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Influence of fertilisation with sewage sludge-derived preparation on selected soil properties and prairie cordgrass yield

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ABSTRACT

The aim of the study was to evaluate the effect of using a fertilizer obtained from waste substances on selected physical and chemical properties of soil and biomass yield *Spartina pectinate*. The fertilizer used for soil (C) fertilisation contained sewage sludge (SS), waste soil fractions of brown coal (BC), brown coal ash (BCA) enriched with mineral potassium (K) fertilizer (C + SS + BC + BCA + K). The composition of the preparation was developed by the authors and adjusted to the quality of the fertilised soil and the individual characteristics of the plant. It was assumed that the preparation should replace expensive conventional fertilisation methods, allow for management of waste substances and improve soil properties, leading to a high yield of *Spartina pectinata* used as energy crop. The plants were grown on the soil from the Huta Częstochowa steelworks effect zone. The soil was light, with acid reaction (pH_{KCl} = 5.5), with small contents of such contaminants as Cd and Zn and elevated Pb content. Based on a three-year pot experiment, the paper presents the results of the examinations concerning the effect of fertilisation on soil pH, hydrolytic acidity, sorptive properties, content of humic acids, organic coal and total nitrogen in soil and crop yielding.

The effect of the use of the fertilizer (C + SS + BC + BCA + K) was compared with the use of the sludge (C + SS), sludge with mineral fertilizers (C + SS + NPK), mixture of brown coal and mineral fertilizers (C + BC + NPK) and effect of only mineral fertilizers (C + NPK).

Fertilisation with (C + SS + BC + BCA + K) led to the increase in soil pH from 5.5 to 6.0, which is considered sufficient for light soils. The fertilised soil was characterized by sorption capacity of ca. 5.8 cmol(+)/kg, and, after fertilisation with O + W + P, reached the value of ca. 8.0 cmol(+) kg^{-1}. Consequently the soil can be regarded as of good quality in terms of its capability to store nutrients. The C:N ratio was also extended from 11:1 (control soil) to 14:1 (C + SS + BC + BCA + K). The yield of *Spartina pectinata* in the first year was 1.6 and in the third year 2.7 times higher in the case of fertilisation with the investigated mixture as compared to the control.

1. Introduction

This study presents opportunities for management of light and acid soils with slight content of cadmium and zinc contaminants, with elevated content of lead, which are barren and located in the steelworks effect zone. According to the recommendations of the ecological policy, these soils should be subjected to reclamation and used for non-food crop production. The problem of soil contamination and degradation concerns many regions of the world (Ravisankar et al., 2006; Karczewska and Kabała, 2010; Gomiero, 2016). Many authors have emphasized that one of the effective initiatives is to use these soils to grow energy crops (Ociepa et al., 2008; Aronsson et al., 2014; Serapiglia et al., 2013). Studies have demonstrated that *Spartine pectinata* can be grown on soils with low fertility, but the plants require the relatively intensive fertilisation with NPK fertilizers with the yearly amounts of N: 100–170, P: 60–80, K: 100–120 kg/ha, leading to high costs (Kowalczyk-Juśko et al., 2004). Furthermore, production of nitrogen-based and phosphorus-based fertilizers is very energy-consuming, which leads to reduction in energy benefits. Production of mineral fertilizers additionally generates several ecological problems. Therefore, from the economic and ecological standpoint, various types of waste should be used as a source of nutrients for plants used as energy crops.

The application of a fertilising mixture (C + SS + BC + BCA + K) consisting of sewage sludge (SS), waste earthy fraction of brown coal (BC), ash produced from brown coal (BCA), and enriched with potassium mineral fertilizer (K) was a recommended solution for soil reclamation. The composition of the mixtures and the recommended

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doses were determined and tested by the author of this study. The composition and doses of this fertilising mixture were adjusted to the plant demands (*Spartina pectinata),* soil quality and current legal regulations.

Sewage sludge can be used for fertilisation as it contains nutrients and organic substances which are valuable for plants. The value of sludge fertilizers has been presented in numerous studies (Gasco et al., 2004; Ociepa-Kubicka et al., 2016; Suhadolc et al., 2010; Wolski and Zawieja, 2014). However, its biological use is possible only if stringent regulations are met (The Regulation of the Minister of the Environment on municipal sewage sludge of 6 february 2015), as it may contain high amounts of heavy metals and be an organic and microbiological pollution carrier (Kacprzak and Fijałkowski, 2009; Pachura et al., 2016). A potential solution to the reduction of the threats resulting from the application of the sewage sludge is to mix the sewage sludge with brown coal and brown coal ash. The chemical composition and porous structure of brown coal – which results in high sorption properties – allow for the application of earthy forms of brown coal in soil fertilisation. Another important property of brown coal is its durability and susceptibility to microbiological degradation. Brown coal ash is a valuable and rich source of calcium, magnesium and microelements. Brown coal ash introduced to soils increases the sorption complex capacity, water holding capacity and pH of acidic soils (Kwiatkowska, 2007).

