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Growth Parameters of Herbaceous Plants on Phosphogypsum Dumps with Using Soil Coverings Based on Sewage Sludge

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ABSTRACT

The phosphogypsum dumps are one of the most toxic solid wastes of phosphoric acid, phosphate and phosphorus fertilizers manufacturing enterprises. In the article the possibility of remodeling of phosphogypsum dumps with using the *Poaceae* family herbaceous plants seeding was considered. On the basis of determination of growth parameters as well as sulfur and fluorine ions accumulation in the plants, the expediency of the dumps surface covering with a ground-covering mixture consisting of sand and sediment of wastewater in the amount of 10% or 20% by weight is established. In the dumps *Bromus inermis* Leyss., *Dactylis glomerata* L., *Elytrigia pseudocaesia* (Pacz.) Procud., *Festuca arundinacea* L. and *Festuca altissima* L. are the most suitable plants for cultivation.

Keywords: phosphogypsum, sewage sludge, cover substrate, herbaceous plants

INTRODUCTION

In the industrial regions the solid waste dumps, in particular, the extraction of minerals such as waste piles, overburden, etc., for technological processes as slag dumps, sludge drives, etc. is one of the most dangerous problems (Drijenko, 1985; Kharlamova, 2011; Sukhina, 2005; Kharytonov, Resio Espejo, 2013). These processes are accompanied by the toxic substances accumulation. The analysis of the content of water-soluble compounds of mine rocks and artificial soils suggests that the mine rocks contain from 0.8 to 0.85 % salts (Vangronsveld et al., 1996; Maltseva, Yudavicheva, 1985). The conditions created on the land disturbed by industrial production are characterized as unfavorable for plants. Therefore, in these areas the soil porosity and the salts accumulation increase (Zverkovskyi, Zubkova, 2015; 2016; Kharytonov, Resio Espejo, 2013), the nutrients removal considerably increases and the organic matter content decreases in the soil (Sheoran et al., 2010).

Violation of land has a negative impact on the environment. In particular, there is a decrease in biological diversity, reducing the number of plant species, mycorrhizal fungi and soil microorganisms living on the contaminated area (Vangronsveld et al., 1996; Sheoran et al., 2010; Uzbek, 2015; Arshi, 2017; Prysedskyi., Lykholat, 2017; Andrusevich, et al., 2018; Nazarenko et al., 2018).

The main solid waste to produce phosphoric acid is phosphorous gypsum. The amount of formed phosphogypsum depends on used raw material type, production technology, used equipment, and is in the range from 3.9 to 6.8 tons of phosphorous gypsum per 1 ton of phosphoric acid (Maltseva, Yudavicheva, 1985). The phosphogypsum obtained in extractive phosphoric acid production is mainly stored in dumps, that is associated with the alienation of large land areas (in a number of cases, cultivated), groundwater pollution due to the washing of soluble phosphoric and fluoride compounds, as well as great capital and operating costs. One of the most promising ways of phosphogypsum utilization is its processing from lime and sulfuric acid, the production of viscous materials and building plaster, as well as the use as a chemical reclamation of saline soils (Kobozev et al., 1985; Epifanov et al., 1985; Cherviakov, Suprun, 2013; Malanchuk et al., 2016). At the same time, the degree of phosphogypsum use is currently only 11% of its total amount formed at the production process. In this context, one way to prevent the harmful effects of phosphorous gypsum dumps on the environment is their reclamation.

The solution of the problem ytlatd to the negative influence of dumps is possible due to the reclamation or remediation of disturbed lands (Sukhina, 2005; Arshi, 2017; Halahan, 2014, 2016). For such works, natural or artificial ground cover substrates are widely used (Panas R., Malanchuk, 2010; Zverkovskyi, Zubkova, 2015, 2016, Prysedskyi, 2017). This reduces the toxic effect of acidity, the metal ions excess and other components on plant organisms as well as increases their survival (Vrana et al. 1989; Banasoya , 1989; Kovda et al., 1964; Mihunova, Mozheiko, 1966; Zverkovskyi, Zubkova, 2015; Kondratyuk et al. 1980; Travleev, 1989). Many authors propose the lime treatment of acidified dumps (Motorina, Ovchinnikov, 1975; Bezenkova, Kolesnikova, 1989), the use of mineral and organic fertilizers (Vigna, 1989), nutritional polymer lamina (Prezorova, 1990), etc. Kot (1990) and Boykiv (1990) suggest using the upper active peat layer.

