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EFFECTS OF LONG-TERM FERTILIZATION ON YIELD OF SIDERATES AND ORGANIC MATTER CONTENT OF SOIL IN THE PROCESS OF RECULTIVATION

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ABSTRACT

The aim of this research was to determine the possibility of increasing organic matter content in humusless deposol topsoil and forming of a more favourable adsorptive complex by introducing green manure. Green manure biomass came from these compound plant species: winter rye + common vetch, forage pea + rapeseed mustard and Sudan grass. Compound feed was sown on degraded soil (type deposol) of the Stanari coal mine. Applied cultivation practices included primary and secondary tillage and additional plant nutrition. Mineral fertilizers were applied: NPK 7:20:30 (400 kg ha^{-1}) and CAN 27% (200 kg ha^{-1}). One of the treatments included addition of bentonite clay as absorbent of nutrients. During intensive vegetation the growth of the green biomass was measured, the crops were harvested, cut and ploughed in deposol topsoil. Organic matter content in deposol was determined when soil samples were taken 6 months after green manure incorporation. The results show that the mineral fertilization of siderates significantly increased green biomass yield and Sudan grass gave two cuts, which positively affected the increase of organic matter content in soil.

Key words: *mixtures; degraded soil; mineral fertilizers; biomass yield; organic matter content.*

INTRODUCTION

Ore minerals are one of the main factors of industrial development, but strip mining can have negative effects on the quality of surface and underground waters, soil, flora and fauna. During strip mining, overburden is continually placed on surrounding arid soil as ample area is formed for excavation (Drazic 2011). Demand for ores is ever increasing. Authors Resulovic *et al.* (2008) state that present exploitation of solid fuels is governed by their increased use which causes considerable increase of arid soil surrounding strip mines being covered by overburden, as opposed to previous practice of rather small strip mines. Most profound negative consequence of strip mining is the formation of large areas of degraded soil, most characteristic of which are deep craters and open overburden landfills.

These newly-formed technogenic soils (deposols) need to be recultivated in order to diminish the negative effects of strip mines and enable them to be used for other purposes. This recultivation process includes monitoring mining activities, taking biological measures of rebuilding over burden land fill sand reformation of degraded soil so as to establish different vegetation areas and other ecosystems on the newly-formed deposols. Authors Allen (2000), Loncar (2009) and Lal (2015) show that by proper choice of recultivation technology degraded soils of strip mines can be transformed into new grass, agricultural, forest, aquatic and other ecosystems.

The process of deposol recultivation should be urged to decrease the harmful effects on the ecosystem. Lal (2015) state that the soil organic carbon pool, its amount and depth-distribution along with turnover and mean residence time, is a critical component of soil quality and source of numerous ecosystem services. Re-carbonization of the depleted soil organic carbon pool, which is essential to numerous functions, requires regular input of biomass-C and essential elements (i.e., N, P, and S)

Choice of plant species to be used as siderates for recultivation greatly affects improvement of physical and chemical properties of deposols. Živkovic *et al.*(2013) confirms that the production of forage crops can be successfully organized on recultivated land, but the yields obtained are lower than the yield obtained on arable land. The level of forage yield very significantly depends on forage species, the exploitation phase and their interaction.

Drazic (2011) concludes that the use of larger quantities of organic matter and mineral fertilizers (especially nitrogen and phosphorus) have very favourable effect on the recultivation processes. Effect of organic and mineral matter used for recultivation depends on weather conditions (annual precipitation quantity and distribution). Krümmelbein *et al.* (2010) who studied soil recultivation on strip mines of the mining areas in Germany, state that recultivation efforts attempt to regenerate mining areas for new agricultural land use options. Nitrogen is the most limiting nutrient in the soil. Adequate supply of nitrogen to crops is fundamental to optimize crop yields, mismanagement of nitrogen, such as excessive N application results in contamination of ground water (Jamil *et al.,* 2017; Zaman *et al.,* 2018).

Aim of this research was to determine the possibility of increasing organic matter content in humusless deposol topsoil and to form a more favourable adsorptive complex by introducing siderates, or green manure and growing siderates whose roots have beneficial effect on soil structure besides general increase of soil organic matter.

MATERIALS AND METHODS

Experimental design: Two-factorial micro-trial (3x3) was set up as randomized block design with four replicates in the period 2009-2011. The trial included three mixtures: (A_1) rye, cv. Oktavija + common vetch, cv. Neoplanta, (A_2) rapeseed mustard, cv. PVH + forage pea, cv. NS Pionir, and (A_3) a single crop Sudan grass, cv. Piper sweet. The second factor was additional plant nutrition: (B_1) control, (B_2) 500 kg ha^{-1} of NPK 7:20:30 and 400 kg ha^{-1} of CAN (27% nitrogen) and (B_3) 500 kg ha^{-1} of NPK 7:20:30 and 400 kg ha^{-1} of CAN (27% nitrogen) and 250 m^3 ha^{-1} of bentonite clay used as nutrient absorbent. Manual sowing was performed in autumn and spring after soil tillage. Crops were harvested in the period of maximum plant organic production when biomass yield was determined. Crops were then cut and ploughed in topsoil. Winter crops (A_1 and A_2) were harvested in May, and Sudan grass (A_3) in July and October. Crops were grown in monoculture, and in the third year, six months after ploughing of siderates, soil samples were taken to determine organic matter content in deposol. Experimental data were processed via analytical statistics using STATISTICA 12 for Windows (Stat Soft).

