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POSSIBILITY OF GROWING RYE ON DEGRADED SOIL OF OPEN PIT MINES IN THE PROCESS OF BIOLOGICAL RECULTIVATION

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Abstract

To avoid negative effects of open pit mining development, mining activities should be accompanied with biological recultivation of waste dumps and rehabilitation of degraded areas in order to establish different vegetation and other ecosystems on newly created deposols. The goal of this research is to identify possibilities for rye production in these areas, having rye as a rotating crop. Some amelioration practices were applied before planting, such as: lime treatments combined with different rates of mineral fertilizers (200 and 400 kg ha^{-1} of NPK) and treatments with no lime application with 200 and 400 kg ha^{-1} of NPK. Side dressing was carried out in spring with 200 and 400 kg N ha^{-1}. After sampling, in order to speed up the recultivation process, the biomass was mown, chopped and ploughed into the surface layer of deposol. The rye yields ranged 2.30-2.59 tha^{-1} were obtained on ameliorated deposol using pre-planting lime application combined with 200 and 400 kg ha^{-1} of NPK mineral fertilizers and 400 kg N ha^{-1} side dress. The treatments without pre-planting lime application yielded 0.95-1.85 tha^{-1}. Considering economic efficiency, it is recommended to use 200 kgha^{-1} of NPK and 200 kg N ha^{-1} side dress.

Key words: *Biological recultivation, degraded soil, yield, rye.*

Introduction

The development of open pit mines as energy-industrial complexes has many negative effects on environment, which obliges people to do integration planning, to revitalize and rehabilitate degraded areas and use them in the post exploitation period. Recultivation and restructuring of the furrow surface provide many opportunities (*Dražić,* 2011). To avoid negative effects of open pit mining development, mining activities should be accompanied with biological recultivation of waste dumps and rehabilitation of degraded areas in order to establish different vegetation and other ecosystems on newly created deposols. Many research studies have shown (*Alen,* 2000*; Hadžić et al,* 2001*; Lončar,* 2009*; Malić et al,* 2009) it is possible to establish new agricultural, forest, aquatic, meadow and other ecosystems in such degraded areas. *Bolinder et al* (2002) pointed out that mineral resources are one of the main factors in the development of a society. However, mining activities in open pit coal mines have many potential effects on the quality of surface and underground water, soil, flora and fauna, etc. Waste is disposed of in an external waste dump until the space for an inner waste dump is provided in one particular open pit mine or in adjacent ones. Nowadays, the development of mines is planned according to their exploitation rate. Unlike old, relatively small open pit mines, today's mines are built to provide optimal and continual ore exploitation, which means they occupy vast land areas due to growing needs for fuels and the development of mining techniques and technologies (*Resulović et al*, 2008). The main goal of recultivation is not to achieve the condition similar to a pre-exploitation one but to revalorize the soil, meet the needs of local people and satisfy natural conditions. Biological recultivation includes a set of biotechnological, agro-technical, ameliorative and other practices for restoring fertility to damaged soils, disturbed ecosystems and landscapes (*Spasić et al*, 2005). Biological practises are applied in the last phase of recultivation. To speed up the recultivation process, it is necessary to apply large amounts of organic and mineral matter and therefore compensate for the lack of nutritional elements, especially nitrogen and phosphorus (*Dražić,* 2011). The selection of plants for recultivation depends on many factors. Some of them are soil degradation level, and its pedological properties, climatic conditions, future use of land and agro-ecological requirements of a plant species. When it comes to soil recultivation, rye is a widely used plant species because of its modest environmental requirements. Rye is distinctive for modest water and land requirements and its tolerance to low temperatures (*Glamočlija et al,* 2010). This is the reason why rye is grown within the program of recultivation of open pit mines, which combined with new mining technologies provide optimal ore exploitation with a minimum adverse impact on the environment. Rye can be used in biological recultivation as a siderate (green fertilizer) and for grain production, using plant residues for humification.

