Evaluation of Impact Beetroot Pulp Obtained as a By-Product of Sugar Production Has on Quality of Grey Forest Soil

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Abstract. This article studies the impact of beetroot pulp as a by-product of sugar production on the soil cover. The results of soil cover analysis and the nutritional properties of grey forest soil in Oryol Oblast show that beetroot pulp can be used as an organic fertilizer. The manganese content was within the MAC in all of the samples, however, the background value was exceeded, which means that manganese can accumulate in the soil. The plot in question is an increased-risk agricultural land susceptible to biological pollution and polluted with heavy metals. The overall soil cover pollution with manganese is at the average level. It is possible to use the pulp as an organic fertilizer on a long-term basis provided the content of heavy metals in the soil is strictly controlled.

1. Introduction
The agricultural industry is a crucial part of human life sustenance. The companies processing agricultural produce harm the environment, especially the soil cover [19].

According to the analytical service of Soyuzrossakhar, “183 thousand tons of beet sugar was produced in January 2021, which is three times lower than in January 2020 (547 thousand tons). The overall production of sugar in the season of 2020/21 is estimated to be 5.18 million tons, which is 1.5 times lower than the value for the preceding production season of 2019-2020 and also the smallest of the last five years” [12].

Sugar production is a very material-and-energy-consuming industry [21]. While the output is relatively small, there is a lot of by-products like pulp, plant material residues, molasses, lime cake, pulp and sugar dust, filter gases, etc. [4,18].

Today, the beet pulp disposal is one of the key environmental problems. Beet pulp is categorized as class five dangerous toxic waste [11]. Applying beet pulp to fields without the required processing and recycling results in global environmental problems [4,6]. The impacts the pulp has on the ecosystems are normally mitigated within 3 to 5 years.

According to S.A. Kolycheva, “beet pulp is spent beet chips (80-82% of the weight of the processed sugar beet with the solids content of about 6.5-7.0%). In terms of chemical composition,
fresh beet pulp (solids) contains 45-47% of cellulose, up to 50% of pectins, 2% of proteins, 0.6-0.7% of sugar, and about 1% of minerals, as well as vitamins and organic acids” [9,10].

The pulp obtained through the processing of sugar beet can be used as a valuable biological resource or animal feed, and it can be made into an organic fertilizer to be used in fields [1,2]. The restructuring of the agricultural industry resulted in the cattle stock reduction. “Sugar producers face a serious environmental problem of sugar by-product disposal, raw pulp in particular” [13,20].

Dry beet pulp contains vitamins, micro and macroelements, as well as organic substances. In general, it increases the biological activity of the soil, improves the nitrogenous nutrition of crops, and promotes the efficient uptake of minerals and organics [5].

Due to this, the purpose of the research work was to assess the impact the beet pulp has on the quality of grey forest soil.

The objectives of the research were as follows:
1. Assessing the impact of beet pulp on the nutritional properties of soils.
2. Identify the degree of manganese pollution of grey forest soil.

The research was carried out on a land plot, cadastral no. 57:11:0020301:535, located at the following address: Oryol Oblast, Mtsensky district, Otradinsky rural area, south of Kikino. The soil cover is grey forest middle loamy soil.

The analysis of the nutritional properties of the cropland was carried out using the data from Orlovsky Center for Chemization and Agricultural Radiology for 2018-2020. [14]. The analysis of the manganese content was conducted using the data from the Oryol branch of Central Scientific and Methodical Veterinary Laboratory (2020).

The study of the nutritional properties of the soil cover was carried out following the Guidelines on Comprehensive Monitoring of Soil Fertility for Agricultural Lands (Rosinformagrotekh, 2003) [8].

Soil samples were analyzed in compliance with the established procedures:
– GOST 26213-91. Soils. Methods for determination of organic matter.;
– GOST 26207-91 (GOST R 54650-2011). Soils. Determination of mobile phosphorus and potassium compounds by Kirsanov method modified by CINAO;
– GOST 26210-91 (GOST R 54650-2011) Soils. Determination of exchangeable potassium by Maslova method;
– GOST 26483-85. Soils. Preparation of salt extract and determination of its pH by CINAO method.

2. Results and discussion

To assess the impact of beet pulp on the nutritional properties of the soil, we took soil samples from 5 plots in 2018, 2019, 2020 and found average values for their parameters.

Samples 1 and 2 feature a steady accumulation of organic matter (humus) from 3% to 3.26% and 3.67% respectively between 2018 and 2020 (Figure 1).

Samples 4 and 5 show a reduction in the humus content in 2018 and 2019 from average to low, and then the increase by 2.3 and 2.1 times in 2019-2020. In Sample 3, the humus content was below average throughout the research period and fluctuated between 3.03 and 2.63%.
Figure 1. The humus content in the soil in 2018-2020, %.

Potassium is necessary for plant growth and development because it participates in the metabolism and determines the yield quality. Large amounts of potassium are taken out from cereal crop fields during harvesting. This calls for the monitoring of potassium content in the soil [15]. Dry beet pulp contains a decent amount of potassium (3.08 g/kg) (Figure 2).