Soil analysis: Three-year study (2009-2011) was carried out on deposol of external overburden landfill from strip mine Raskovac in Stanari, Republic of Srpska. By definition of Resulovic *et al.* (2008) this soil belongs to the type of deposol. It is classified in the VII class of terrestric (automorphic) soils – class of technogenic soils (technosols); I subclass – soil on modified natural substrate. Before trial was set up, five soil samples were taken from the site and agrochemical analyses were performed in the laboratory of Agricultural Institute in Banja Luka, B&H (Table 1).

Deposols are generally acid, so that the site soil was highly acid (pH in KCl 4.6) (Table 1).

Table 1. Agrochemical analysis of deposol fertility.

Parameters	pH		Organic matter, (%)	Humus (%)	N (%)	P_2O_5	K_2O
	H_2O	KCl				mg/100g	
Values	5.8	4.6	1.6	0.01	0.0	0.38	1.94

Veselinovic *et al.* (2010) point out that acidity of Stanari deposols is higher than Kolubara deposols, but considerably lower than deposols from copper mine Majdanpek. The soil had a very low percent of organic matter and humus, no nitrogen salts were found in topsoil, and content of readily-available phosphorus and potassium was very low. Many authors state that most technogenic soils contain very low basic nutrients (NPK) and organic matter resulting in low biological activity both in surface and deeper layers.

Heavy metals were found in all soil types as the result of parent material decomposition, but their concentrations were not as high so as to hinder plant growth. However, certain heavy metals can be found in deposols in higher quantities, e.g. Zn, Fe, Mo, Mn, Co, Cu and Se. Increased concentrations of these heavy metals are toxic for most plants, while cadmium and lead are phyto-toxic even in low concentrations (Table 2).

Table 2. Total content of heavy metals in the soil, mg kg^{-1} (ppm).

Element	Pb	Cd	Cu	Zn	Fe	Mn
Values	15.8	< 1	18.8	38.7	306.8	229

Chemical analyses of soil samples showed high concentrations of iron, manganese and lead. Content of other heavy metals was below maximum allowable concentration determined by Regulation on allowable concentration of dangerous and harmful materials. When these values are below potentially harmful, such elements present plant assimilates (Malic *et al.* 2011). The results demonstrate that lead concentrations in the dust from different sites of Karachi, Pakistan were significantly different, $p < 0.001$ (Farid *et al*., 2017).

RESULTS AND DISCUSSION

Green biomass yield: The end result of this research was increased organic matter content in topsoil of humus less deposol resulting from incorporation of siderates green biomass. Three-year average yield of green biomass ranged between 1.13 t ha^{-1} and 79.25 t ha^{-1}. Mineral nutrients and plant species grown as siderates caused statistically significant variations of the yield (Table 3).

Application of NPK fertilizers and bentonite clay increased significantly the yield of green biomass from 2.2 t ha^{-1} in control to 41.75 t ha^{-1} in the third variant. The effects of mineral fertilizers application were highest in Sudan grass crop, which is in accordance with Ikanovic *et al.* (2010). Bentonite clay applied in nutrition did not cause the increase of green biomass yield in group treatments, but differences were significant in individual treatments. Bentonite clay significantly contributed to the effect of mineral nutrients on green biomass yield in mixes rye + vetch and pea + rapeseed mustard. Value of green biomass yield depended on plant species used as siderates. The lowest values in all nutrition variants were achieved by mix forage pea + rapeseed mustard, significantly higher by mix rye + vetch, and the highest by Sudan grass.

Table 3. Average three-year yield of siderates green biomass, t ha^{-1}.

Nutrition (B)		Siderates (A) 1. Rye+vetch	2. Pea + rapeseed mustard	3. Sudan grass	$\bar{X}_{(B)}$
1.Control ($N_0P_0K_0$)		2.10 ±0.16	1.13 ±0.22	3.50 ±0.85	2.20
2. ($N_{143}P_{100}K_{150}$)		30.00 ±1.87	9.50 ±1.8	79.00 ±1.58	39.50
3. ($N_{143}P_{100}K_{150}$+ bentonite clay)		35.00 ±3.08	11.00 ±2.4	79.25 ±0.96	41.75
$\bar{X}_{(A)}$		22.36	7.16	53.92	-
Basic factors		A	B	AB	
Analysis of variance – $F_{calculation}$		33.175 **	28.785 **	74.82 **	
LSD	0.05	3.38	2.76	7.415	
	0.01	5.57	4.18	11.768	

Recultivation of deposols and restoration of soil for agricultural production at strip mining coal mine sites can be performed by application of different organic matters (manure, compost and other organic waste), according to Krümmelbein *et al.* (2010). However, the authors give preference to growing siderates whose roots have beneficial effect on soil structure, in addition to the general increase of soil organic matter.