The aim of the examinations presented in this paper was to determine the effect of fertilisation with preparation made of sewage sludge, brown coal, brown coal ash enriched with potassium fertilizer on soil properties and *Spartine pectinata* yielding. The following research theses were presented before the examinations:

- agriculturally poor soils, contaminated with heavy metals, acidified and barren, can be reclaimed by addition of waste substrates and used as energy crops.
- a mixture of sewage sludge, brown coal and brown coal ashes enhanced with potassium fertilizer has a beneficial effect on soil properties and *Spartine pectinata* yielding.

The results obtained in the study represent the extension and supplementation of the knowledge concerning:

- physical and chemical modifications of soil properties, development and yielding of *Spartine pectinata*,
- opportunities for biomass generation for the purposes of renewable energy using unconventional fertilisation methods,
- the use of sewage sludge and waste fraction of brown coal and brown coal ashes for soil fertilisation.

2. Materials and methods

2.1. Description of the pot experiment

The examinations were based on the analysis of soil and plant samples obtained from a pot experiment. The fertilising substrates (Table 1) were added to the bottomless PVC pots (inserted in the soil) with the diameter of 30 cm and height of 80 cm, containing 40 kg of soil. Six fertilising combinations were used, with each combination repeated in three pots. The soil for the pot experiment was obtained from the area located around 1 km north-east of the Huta Częstochowa steelworks. The depth of soil sampling ranged from 0 to 25 cm. Thirty individual samples were obtained to prepare the averaged sample from one area. The number of individual samples was adjusted to the size of the field (1500 m^2). The results presented in the study are the mean value of three measurements of the average sample used in the analysis.

The pots were filled with soil in the state of its natural humidity, previously sieved using a sieve with mesh size of 5 mm. The fertilizer doses were determined based on the plant demand for nutrients (with particular focus on nitrogen and phosphorus) and soil nutrient abundance. The principles of good agricultural practices were used in order not to cause excessive fertilisation (damages from the standpoint of environmental protection, plant yielding, high costs of cultivation). Differences in the level of fertilizer doses result from different chemical composition of individual substrates. Similar doses of basic nutrients (nitrogen, phosphorus, potassium) were used to compare the effect of different types of fertilisation on the plants tested.

Two seedlings of *Spartina pectinata* were planted in each pot. In the first year of the pot experiment – before planting the seedlings – single doses of the following substances were applied: sewage sludge, brown coal, brown coal fly ash and mineral fertilizers. During the next two years of the pot experiment, mineral fertilisers (the doses of fertilisers are provided in Table 1) were used each spring before the onset of plant vegetation. The samples of soil and plant biomass were obtained during and after completion of the pot experiment. Clean plant biomass from each pot was divided into above-ground and underground parts, and then dried and ground in a laboratory grinder. Prior to further analysis, the plant biomass samples were stored in airtight containers.

2.2. Characteristics of soil and fertilising substrates

Analysis of the granulometric soil composition showed that, due to the content of floatable fractions (< 10%) and according to the criteria specified by the Instytut Uprawy, Nawożenia i Gleboznawstwa Puławy, this soil should be categorized as very light. With reference to the structure of soil profile and the analysis of soil maps, the soil used for the experiments showed the characteristics of lassie top gelyic soil and belonged to the granulometric group of slightly loamy sand with acidic reaction. The soil was acid with pH 5.5.

Table 2 presents characterization of soil and substrates used in the experiment.

Fertilising mixtures were prepared from the sewage sludge collected from a mechanical and biological municipal wastewater treatment plant. Sewage sludge (SS) was stabilized, dewatered, and characterized by slightly acidic reaction, high content of organic matter and relatively low content of heavy metals. Sewage sludge used for the experiment showed good fertilising properties due to the content of nitrogen and phosphorous. Physical, chemical and microbiological properties of sewage sludge allowed for the fertilisation of plants not intended for

Table 1
The investigated fertilisation combinations in the pot experiment.

Fertilisation combinations	Fertilisation type and dose
C	control – 40 kg of soil
C + SS	40 kg of soil + 2892 g sewage sludge (36 Mg d.m./ha)
C + SS + BC + BCA + K	40 kg of soil + 1736 g of sewage sludge + 308 g of brown coal + 80 g of brown coal ash (ok.36 Mg d.m./ha) + 2.0 g of potassium salt (100 kg/ha)
C + SS + NPK	40 kg of soil + 1448 g of sewage sludge (18 Mg d.m./ha) + 3.0 g *Polifoska 8* fertilizer + 2.0 g calcium ammonium nitrate + 1.0 g ammonium nitrate(300 kg/ha)
C + BC + NPK	40 kg of soil + 1024 g of brown coal (36 Mg d.m./ha) + 3.0 g *Polifoska 8* fertilizer + 2.0 g calcium ammonium nitrate + 1.0 g ammonium nitrate (300 kg/ha)
C + NPK	40 kg of soil + 6.0 g *Polifoska 8* fertilizer + 4.0 g of calcium ammonium nitrate + 2.0 g of ammonium nitrate (600 kg/ha)