Taking into account the above, the authors have studied the possibility of using a ground cover on the basis of clay or sand and sewage sludge to grow grassy plants on phosphogypsum dumps.

MATERIALS AND METHODS

To find out the possibility of using sewage sludge for growing herbaceous plants at the phosphogypsum dump, phosphogypsum from the dump of the Rivne production association "Azot" was used. Phosphogypsum was placed in 20 cm layer in special polystyrene vessels. Coating soil based on clay or sand containing sewage sludge was applied to the phosphogypsum (Table 1).

At these ratios, the amount of sewage sludge in the cover soil was 50, 100 and 200 g per kg of soil mixture, respectively. The covering soil mixture with a layer of 20 cm was applied to the phosphogypsum. Sewage sludge was received at the wastewater treatment plant of Rivne industrial association "Azot"

Six types of lawn grass seeds were planted on the prepared mixture: *Agropyrum pectiniforme* Schult., *Bromus inermis* Leyss., *Dactylis glomerata* L., *Elytrigia pseudocaesia* (Pacz.) Procud., *Festuca arundinacea* L. and *Festuca altissima* L. Plant cultivation was carried out for 6 months. The growth parameters of plants were determined according to standard methods. The method proposed by Pochinok (Pochinok, 1976) was used in the investigation of sulfur accumulation in plants. Fluoride ion accumulation was measured using an ion selective electrode EF-IV (Jacobson, Heller, 1971).

Statistical processing of the obtained results was carried out using the methods of dispersion analysis. Comparison of the meanings was carried out by Duncan's multiple comparison methods for $\alpha = 0.05$ (Prysedskyi, 1999, 2005).

RESULTS

The conducted studies allow us to conclude on ambiguity of the plants reaction to growing on phosphogypsum dumps. Thus, the *A. pectiniforme* plants on sandy substrates perished after 2 months of cultivation, regardless of the sewage sediment content. On clay substrates containing 5% and 10% of sewage sludge, the plant death was observed after the third month of growth. The growth of plants of this species during the whole period of the experiment was observed only on the substrate, which consisted of clay and 20% of sewage sludge (Fig. 1). Thus, the *A. pectini-forme* plants exhibited low resistance to the growth conditions on phosphogypsum, making this species unsuitable for growing in the dumps.

Table 1. Variants of ground cover mixes

Quantity of sewage sludge in ground cover, %			
On clay basis		On sand basis	
Variant	Quantity of sewage sludge	Variant	Quantity of sewage sludge
1	5.0	4	5.0
2	10.0	5	10.0
3	20.9	6	20.9

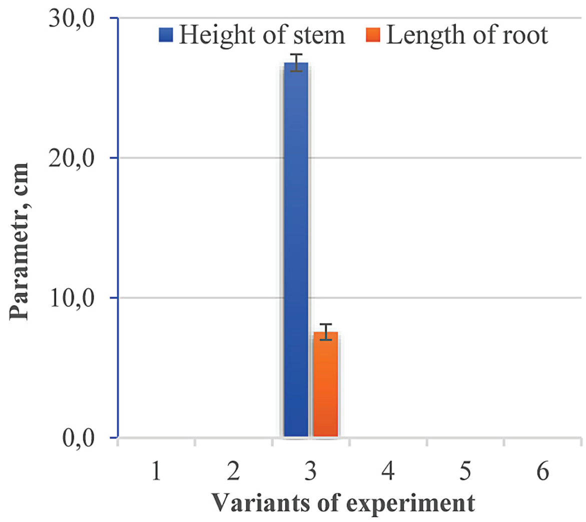

Figure 1. Growth parametrs of *A. pectini-forme* on phosphogypsum (variants of experiment in Table 1)

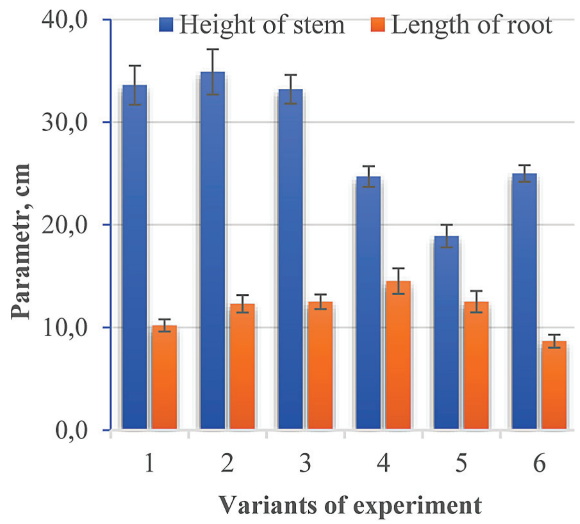

Figure 2. Growth parametrs of *B. inermis* on phosphogypsum (variants of experiment in Table 1)