Intensified deposol recultivation in mining areas of Serbia was aided by combined application of mineral fertilizers and growing siderates, as reported by Živkovic *et al.* (2013)

Sudan grass was preferred since it is more tolerant to drought and high temperatures in summer. Aside from the fact that they grow well on degraded soils, Sudan grass and hybrids Sudan grass and sorghum give two to three cuts in a year under intensive fertilization and depending on water regime (Ikanovic *et al.* 2010, 2011; Glamoclija *et al.,* 2011). In their long-term research on the effect of various cultivation practices on the regeneration of volcanic ash soils, Podwojewski *et al.* (2008) conclude that introduction of siderates into crop rotation significantly enhanced chemical and physical soil properties. The effect of applied cultivation practices (Popovic *et al.* 2011 and 2013; 2016; Khan *et al.* 2016 and 2017; Terzic *et al.* 2017 and 2018; Đekić *et al*. 2018; Lakić *et al*. 2018; Ikanović *et al*. 2018) and level of plant yield (barley, maize, triticale, pea and vetch) significantly depend on precipitation quantity and distribution, because such soils quickly lose water from rhizosphere due to low organic matter quantity and unfavourable physical soil properties, which is in accordance with Jakšić *et al.* (2013), Đekić *et al*. (2014) and Sikora *et al.* (2015). The study revealed that application of N, P and K was crucial for maintaining long-term yield and yield trend. In the process of soil recultivation, rye used as a siderate has advantages over most annual plants because it also uptakes and neutralizes heavy metals that are leached into deeper layers of soil, apart from giving high biomass yield (Bolinder *et al.* 2002).

Content of soil organic matter: After three-year trial of growing combinations of siderates on strip mine deposols in Stanari, organic matter content was analysed in soil samples. The results showed that organic matter content increased as compared to the initial state (Table 4).

Average organic matter content before trial was 1.6%. At the end of the three-year trial of ploughing green biomass, the content of organic matter increased by 0.8% in the variant without NPK mineral fertilizer application as compared to initial state. In the variant with NPK bentonite clay application it increased by 3.87%. Mineral fertilization of siderates significantly increased the yield of green biomass, and Sudan grass gave two cuts, which positively affected the increase of organic matter content in soil.

Table 4. Average content of deposol organic matter, %.

Nutrition (B)		Siderates (A) 1. Rye + vetch	2. Pea + rapeseed mustard	3. Sudan grass	$\bar{X}_{(B)}$
1. Control ($N_0P_0K_0$)		2.95 ± 0.76	2.58 ±0.38	1.70 ± 0.33	2.40
2. ($N_{143}P_{100}K_{150}$)		5.13 ± 0.6	3.10 ± 0.87	7.50 ± 1.02	5.24
3. ($N_{143}P_{100}K_{150}$+ bentonite clay		5.10 ±0.43	3.63 ±1.01	7.70 ± 1.13	5.47
$\bar{X}_{(A)}$		4.39	3.10	5.63	-
Before sowing					1.60
Basic factors:		A	B	AB	
Analisys of variance – $F_{calculation}$		1.984 **	3.603 **	9.72 **	
LSD	0.05	3.38	2.76	6.816	
	0.01	5.57	4.18	11.798	

High genetic yield potential and high dry matter content in the above-ground biomass of Sudan grass is highlighted by Ikanović *et al.* (2010). Comparing the grain yields in recultivated land with yields obtained on the arable land, the yields achieved on the recultivated land were lower by 15-30% depending on the crops. The highest yield was achieved in variants with the use of manure fertilization (Živković *et al.* 2013).

Incorporated quantity of siderates organic matter during agro-technical recultivation provides gradual formation of reclaimed deposol and decreases concentration of heavy metals by inactivation, according to Malić *et al.* (2011).

Mixed cropping are more effective over pure with regard to the use of resources for plant growth and nitrogen transfer from legume to grasses (Jani *et al.*, 2016; Vasileva 2017 and Vasileva *et al.*, 2012). More stable productivity of plant biomass was obtained in mixtures. Higher productivity was found with the treatments of mixtures, i.e., for dry above ground biomass, by 20.4%, and for dry root biomass, by 25.4%, respectively (Vasileva *et al*., 2017).

Conclusions: The end result of this research was increased organic matter content in topsoil of humus less deposol as a result of the incorporation of green manure of siderates. Three-year average yield of green biomass ranged between 1.13 t ha^{-1} to 79.25 t ha^{-1}. Sudan grass gave two cuts, which positively affected the increase of organic matter content in soil.

Green biomass yield depended on plant species used as siderates. The least values in all nutrition treatments were achieved by forage pea and rapeseed mustard mix, significantly higher values were achieved by winter rye and common vetch mix and the highest by Sudan grass.

Mineral nutrition of siderates significantly increased the yield of green biomass.

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