Figure 2. The content of mobile potassium in 2018-2020, mg/100 g of soil.

The analysis of mobile potassium in the soil cover after the application of beet pulp showed that from 2018 to 2019 the content of potassium in Sample 4 reduced significantly from high to low levels (17.0 to 6.3 mg/100 g) and in Sample 5, it reduced to the average level (from 19.5 to 8.5 mg/100 g). By 2020, it increased by 13.9 mg/100 g in Sample 4 and 2 mg/100 g in Sample 5. In Samples 1 and 2, the content of mobile potassium in the soil increased from high to very high (17.6-25.2 and 20.3-25.2 mg/100 g of soil respectively). The high content of potassium was observed in Sample 1 even before 2020, and in Sample 2 it reduced dramatically from very high to average (a drop of 15.5 mg/100 g of soil).
soil). Sample 3 shows an insignificant reduction in mobile potassium from 2018 to 2020 (12.2 – 11.7 – 7.0 mg/100 g of soil).

The importance of phosphorus, along with humus and other macro and microelements, for the growth and development of plants and yield formation should not be underestimated. The content of phosphorus in dry pulp is 2.8 times lower than that of potassium. The character of mobile phosphorus accumulation in soil samples is shown in Figure 3.

![Figure 3](image_url)

**Figure 3.** The content of mobile phosphorus in 2018-2020, mg/100 g of soil.

Samples 1, 2, and 3 for 2018 and 2019 showed an increase in the content of phosphorus in the soil of 1.4; 1.6; 3.0 mg/100 g of soil and a reduction of 1.2, 9.5, and 5.7 mg/100 g of soil respectively by 2020. The significant fluctuations of the phosphorus content were observed in Sample 4 soil: from high to average (2018-2019), and then a rapid increase from average to high (2019-2020). Samples 1 and 5 had changes in the amounts of mobile phosphorus in soil throughout the entire research period but this figure remained high [3].

Sugar production wastes, including pulp, impact the acidity of soils, and their long use results in deoxidization. Soil Samples 3 and 5 had insignificant changes in the pH value over the three years of study. All samples taken between 2018 and 2019 featured an increase in soil acidity, which was later reduced by 2020. However, soil acidity remained close to neutral. In Sample 2, the soil reaction changed insignificantly and remained between 6.5-6.6 units (Figure 4).

Soil acidity increased because of the pulp application in Samples 1 and 4. Soil reaction changed from neutral to close to neutral 6.2-5.7 in Sample 1; 6.3-5.7 units. in Sample 4 (2018-2019). Then it was reduced to close to neutral (5.7 units) and then back to neutral (6.7 pH) (2019-2020).
Figure 4. Soil acidity in 2018-2020, pH units.

When used, sugar production wastes impact not only the content of macroelements and the reaction but may also provoke the accumulation of heavy metals, such as manganese, in soils [7]. Manganese is a Class 3 toxic element. To assess the degree of soil cover pollution with manganese caused by the application of beet pulp, we took 18 soil samples, including 2 reference ones (Table 1).

| Sample No | Content, mg/100 g of soil | Degree of pollution |
|-----------|---------------------------|---------------------|
| 1         | 6.25                      | 3.17                |
| 2         | 4.2                       | 2.13                |
| 3         | 5.61                      | 2.85                |
| 4         | 5.67                      | 2.88                |
| 5         | 2.27                      | 1.15                |
| 6         | 2.81                      | 1.43                |
| 7 (background) | **1.97**           | **1.00**            |
| 8         | 2.62                      | 1.33                |
| 9         | 3.94                      | 2.00                |
| 10        | 4.29                      | 2.07                |
| 11        | 3.15                      | 1.52                |
| 12        | 16.26                     | 7.86                |
| 13        | 10.59                     | 5.12                |
| 14        | 6.7                       | 3.24                |
| 15        | 5.14                      | 2.48                |
| 16        | 5.14                      | 2.48                |
| 17 (background) | **2.07**           | **1.00**            |
| 18        | 2.63                      | 1.27                |
| MAC≦100  |                           | Zc=27.98            |

The analysis of manganese content in the samples did not show any values exceeding the MAC but all of the samples studied had a 1.15-7.86 times increase in the background manganese content. The aggregate manganese pollution of the soil cover Zc=27.98, which stands for average pollution as
compared to the background values [16,17]. It is possible to use beet pulp as an organic fertilizer provided the content of heavy metals in the soil is strictly controlled.

3. Conclusions
The obtained assessments of the beet pulp impact on the quality of grey forest soil make it possible to use it as an organic fertilizer, provided that the content of heavy metals and nutrients, as well as soil acidity, are controlled.

The analysis of nutrient content in cropland between 2018 and 2020 showed that they accumulated unevenly. Only Sample 4 showed a steady accumulation of humus, mobile phosphorus, and exchangeable potassium. In terms of humus content, four out of five samples showed an increase in organic matter. The application of beet pulp to the topsoil resulted in changes in soil acidity with beet pulp pH of 6-8. The content of nutrients reduced dramatically and soil acidity changed by 2019 and then increased in 2020. Beet pulp is a good agricultural solution that helps increase the content of plant nutrients in the soil.

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