the most common in herbal mass in I/G, II/G and IV/G, while Italian rye-grass was dominant in III/G. The participation of other components in the mentioned mixtures was exceptionally low. Legumes were represented in a small percentage. On all types of grasslands and at all test sites, the average share of grasses in grass biomass was 61-68%, the prevalence of legumes was 4-7%, and the share of plants from other families was 29-33% (Dubljević et al., 2020).

Coverage of degraded soil with plant cover. The results of examining the coverage of degraded soil with plant cover are shown in the Table 4.

The analysis of variance determined the existence of statistically significant differences between examined treatments. The type/mixture (factor B) and interaction of species/mixtures x years (AxB) had a very significant impact on soil cover. The impact of the year on the cover (the plant cover density) of the degraded soil was not significant.

During the first study year, the best coverage of degraded soil was achieved with the mixture III/G (89.8%). In 2013, the highest coverage was found in mixture II/G (94.1%). From the results shown in Table 5, it can be seen that the coverage of the degraded soil by plant cover in the second year of testing was higher in alfalfa and all mixtures, except for the mixture III/G. At the III/G mixture, a decrease in the coverage of the surface of the degraded soil by plant cover was found for 43%. The highest increase in the coverage of degraded soil by plant cover was in the second testing year with the mixture II/G (12.7%). During these trials, the highest average land cover was achieved with a mixture of IV/G (88.4%). The mixture III/G during these tests had the weakest coverage (68.3%).

Table 4. Degraded soil coverage with plant cover (%)

Type/mixture	Soil cover per year, (%)		Average	Increase/decrease of soil cover 2012-2013, %
	2012	2013		
Alfalfa	81.9	91.1	86.5	+10.0
Mixture I/G	83.4	92.9	88.2	+9.5
Mixture II/G	81.4	94.1	87.7	+12.7
Mixture III/G	89.8	46.8	68.3	-43.0
Mixture IV/G	83.1	93.8	88.4	+10.7
Factors	A	B	AB	
F-calculated	244.056**	0.222^{ns}	462.748**	
LSD 0.05 0.01	 0.99 1.31	 1.57 2.07	 2.21 2.93	

ns – non-significant; ** highly significant

The yield of green mass of alfalfa and grass-leguminous mixtures. The achieved biannual green mass yield of alfalfa and grass-leguminous mixtures grown on soil degraded by mining activity are shown in Table 5 and Figure 9 and 10. The method of variance analysis revealed that the differences between yields of tested species are statistically highly significant. Also, during these testing, highly significant effects of the year and interactions of types/mixtures x years (AxB), was established.

Tab. 5. Green mass yields of alfalfa and grass-leguminous mixtures on soil degraded by mining activity

Type/mixture	Green mass yield (t ha^{-1})		$\bar{X}$
	2012	2013	
Alfalfa	0.5	21.0	10.8
Mixture I/G	0.4	23.3	11.8
Mixture II/G	0.3	17.6	8.9
Mixture III/G	4.5	21.2	12.8
Mixture IV/G	0.4	25.8	13.1
Basic factors	A	B	AB
F - calculated	236.17**	43221.37**	276.26**
LSD 0.05 0.01	0.2 0.3	0.3 0.4	0.4 0.6