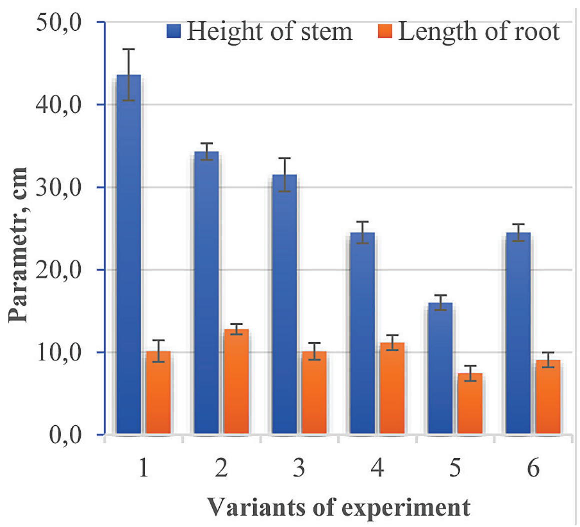

Figure 3. Growth parametrs of *D. glomerata* on phosphogypsum (variants of experiment in Table 1)

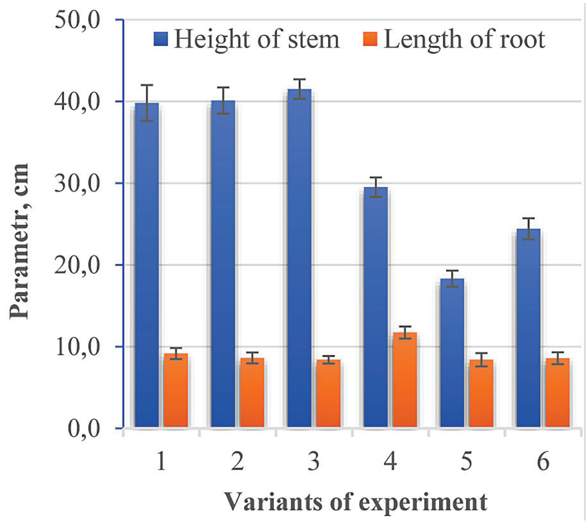

Figure 4. Growth parametrs of *E. pseudocaesia* on phosphogypsum (variants of experiment in Table 1)

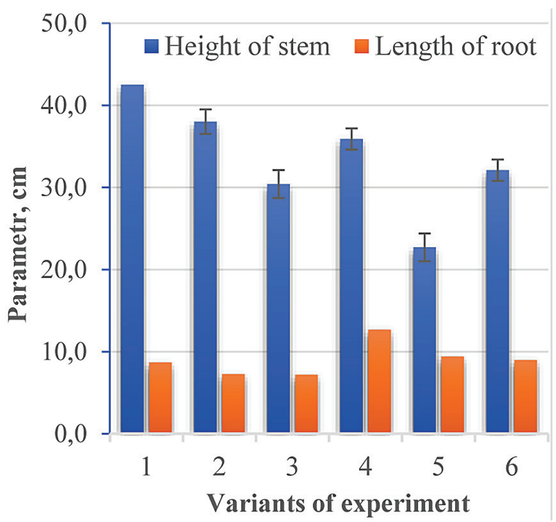

Figure 5. Growth parametrs of *F. arundinacea* on phosphogypsum (variants of experiment in Table 1)

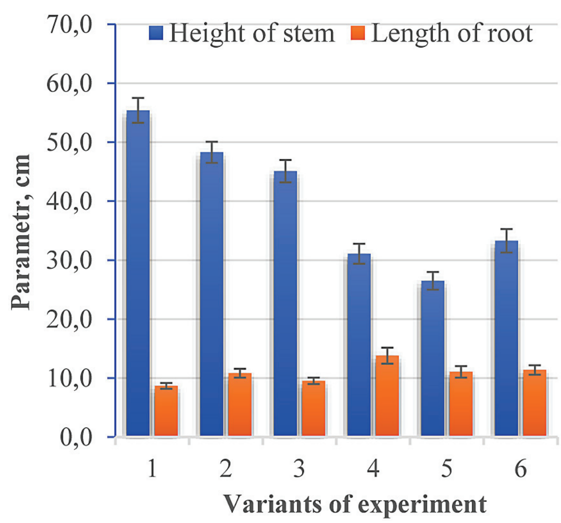

Figure 6. Growth parametrs of *F. altissima* on phosphogypsum (variants of experiment in Table 1)

