Artificial Soil Mix Based on Zoo Compost of the Black Soldier Fly

E A Pendyurin¹, L M Smolenskaya¹, S Yu Rybina¹
¹Belgorod State Technological University V.G. Shukhov, Belgorod, st. Kostyukova, 46, 308012 Russia

E-mail: pendyrinea@yandex.ru

Abstract. Compositions of artificial soil mix have been developed that, along with sand and clay, contain wet magnetic separation waste, citrogypsum, and zoo compost of black soldier fly larvae. It has been established that the soil mix compositions are not toxic and can be used to grow watercress.

1. Introduction

Soil is a complex combination of organic and inorganic substances, the upper layer of the Earth's crust, the product of countless generations of living organisms, and the basis of the planet's biosphere. The soil is often called the main wealth of any state since about 90 % of human food is produced on and in it [1].

Human economic activity is accompanied by soil destruction. The soil cover area is steadily decreasing due to constructing new enterprises and cities, laying roads and high-voltage power lines, flooding agricultural land when constructing hydroelectric power plants, and developing the mining industry. Desertification of lands, erosion, depletion of fertility, and salination bring a serious danger [2]. Under current conditions, preserving the soil in its natural state is virtually impossible since the entire Earth’s surface is exposed to the impact of anthropogenic factors to one degree or another [3].

Population growth and limited areas suitable for agriculture have brought the issue of soil reclamation, rehabilitation, and protection to the fore [4].

One of the promising options to solve this issue can be creating artificial soil mixes combining organic and inorganic materials suitable for biological reclamation of disturbed lands. Such soil mixes may contain sand, gravel, sawdust, peat, and many other materials [5]. In artificial soils, the same processes occur as in natural ones, so they may partially or completely replace natural soils.

Soil mixes can be composed depending on their purpose and further use. For each plant species, the soil components should be selected experimentally [6].

When performing literary and patent search for analogs of creating artificial soil mixes, disadvantages have been identified such as obligatory using expensive mineral fertilizers and neutralizing peat since without meeting these conditions, the components themselves do not allow obtaining a nutritious soil mix containing a balanced amount of elements required for optimal growth and development of plants, and consequently, do not provide a high yield. The soil mixes presented on the market do not contain not widely-used industrial waste storing at landfills. The use of various types of waste in the soil mix composition reduces the anthropogenic load on the environment; their process recycling contributes to the creation of low-and waste-free technologies [7-10].
Therefore, the search for effective options for replacing soils and expanding the range of artificial soil mixes with high fertility rates is an urgent scientific and technical problem.

The artificial soil mix developed contains clay, citric acid waste - citrogypsum, bio compost of black soldier fly, the iron ore wet magnetic separation waste, and sand. Such a composition of an artificial soil mix allows obtaining a fertile highly nutritious soil mix with specified physicochemical properties due to the chemical reactions proceeding between all the mix components [9].

2. Research objective
Creating artificial soil mixes samples is based on GOST R 53381-2009.

Before testing, the toxicological properties of the artificial soil mixes developed have been determined by phytotesting [11]. Phytotest is based on the ability of seeds to respond to a negative impact by changing the root penetration intensity, which allows taking the root length as an indicator of the test function. The phytotoxic effect has been determined by comparing the test function (Lcp) values for reference and experimental seedlings. The Lcp values of the reference and experimental plants have been calculated as the arithmetic mean of the seedling roots length data set obtained in three replications [12].

The soil mixes created have been placed in vessels with agricultural crops of ‘Spring’ watercress for research in laboratory conditions.

3. Results and discussion
Artificial soil mix is a composition consisting of both organic and inorganic materials.

Since the soil is a mix of physical sand, physical clay, and organic matter, different soil mix compositions have been chosen based on this definition.

The chemical composition of sand is given in Table 1.

Table 1. Chemical Composition of Sand.

|        | Content of Components, % |
|--------|--------------------------|
| SiO₂   | 75.0-94.0                |
| FeO₂+Al₂O₃ | 2.6-4.2               |
| CaO    | 0.5-2.0                  |
| MgO    | 0.0-0.4                  |
| SO₂    | 0.10-0.80                |
| n.n.n. | 1.5-4.0                  |

As can be seen from the tabular data, the sand mainly consists of silicon oxide with inclusions of calcium and magnesium oxides.

The chemical composition of clay is given in Table 2.

Table 2. Chemical Composition of Clay.

|        | Content of Components, % |
|--------|--------------------------|
| SiO₂   | 45-66                    |
| Al₂O₃  | 14-23                    |
| TiO₂   | 0.5-1.6                  |
| Fe₂O₃  | 3.0-5.0                  |
| CaO    | 1.0-2.0                  |
| MgO    | 0.1-0.5                  |
| K₂O    | 2.0-2.5                  |
| Na₂O   | 0.5-1.5                  |
| n.n.n. | 4.0-7.0                  |

The clay consists of silicon and aluminum oxides as the main components and titanium, iron, calcium, magnesium, and potassium oxides as additional ones.

Citrogypsum is a citric acid production waste with an acidic reaction, which makes the soil mix neutral when interacting with all its components. The chemical composition of citrogypsum is given in Table 3.