** highly significant

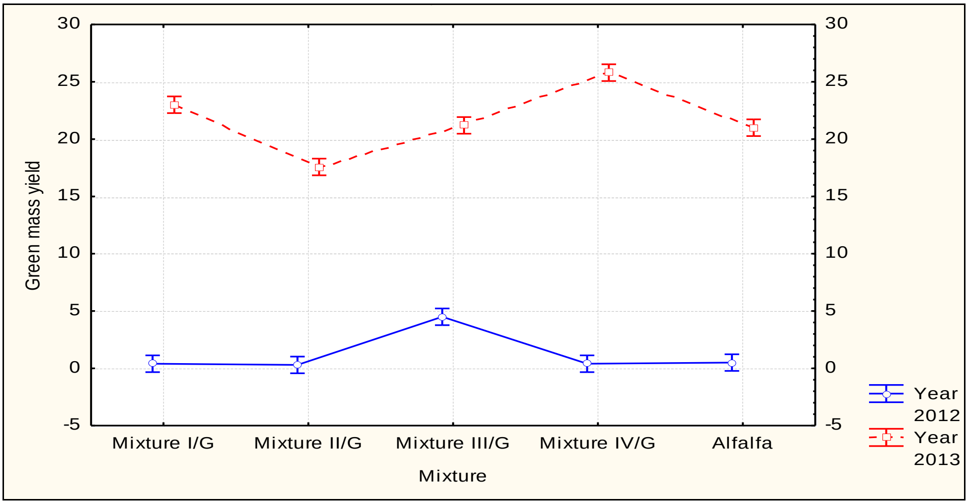

Fig. 9. The effect of the year and the mixture on the yield of green mass

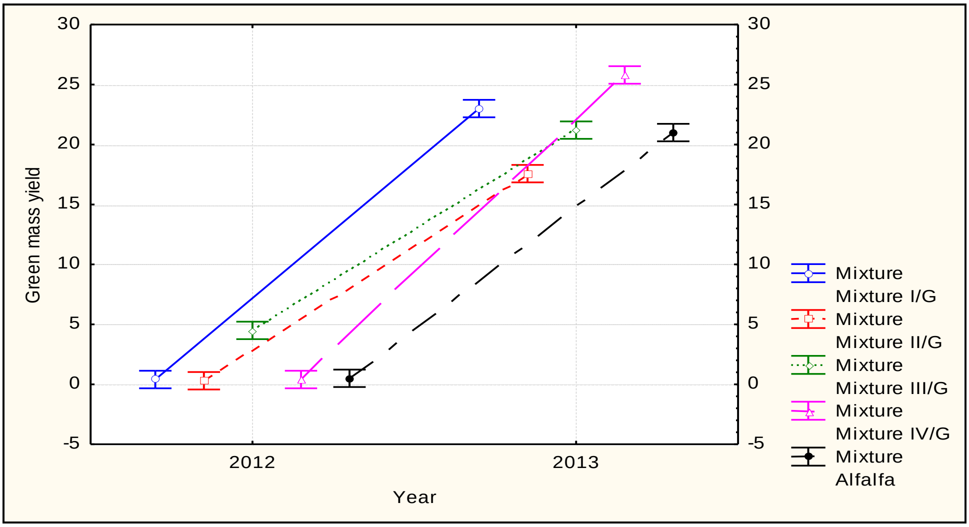

Fig. 10. The effect of the mixture on the yield of green mass

Low yields of green mass were achieved in the first year of the survey. During 2012, regarding the yield of green mass, the mixture of III/G (4.5 t ha^{-1}) was prominent. In the following year significantly higher yields were achieved for all sown types/mixtures. The highest growth of yield of green mass in the course of these tests was achieved with a mixture of IV/G (25.8 t ha^{-1}).

The content of microelements and heavy metals in plant mass. After mowing the first cut, the content of microelements and heavy metals of iron, manganese, zinc, copper, lead, cadmium, nickel, arsenic and mercury was tested in dry plant mass. Table 6 shows the results of the analysis of dry plant mass and of the first cut in 2012.

Table 6. The content of microelements and heavy metals in dry plant mass in 2012 per cuts

Mixture	Cut	Heavy metals and microelements in dry matter, mg kg^{-1}									
		Fe	Mn	Cu	Zn	Pb	Cd	Ni	Cr	Hg	As
Mixture I/G	I	138	27	2	21	8	0.25	3.1	< 0,1	<0.05	<0.1
Mixture II/G	I	133	21	3	23	13	0.26	5.0	< 0,1	<0.05	<0.1
Mixture III/G	I	45	13	2	23	2	0.25	4.8	< 0,1	<0.05	<0.1
	II	159	28	13	43	2,1	0.25	1.4	<0,1	<0.05	<0.1
Mixture IV/G	I	263	47	6	19	7	0.34	5.1	< 0,1	<0.05	<0.1

Table 7. The content of microelements and heavy metals in dry plant mass in 2013 per cuts