Growth parameters of other plant species depended on the composition of the cover mixture (Fig. 2–12). In particular, there is a probable increase in 1.34–2.26 times of the above-ground parts length of plants grown on clay substrates compared with plants grown on sandy substrates in *D. glomerata, E. pseudocaesia* and *F. altissima*. For *B. inermis*, in the substrate the sewage sludge concentration increase likely reduced the growth of the above-ground parts. In other studied species such pattern was not found. In all variants, the difference was unlikely. In *F. arundinacea*, the ground cover composition did not significantly affect the growth parameters of the above-ground parts of plants.

In *D. glomerata, E. pseudocaesia, F. altissima. D. glomerata, E. pseudocaesia* and *F. altissimaane* the root growth did not depend on the substrate composition. In *B. inermis* on sandy substrates with 5 and 10% of the sewage sediment content, the length of roots significantly exceeded by 22.5–42.2% the corresponding index of plants grown on the ground coverings mixtures consisting of clay and sewage sludge.

The crude mass of the above-ground parts of the *B. inermis* plants, grown on sandy soil coverings mixtures, was 2.07–4.11 times lower than the corresponding index of plants grown on the clay substrate. At the same time, the dry mass of this

Table 2. Content of sulphur-ion end fluoride-ion on the plants that grow on phosphogypsum

Variant of experiment	Content of SO_4^{2-}, %	Content of F^-, mg/g
Agropyrum pectini-forme Schult.		
3	0.341 ± 0.001	0.26 ± 0.01
Bromus inermis Leyss		
1	0.312 ± 0.05	0.17 ± 0.02
2	0.301 ± 0.003	0.19 ± 0.02
3	0.225 ± 0.017	0.17 ± 0.03
4	0.319 ± 0.004	0.11 ± 0.01
5	0.291 ± 0.003	0.09 ±0.04
6	0.294 ± 0.001	0.08 ±0.05
Dactylis glomerata L.		
1	0.229 ± 0.017	0.16 ± 0.01
2	0.287 ± 0.008	0.18 ± 0.03
3	0.232 ± 0.002	0.13 ± 0.01
4	0.294 ± 0.003	0.11 ± 0.02
5	0.229 ± 0.002	0.12 ± 0.02
6	0.237 ± 0.005	0.10 ± 0.02
Elytrigia pseudocaesia (Pacz.) Procud		
1	0.359 ± 0.036	0.22 ± 0.05
2	0. 336 ± 0.005	0.25 ± 0.03
3	0.237 ± 0.004	0.24 ± 0.03
4	0.321 ± 0.002	0.16 ± 0.02
5	0.294 ± 0.022	0.16 ± 0.02
6	0.212 ± 0.002	0.11 ± 0.04
Festuca arundinacea L		
1	0.334 ± 0.024	0.17 ± 0.03
2	0.254 ± 0.003	0.18 ± 0.05
3	0.227 ± 0.003	0.21 ± 0.01
4	0.290 ± 0.007	0.12 ± 0.03
5	0.275 ± 0.002	0.11 ± 0.03
6	0.256 ± 0.002	0.10 ± 0.05
Festuca altissima L.		
1	0.363 ± 0.004	0.23 ± 0.05
2	0.296 ± 0.004	0.22 ± 0.04
3	0.243 ± 0.008	0.18 ± 0.06
4	0.320 ± 0.002	0.15 ± 0.02
5	0.261 ± 0.004	0.15 ± 0.03
6	0.344 ± 0;011	0.12 ± 0.01

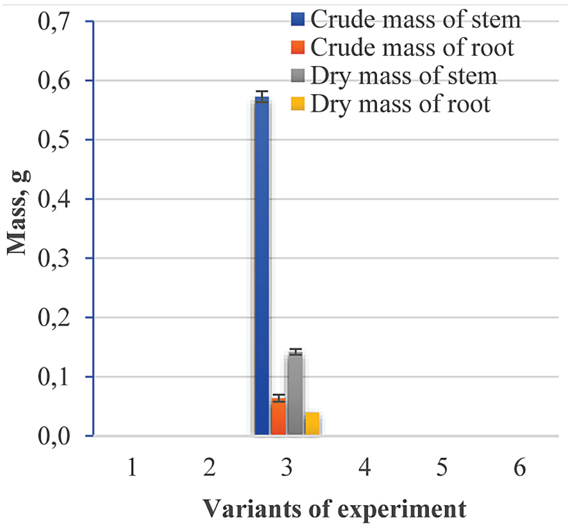

Figure 7. Mass of A. pectini-forme plants on phosphogypsum (variants of experiment in Table 1)

