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THE USE OF WASTE FROM THE PRODUCTION OF GRAVEL AS FERTILIZER FOR CULTIVATION OF TECHNICAL ENERGY CROPS

The object of research is the process of management and treatment of crushed stone production waste. Modern approaches to the disposal of crushed stone production waste are analyzed. It is revealed that crushed stone production wastes are mainly used in the construction industry, and their volumes of use are insufficient to neutralize the impact of dumps on the environment. The chemical composition of crushed stone production wastes was analyzed and an experiment was carried out to determine the possibility of their use as fertilizers for the cultivation of industrial energy crops. For the experiment, an energy crop was chosen – sorghum. Sorghum seeds were placed in two types of soil: regular peat substrate and peat substrate with the addition of rock in a ratio of 60:40. Waste from crushed stone production – rock, which includes: quartzite – 90–98 %, pyrophyllite – 1–9 %, ore mineral – 0.3–1 %. The results of the experiment showed an increase in the biomass of sorghum grown on a peat substrate with the addition of rock, 1.5 times, compared with that grown on a conventional peat substrate. Accordingly, the energy yield of sorghum per hectare of field will also grow by 50 %. In addition to increasing the biomass of sorghum, as a result of the experiment, an increase in the number of secondary and tertiary roots was found when it was grown on a peat substrate with the addition of rock. A more developed root system allows the plant to receive more moisture and nutrients, thereby increasing its endurance and drought resistance. The results obtained can be explained by the positive effect of silica, of which more than 90 % of the rock is composed, on the growth and development of plants. It is proposed to increase the level of environmental safety of mining regions through the use of crushed stone waste as fertilizers for industrial energy crops and the transition to alternative energy sources, in particular biofuels made on the basis of these crops.

Keywords: *utilization of rock dumps, energy characteristics of sorghum, physicochemical characteristics of sorghum.*

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1. Introduction

The mining industry is one of the main air pollutants. During mining operations, a significant amount of dust and gases enters the air. The main sources of inorganic dust emission during opencast mining are the following technological processes: well drilling, blasting operations, excavation and loading operations, transportation of rock mass, crushing, dumping. Among the pollution processes, an important place is occupied by dumping and, as a result, dusting of dumps [1]. Today, crushed stone production waste is mainly used in the construction industry [2–4], which is insufficient to neutralize the impact of dumps on the environment. The chemical composition of the rock makes it possible to use crushed stone production wastes in many other sectors of the economy [5], including the strategically important energy one.

Until now, traditional fuels prevail in the structure of the world's energy balance, in particular oil, coal, peat, shale, natural gas, which negatively affects the level of world energy security and the state of the natural environment [6]. This situation will intensify the search for alternative energy sources, in particular the development of bioenergy projects that involve the intensive cultivation of energy crops.

The choice of an energy crop for cultivation is determined by a number of factors, namely: the type of soil, water balance, type of landscape, availability of transport links, location of potential fuel consumer, competition with other crops, social thought, etc. [7]. Energy crops include fast-growing trees of various types of willow and poplar, annual and perennial herbaceous plants, for example, sorghum, sugarcane, miscanthus, amaranth, Rhaponticum repens, Sakhalin knotweed, Pennsylvanian mallow, Rumex, panicgrass, hybrid tobacco. Energy crops of algae include chlorella, dunaliella, botryococcus, etc. Today, one of the most promising energy crops is sorghum [8, 9].

Sorghum is characterized by low costs of its cultivation technology. This crop can grow on soils with low levels of fertility, does not require a large amount of fertilizer and needs a minimum amount of water. Sugar sorghum ripens in 90–120 days, but sugarcane takes 12–14 months. In addition, it costs 1.74 USD to produce a gallon of ethanol from sugar sorghum, compared to 2.19 USD from sugarcane and 2.12 USD from corn. In bioenergy, there are three areas of using sugar sorghum: the production of bioethanol, solid fuel (briquettes, pellets, etc.) and biogas. The bioethanol yield depends on the sugar content in the juice. Depending on the varietal characteristics and the harvesting phase, sorghum juice can contain from 8 to 30 % sugar. With an average yield of green mass of 40 t/ha, it is possible to obtain 6–12 tons of alcohol per hectare and 12–15 tons of by-products, which can be used in fodder production or as solid fuel [6].

Thus, the use of crushed stone waste as fertilizers for the cultivation of industrial energy crops, in particular sorghum, is an urgent scientific and practical task. So, *the object of research* is the process of management and treatment of crushed stone production waste. *The aim of research* is to increase the level of environmental safety of mining regions through the use of crushed stone waste as fertilizers for energy crops and the transition to alternative energy sources, in particular biofuel.

2. Methods of research

To achieve this aim, the experimental method was used. For the experiment, an energy crop was chosen sorghum. Sorghum seeds were placed in two types of soil: a regular peat substrate (pH 5.8–6.8) and a peat substrate with the addition of rock in a ratio of 60:40. Planting was carried out in containers of the same size, where the soil or soil with the breed was first placed, and then the seeds – 100 seeds in each container. The seeds were spread evenly. Watering was carried out every two days. Measurements and photos were taken as external changes were made (Fig. 1).