Type /mixture	Cut	Heavy metals and microelements in dry mass (mg kg^{-1})									
		Fe	Mn	Cu	Zn	Pb	Cd	Ni	Cr	Hg	As
Alfalfa	I	132	17	3	23	2.5	0.30	2.3	< 0.1	<0.05	<0.1
	II	76	22	9	18	2.6	0.14	4.5	< 0.1	<0.05	<0.1
	III	93	16	9.6	20	1.0	0.09	1.8	< 0.1	<0.05	<0.1
Mixture I/G	I	105	21	6	22	2.3	0.22	1.1	< 0.1	<0.05	<0.1
	II	117	33	11	19	2.4	0.14	2.6	< 0.1	<0.05	<0.1
	III	68	19	9.5	17	1.3	0.12	1.9	< 0.1	<0.05	<0.1
Mixture II/G	I	96	17	6	21	2.1	0.29	2.9	< 0.1	<0.05	<0.1
	II	125	26	8	21	3.1	0.21	1.5	< 0.1	<0.05	<0.1
	III	68	17	3,2	21	1.4	0.07	1.2	< 0.1	<0.05	<0.1
Mixture III/G	I	125	16	3	20	2.5	0.42	1.1	< 0.1	<0.05	<0.1
	II	130	24	7	24	3.6	0.24	1.5	< 0.1	<0.05	<0.1
	III	77	14	7.1	22	1.1	0.09	1.3	< 0.1	<0.05	<0.1
Mixture IV/G	I	105	20	9	19	2.3	0.30	3.8	< 0.1	<0.05	<0.1
	II	68	28	11	20	1.4	0.20	2.7	< 0.1	<0.05	<0.1
	III	96	25	14.5	20	1.0	0.08	1.0	< 0.1	<0.05	<0.1

According to the study results of dry plant mass per cuts in 2012, the content of microelements and heavy metals was within the allowed limits. During that year, only the mixture III/G had two cuts. In the plant material of the second cut, a higher content of Fe, Mn, Cu, Zn and Pb was determined in relation to the content of the same elements in the first cut. The content of Cd remained the same as in the first cut.

The study results of the content of microelements and heavy metals in dry plant mass of the first, second and third cut in 2013 are shown in the Table 7.

The obtained values of the content of microelements and heavy metals in the dry plant mass of all cuts were within the allowed limits. It is interesting that the content of Mn, Cu and Pb in all mixtures/types was higher in the second cut compared to the first one. The content of Cd was reducing in plant weight in each subsequent cut in all mixtures/alfalfa.

The structure of the soil is of great importance for plant production. If the soil structure is favorable, it can, to a certain extent, affect the unfavorable mechanical composition. This is most often manifested in such a way that a favorable soil structure influences the provision of a favorable aquatic-air regime in the soil and provides conditions for the normal growth and development of the root of the plant (Racz, 1994).

Contamination of agricultural lands with heavy metals presents risk and danger for humans (Xu et al., 2017). Arenas-Lago et al. (2014) conducted tests on the mobility of Pb, Zn and Cd in the area of mining zone of Rubiais - Lugo, Spain. Tests were conducted at nine locations. The pH values of the soil affects the bioaccesibility of metals and the process of their absorption trough the root.During the testing of the land in mining zones, the following concentrations of the tested heavy metals were: Pb 0.850-6.761 mg kg^{-1}, Zn 1.754-32.287 mg kg^{-1} and Cd 1.8-43.7 mg kg^{-1}. The above Pb values were compatible with our results, while the above values for Zn and Cd in those studies were significantly above the highest values we found during these studies. Kabata-Pendias et al. (1989) found that the average content of total Zn in the surface layers of agricultural land varied from 17 to 125 mg kg^{-1}, which was below the permissible limit value of 200 mg kg^{-1} of soil.

During the restoration of the lawns in the Hortobagi National Park in eastern Hungary, two grass mixtures suitable for alkaline soils were used: *Festuca pseudovina* (67%), *Poa angustifolia* (33%) and *Festuca rupikola* (40%), *Bromus inermis* (30%), *Poa angustifolia* (30%). The sowing norm was 25 kg ha^{-1} (Török et al., 2012). Approximate quantities of seed during the restoration of the lawn were used by Kiehl et al. 2010; Török et al. 2011a. The given quantities of the used seed were slightly lower than those used during our research. The larger quantities of seeds during the restoration of lawns on degraded surfaces were reported by Van Andel & Aronson (2006). Orchad grass can succeed on different types of soil. This plant species tolerates drought well, it is able to regenerate rapidly after mowing or grazing and has a good summer increase (Lakić et al., 2009). During these studies, orchard grass was predominantly represented in the green mass of I/G, II/G and IV/G. The mixture III/G was dominated by the Italian ray grass, while the red clover was represented in traces. Török et al. (2011b) stated that with the sowing standard of alfalfa of 30 kg ha^{-1} in the first year the land cover of over 70% was achieved, which was in accordance with our results. According to the above-mentioned authors, the soil coverage began to decrease gradually only after the third year. During the research carried out by Li Xu & Vang (2008), the alfalfa sowing norm was 22 kg ha^{-1} of seed, and in the first year the soil coverage was about 50%.