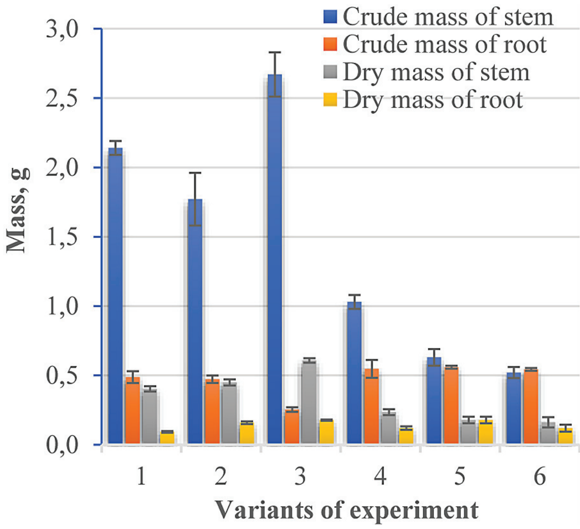

Figure 8. Mass of *B. inermis* plants on phosphogypsum (variants of experiment in Table 1)

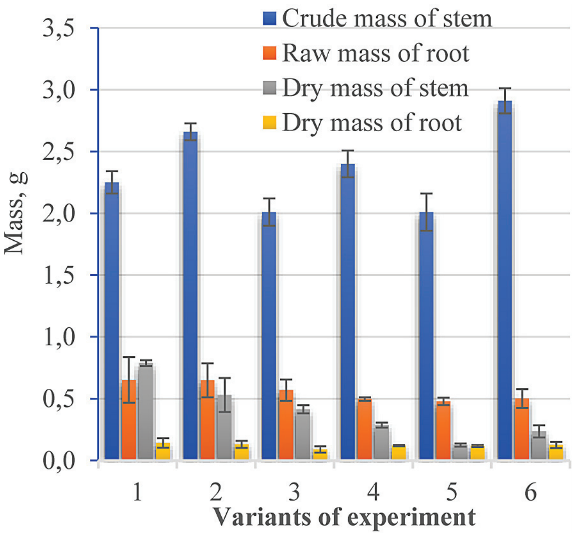

Figure 9. Mass of D. glomerata plants on phosphogypsum (variants of experiment in Table 1)

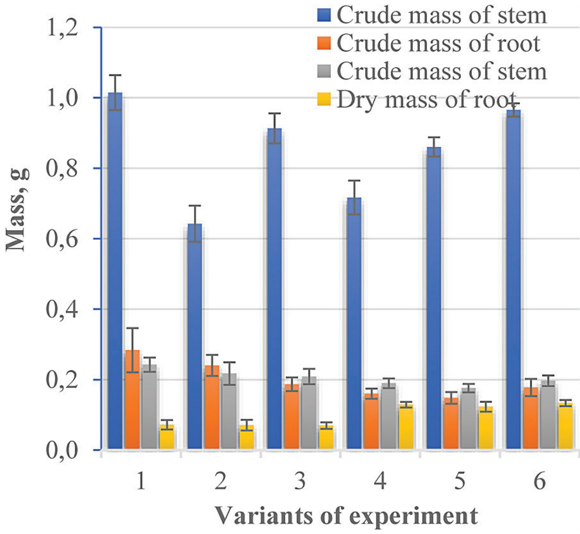

Figure 10. Mass of *E. pseudocaesia* plants on phosphogypsum (variants of experiment in Table 1)

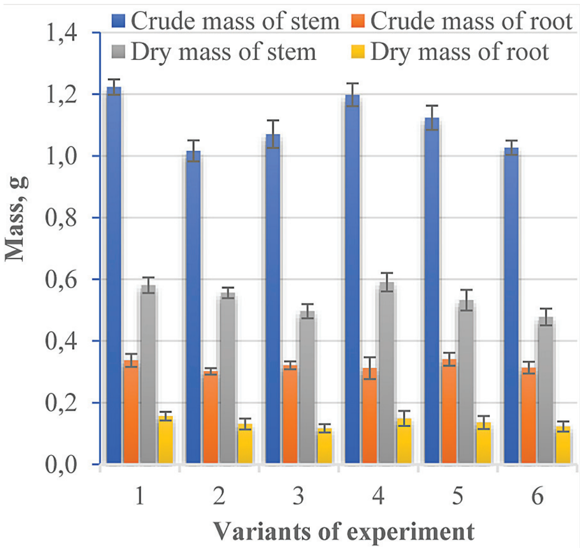

Figure 11. Mass of *F. arundinacea* plants on phosphogypsum (variants of experiment in Table 1)