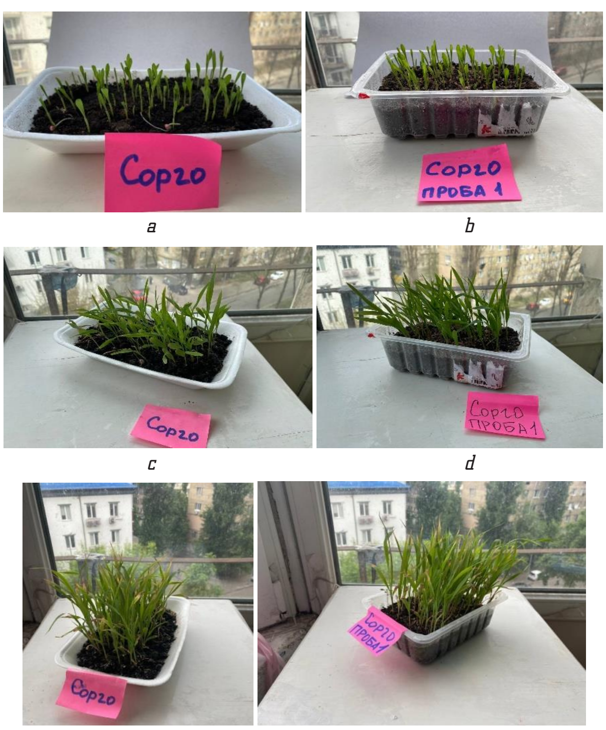

Fig. 1. Germination of sorghum on an ordinary peat substrate and a peat substrate with the addition of rock in a ratio of 60:40 (sample 1) on: *a, b* – 3 days after bedding, respectively; *c, d* – 20 days after bedding,, respectively; *e, f* – 45 days after bedding, respectively

Waste from the production of crushed stone was obtained from the Private Joint Stock Company Tolkachevsky Mining and Processing Plant (JSC Tolkachevsky Mining and Processing Plant, Pershotravneve, Ukraine), which develops the Tovkachevsky section of the Ovruch deposit. The materials that make up the rock are contained in the following quantities: quartzite – 90–98 %, pyrophyllite – 1–9 %, ore mineral – 0.3–1 %.

3. Research results and discussion

On the 45th day of the experiment, sorghum in each container was cut to the root and weighed on an electronic balance (Fig. 2).

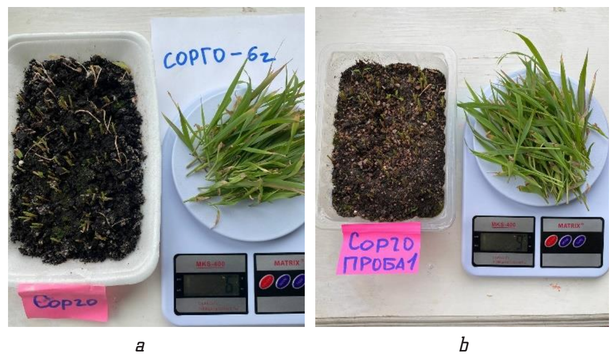

Fig. 2. Results of weighing sorghum grown on: *a* – ordinary peat substrate; *b* – peat substrate with the addition of rock in a ratio of 60:40 (sample 1)

The weighing results showed that under the same planting and germination conditions, the biomass of sorghum grown on an ordinary peat substrate is 6 g, 1.5 times more. Thus, let's assume that the energy efficiency of sorghum from 1 ha of field will also increase by 50 %. The results of calculating the calorific value and energy yield of sorghum are given in Table 1.

Table 1

The results of calculating the energy efficiency of sorghum

Sorghum	Productivity, t/ha/year	Calorific value, GJ/dry ton	Energy yield, GJ/ha/year	Source
Grown without addition of rock to the soil	25	18	450	[8]
Grown with the addition of rock to the soil	37.5	18	675	Authors' calculation

As it is possible to see from the Table 1, the yield of sorghum, provided that rubble production wastes are used, can be 37.5 t/ha/year, and the energy yield is 675 GJ/ha/year, which is 1.5 times more than when it is grown without the addition of rocks. In addition to the increase in the biomass of sorghum, the experiment established an increase in the number of secondary and tertiary roots (Fig. 3). A more developed root system allows the plant to receive more moisture and nutrients, thereby increasing its endurance and drought resistance.

The results obtained can be explained by the positive effect of silica, which is contained in the rock, on the growth and development of plants [10, 11].

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a b

Fig. 3. Root system of sorghum grown on: *a* – common peat substrate; *b* – peat substrate with the addition of rock in a ratio of 60:40

Based on studies [10] on the effect of silicon nutrition on sugar content in sugar beets and sugar cane, it is possible to assume that the sugar content in sorghum will also increase.

4. Conclusions

It is proposed to increase the level of environmental safety of mining regions through the use of crushed stone waste as fertilizers for industrial energy crops and the transition to alternative energy sources, in particular biofuel. An experiment was carried out in which an energy crop, sorghum, was planted in a regular peat substrate and a peat substrate with the addition of rock in a ratio of 60:40. The results of the experiment showed an increase in the biomass of sorghum grown on a peat substrate with the addition of rocks, 1.5 times compared to sorghum grown on a conventional peat substrate. According to the energy yield of sorghum from 1 hectare of field will also increase by 50 %. In addition to increasing the biomass of sorghum, the experiment established an increase in the number of secondary and tertiary roots when growing on a peat substrate with the addition of rocks. A more developed root system allows the plant to receive more moisture and nutrients, thereby increasing its endurance and drought resistance. The results obtained can be explained by the positive effect of silica, of which more than 90 % of the rock is composed, on the growth and development of plants.

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