Materials and methods

The research was conducted from 2009 to 2011 on the degraded soil (deposol) in the Stanari coalmine. A two-factorial trial was set up using randomized block design with four replicates. The size of the plot was 20 m^2 (5 x 4 m). Agro-chemical parameters of soil fertility of deposol were also analysed. The trials started with planting (during the first ten days of October) grains of Oktavija rye variety, selected at the Agricultural Institute in Banja Luka. The factor A included ameliorative practises applied on deposol before planting, such as: lime treatments combined with different rates of mineral fertilizers (200 and 400 kg ha^{-1} of NPK) and treatments with no lime application with 200 and 400 kg ha^{-1} of NPK. Lime of 85-90% Ca was applied. The factor B included 400 and 200 kg N ha^{-1} side dress (N_{400} and N_{200}) and control (N_0) without applying side dress fertilizer. At the end of dormant period, single-pass side dressing was applied with 400 and 200 kg N ha^{-1}. In the stage of technological maturity, grain was manually harvested and yield was measured with a method of counting the number of grain per plant from a determined plot. After sampling, the biomass was mown, chopped and ploughed into the surface layer of deposol. The data were analysed with the statistical package STATISTICA 8 for Windows (StatSoft).

Results and discussion

The agrochemical analysis showed (Table 1) high acidity of the soil from the trial plot, pH in nKCl 4.6. *Veselinović* (1995), *Resulović et al* (1999) and *Malić et al* (2011) pointed out that the acidity of deposols was higher in the Stanari than in Kolubara mining area, but lower than in the Majdanpek mining area. The soil had a very low percentage of organic matter and humus and no nitrogen salts in the surface layer. For its content of easily available phosphorus and potassium, it is classified in a category of very low availability. According to many authors, most technogenic soils contain very few nutritive elements (NPK) and organic matter and therefore have weak biological activities in their surface and deeper levels (table 1).

Table 1. Agro-chemical properties of soil fertility of deposols

Values	pH		Organic matter (%)	Humus (%)	N (%)	Easily available forms	
	N_2O	KCl				P_2O_5 mg/100g	K_2O mg/100g
	5.8	4.6	1.6	0.01	0.0	0.38	1.94

The results of average rye yields for the tested periods are shown in the Table 2 and Table 3. Rye yields mostly depend on nitrogen rates and pre-planting ameliorative practises applied.

Table 2. Average rye yield in the vegetation period 2009/10 (tha^{-1})

Lime application + starter (factor A)		Yield compared to the yield with nitrogen side dressing applied (factor B)			$\bar{X}_{(A)}$
		N_{400}	N_{200}	N_0	
5 t/ha $CaCO_3$+200 $kgha^{-1}$ NPK 15:15:15 ($N_{30}P_{30}K_{30}$)		2.30	1.10	1.00	1.46
5 t/ha $CaCO_3$+400 $kgha^{-1}$ NPK 15:15:15 ($N_{60}P_{60}K_{60}$)		2.39	1.05	0.50	1.31
200 $kgha^{-1}$ NPK 15:15:15 ($N_{30}P_{30}K_{30}$)		1.35	1.60	0.60	1.18
400 $kgha^{-1}$ NPK 15:15:15 ($N_{60}P_{60}K_{60}$)		1.53	0.95	0.20	0.89
$\bar{X}_{(B)}$		1.89	1.17	0.57	-
Basic factors:		A	B	AB	
Analysis of variance – $F_{calculated}$		12.00**	11.86**	2.90**	
LSD	0.05	0.35	0.57	0.32	
	0.01	0.65	0.58	0.46	

N_0- control; N_{200}- 200 kg N ha-1 side dress; N_{400}- 400 kg N ha-1 side dress

Applied nitrogen rates had a significant effect on the increase in rye grain yields. The lime application affected the nitrogen side dressing both directly and indirectly, as well as the change in pH, which has a very important role in many soil processes and crop nutrition. Deposols are soils of very acid to medium acid reactions. To mitigate negative effects on an ecosystem, the recultivation process should be speeded up. Thus *Zhelceva-Bogdanova* (1995) pointed out that use of mineral fertilizers and sideration are the best way for improving chemical properties in the recultivation process.