The use of vegetative cover for soil remediation contaminated with heavy metals requires research to determine the plant species that are most suitable for this matter (Bider et al., 2007). The mentioned authors studying which plant species were the most suitable for the formation of the vegetative cover found that heavy metals such as Cd, Pb and Zn were mostly accumulate in the root, and considerably less in the above-ground part. Symanowicz et al. (2014) examined the influence of nitrates (ammonium sulphate) on the content of heavy metals Cu, Zn, Ni, Cr, Pb and Cd in the dry mass of *Galega orientalis* Lam. During the three-year trials, the abovementioned authors found that nitrates influenced the reduction of Zn, Ni and Cd content in dry herbaceous matter. It was also found that the application of nitrates decreased Cu, Zn and Cr levels in the soil. According to the results of our study, nitrates contributed to the reduction in the dry matter content of Cd in all mixtures and alfalfa during 2013. The content of Zn and Ni gradually decreased in dry weight only in certain grass-leguminous mixtures. In three tests of locations in Montenegro, the content of Ni in the country was higher than the maximum allowed amounts, while the available concentration of Ni was between 0.6-7.9 mg kg^{-1}, and its concentration in plants collected from all locations was below 10 mg kg^{-1} (Simić et al., 2019). Also, the results obtained during these trials were in line with the data of Symanowicz et al. (2014) regarding the effect of nitrate on the reduction of Cu and Cr content in the soil. Karami et al. (2011) cultivated by perennial ryegrass *Lolium perenne* L. var. Cadix after the introduction of compost and biological waste on the land of the former copper mine in Cheshire (UK), which was heavily contaminated with Pb and Cu. Gadepalle et al. (2008) questioned the acceptance of As from contaminated soil by plants after the introduction of compost, zeolite and iron oxide into the soil. The results of the study showed that the plants (*Lolium perenne*) took less than 0.01% of the total As content in the soil. In the dry mass of the Italian raygrass, which was grown on low acidity soil (pH 6), the first cut had a content of Cd 0.79 mg kg^{-1}, Pb 7.98 mg kg^{-1}, Zn 91.0 mg kg^{-1}. The dry mass of the second cut had a content of Cd 0.74 mg kg^{-1}, Pb 7.85 mg kg^{-1}, Zn 93.5 mg kg^{-1} (Kwiatkowska-Malina & Maciejewska, 2013). The values indicated by the mentioned authors were significantly higher than the values determined during these tests in the dry weight of the Italian ray grass and red clover.

The concentration of heavy metals in plants indicates the degree of contamination, but also the ability of different plant species to accumulate metals from the soil. If plants are planted on soil with high content of heavy metals they will absorb and accumulate them in productive organs (fruits or aboveground biomass). The use of such plants for the feeding of domestic animals causes them to be contaminated with heavy metals as well. Meat, milk and eggs of domestic animals fed with such vegetable food will be of low quality and will have a high content of heavy metals (Mitkova et al., 2005).

CONCLUSION

Degraded soil contained significantly higher concentration of cadmium (Cd) than maximum allowed border values for agricultural soil while other tested elements were within the allowed border values. In the soli degraded by mining activity, the content of cadmium (Cd) gradually decreased, but it's content was still above maximum values allowed for agricultural soil.

The analysis of green mass content in mixtures I/G, II/G, III/g and IV/G established that orchard grass (*Dactylis glomerata* L) was dominantly represented compared to other components in the mixtures. The *Italian raygrass* was dominant in the III/G mixture. The participation of other species in the mixtures was extremely low. Legouminous plants were represented in a small percentage in every mixture's green mass.

The biggest plant cover of the soil was achieved with the IV/G mixture (88.4%), which also had the biggest average of green mass yield. The determined values of heavy metals and microelements contents were in the allowed limits.

The nitrates affected the decrease in copper (Cu) and chrome (Cr) content in the soil and cadmium (Cd) content in the plant's dry mass.

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