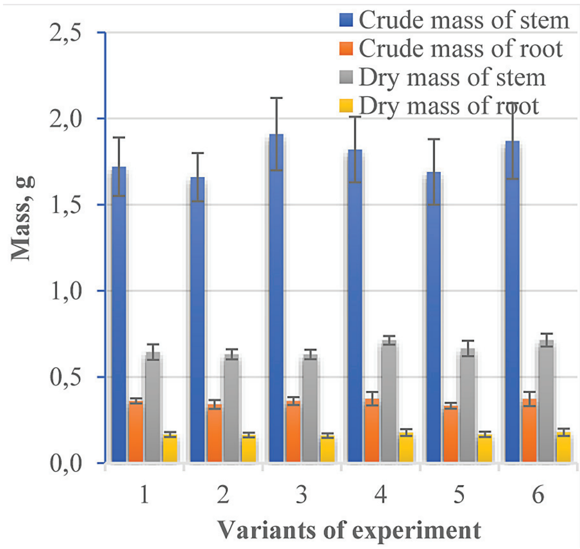

Figure 12. Mass of *F. altissima* plants on phosphogypsum (variants of experiment in Table 1)

species plants did not undergo a probable change in cultivation on different soil coverings. This may be due to violations of the water regime of the plants on sandy substrates. There were no probable changes in the crude and dry masses of the above-ground parts of other investigated species depended on the soil-coating mixtures composition.

The crude and dry mass of root systems did not depend on the soil-covering mixtures composition in all investigated plant species. The analysis of the accumulation of sulfur by the plants (Table 2) showed that for plant cultivation on phosphogypsum using substrates based on clay or sand and sewage sedimentation, its accumulation did not exceed the clarke levels for the plants and fluctuated within 0.23–0.36% range of absolutely dry substances. Depending on the cultivation conditions and plant species in the cereal grasses, the sulfur content ranged from 0.2 to 0.8% of completely dry mass (Tarabrin, Chernshyova 1973). Under the conditions of growing herbaceous plants on the substrates including sewage sediment the greatest sulfur accumulation was manifested at the minimum content of organic matter in the mixtures. Thus, at 5% of the sewage sedimentation amount in clay or sandy substrates the sulfur content depended on the plants type by 1.1–1.5 times exceeded sulfur amount in the plants grown at 20% of the sewage sludge content.

In addition, in the plants between variants differences in the sulfur content were more significant at their cultivation on clay substrates. With the use of sand, these differences were unlikely in most investigated plants species. There was a lower sulfur accumulation by the most species on sandy substrates than on clay substrates.

Fluoride compounds constitute one of the most toxic components of phosphogypsum. Therefore, in plants the accumulation of this ion is the greatest threat to their existence. The analysis of the results of fluorine accumulation by the plants (Table 2) showed that the amount of this anion in the plants grown on ground coverings mixtures consisting of sand and sewage sludge was 0.08–0.16 mg/g depending on the plants type and did not depend on the likelihood of the organic matter amount in the soil. In the plants grown on clay substrates this index fluctuated within 0.16–0.23 mg/g, which probably exceeded the corresponding parameter of plants grown on sandy substrates. This may be due to lower capillary uplift of solutions from phosphogypsum in sand than in clay.

CONCLUSIONS

The conducted studies allowed establishing a high resistance of *Bromus inermis* Leyss., *Dactylis glomerata* L., *Elytrigia pseudocaesia* (Pacz.) Procud., *Festuca arundinacea* L. and *Festuca altissima* L., to gthe rowing conditions on phosphogypsum, while *Agropyrum pectini-forme* Schult. proved to be unsuitable for remediation of the dumps. It was also established that the cultivation of herbaceous plants on phosphorous gypsum is possible due to the use of all investigated variants of soil coverings. Given the growth rates of plants as well as their sulfur and fluoride accumulation, the sand coverings including from 10% to 20% of sewage sedimentation are the best for the restoration of disturbed lands.

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