Table 3. Average rye yield in the vegetation period 2010/11 (tha^{-1})

Lime application + starter (factor A)		Yield compared to the yield with nitrogen side dressing applied (factor B)			$\bar{X}_{(A)}$
		N_{400}	N_{200}	N_0	
5 t/ha $CaCO_3$+200 $kgha^{-1}$ NPK 15:15:15 ($N_{30}P_{30}K_{30}$)		2.56	1.55	1.04	1.72
5 t/ha $CaCO_3$+400 $kgha^{-1}$ NPK 15:15:15 ($N_{60}P_{60}K_{60}$)		2.59	1.25	0.63	1.49
200 $kgha^{-1}$ NPK 15:15:15 ($N_{30}P_{30}K_{30}$)		1.85	1.60	0.75	1.40
400 $kgha^{-1}$ NPK 15:15:15 ($N_{60}P_{60}K_{60}$)		1.83	1.01	0.35	1.06
$\bar{X}_{(B)}$		2.20	1.35	0.69	-
Basic factors:		A	B	AB	
Analysis of variance – $F_{calculated}$		12.40**	12.98**	3.24**	
LSD	0.05	0.49	0.77	0.44	
	0.01	0.83	1.78	0.66	

N_0- control; N_{200}- 200 kg N ha-1 side dress; N_{400}- 400 kg N ha-1 side dress

The highest rye yield (2.30-2.59 tha^{-1}) was achieved with pre-planting lime application combined with mineral fertilizers of 200 and 400 $kgha^{-1}$ of NPK and 400 kg N ha^{-1} side dress in both years of research. There was a significant difference in rye grain yields between the treatment with lime application and the ones without it. When it comes to the treatments in which mineral fertilizers were used without prior lime application, the yield ranged 0.95-1.85 tha^{-1}. In both years the highest yield (1.85 tha^{-1}) was achieved in the fertilization variant with 400 kg N ha^{-1}, and the lowest in the control. However, having in mind also economic efficiency of using different rates of mineral fertilizers in treatments without lime application, it is better to use 200 $kgha^{-1}$ of NPK and 200 kg N ha^{-1} side dress.

The comparison of the rye yields showed that higher yields had been obtained in the second year of the research, which makes sense because nitrogen fertilizers had a favourable effect on increasing the content of mineral matter in soil and consequently on higher yields. According to the results shown by *Bolinder et al*. (2002), ground biomass and roots of perennial papilionaceaes significantly improve physical and chemical properties of degraded soils. *Hadžić et al* (2001) and *Dražić* (2011) found that using higher rates of organic matter and mineral fertilizers (especially nitrogen and potassium) had a favourable effect on recultivation processes. Genetic potentials of this particular rye variety are much higher (*Mandić and Đurašinović*, 2009), thus even better results could be expected from quality recultivation of deposols and using proper agro-technical practises.

Conclusion

Growing rye on technogenic soils gives good results, mostly because of its superiority, resistance, adaptability, and productivity. Significant differences in rye yields have been noted between the treatments with lime application and treatments without it. Those differences show statistical significance. The highest rye yields ranged 2.30-2.59 tha^{-1} were obtained during both years of research on ameliorated deposol using pre-planting lime application combined with 200 and 400 kg ha^{-1} of NPK mineral fertilizers and 400 kg N ha^{-1} side dress. The treatments without pre-planting lime application yielded 0.95-1.85 $kgha^{-1}$. Considering economic efficiency, it is recommended to use 200 $kgha^{-1}$ of NPK and 200 kg N ha^{-1} side dress. The process of deposol recultivation should be speeded up to diminish its negative effects. One of the best methods to improve chemical properties in the recultivation process is to use mineral fertilizers. The organic matter in deposols in Stanari is still one of the biggest issues, so future research should be focused on increasing organic matter in the surface layer of deposols and forming a more favourable adsorption complex.

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