Table 3. Chemical Composition of Citrogypsum.

|        | Content of components, % |
|--------|--------------------------|
| SiO₂   | 0.2-1.7                  |
| SO₃    | 38.3-45.5                |
| CaO    | 29.7-32.6                |
| MgO    | 0.1-0.4                  |
| R₂O    | 0.3-1.2                  |
| n.n.n. | 22.0-28.4                |
The iron ore wet magnetic separation waste (WMSW) is a waste rock of the iron ore dressing containing 65-75 % silicon oxide and biogenic elements. The chemical composition is given in Table 4.

Table 4. Chemical Composition of Iron Ore Wet Magnetic Separation Waste.

| Component | Content of Components, % |
|-----------|--------------------------|
| FeO       | 10-15 2-3 65- 4-8 2-4 |
| Al₂O₃     | 0.1- 0.2 |
| SiO₂      | 75 0.2 |
| FeO       | 2-4 5.0 |
| CO₂       | 0.6 0.8 |
| S         | 3 0.8 |
| P         | 0.7- 0.2 |
| CaO       | 6 0.2 |
| MgO       | 5 0.2 |
| K₂O       | 4.5- 4-5 |
| Na₂O      | 0.4- 0.2 |
| TiO₂      | 0.1- 4-5 |

Bio compost is an organic part, which is represented by organic waste digested by dipteran black soldier fly larvae. Organic waste is a composition of food waste, primarily off-spec grain and foul food products of retail chains. Waste is depacked from any type of packaging and then crushed and homogenized to produce a uniform substance. The larvae grown in the incubator are added to this substance and digest the substrate for several days. At the end of this period, the larvae are separated from the digested waste by sieving. This digested waste is used as an organic component in the artificial soil mix developed.

The chemical composition of bio compost is given in Table 5.

Table 5. Chemical Composition of Bio Compost.

| Component | Content of Components, % |
|-----------|--------------------------|
| N         | 2-3 1-3 |
| P₂O₅      | 1-3 1-3 |
| K₂O       | 15-45 |
| Carbon    | 5-6 1-6 |
| Ash       | Microelements 0.7-2 0.3-0.5 |
|          | CaO MgO Water 20-50 |

An important condition for preparing an artificial soil mix is the thorough stirring of the initial components. The artificial soil mix manufacture is based on the mechanical stirring of heterogeneous components, which may differ significantly in physical, chemical, and biological properties.

7 compositions of artificial soil mix have been prepared (Table 6). All samples are non-toxic since their toxicity does not exceed 20 %, therefore, they can be used in the manufacture of artificial soil mixes [11].

An artificial soil mix may be considered suitable to grow plants if provides the optimal conditions required for their growth. To further use the soil mixes developed, their preliminary maturation as a result of physical and chemical processes is required. Therefore, the artificial soil mix samples obtained have been kept under static conditions with continuous equalizing and moistening.

Table 6. Component Composition of Artificial Soil Mix, %.

| Composition | Clay | Citrogypsum | Bio Compost | WMSW | Sand |
|-------------|------|-------------|-------------|------|------|
| 1           | 35   | 20          | 20          | 5    | 20   |
| 2           | 30   | 15          | 15          | 15   | 25   |
| 3           | 35   | 10          | 15          | 20   | 20   |
| 4           | 25   | 5           | 30          | 10   | 35   |
| 5           | 20   | 20          | 25          | 15   | 20   |
| 6           | 35   | 15          | 5           | 20   | 25   |
| 7           | 35   | 15          | 10          | 15   | 25   |

The reference sample is typical black soil of the Belgorod Region.

The quantitative and qualitative indicators have been subsequently evaluated in a laboratory experiment [GOST 24026-80]. The artificial soil mixes developed were placed in the research vessels, into which an agricultural crop – ‘Spring’ watercress was sowed. It should be noted that watercress is an ephemeral vegetable plant highly sensitive to soil contamination with heavy metals. This
bioindicator is characterized by fast and almost 100% seed germination, which is noticeably reduced in the presence of contaminants. Also, pollutants cause noticeable morphological changes in the plant’s shoots and roots (growth retardation and distortion of shoots, a decrease in the length and mass of roots, as well as the number and weight of seeds). Sowing rate and depth are 1 g/m² and 0.5-1 cm, respectively. Watercress sown was harvested 10 days after full germination, then removed from the artificial soil mix, and its yield was determined. The yield indices are given in Table 7.

Table 7. Yield Indices of Artificial Soil Mixes.

| Artificial Soil Mix Composition | Yield, kg/vessel | Increase in Yield, kg |
|---------------------------------|-----------------|----------------------|
| Reference Composition (Soil)    | 0.15            | -                    |
| 1                               | 0.21±0.005      | +0.06                |
| 2                               | 0.18±0.005      | +0.03                |
| 3                               | 0.15±0.005      | -                    |
| 4                               | 0.19±0.005      | +0.04                |
| 5                               | 0.14±0.005      | -0.01                |
| 6                               | 0.14±0.005      | -0.01                |
| 7                               | 0.15±0.005      | +0.04                |

Estimating the suitability of the artificial soil mix developed based on industrial waste for biological reclamation by the same parameters has shown that the artificial soil mixes being analyzed are suitable for the reclamation of lands disturbed. [GOST R 57446-2017 Best Available Techniques. Disturbed Land Reclamation. Restoration of Biological Diversity].

Studies have shown that the first, second, fourth, and seventh artificial soil mix compositions are superior in yield to the reference one and can be used in commercially growing plants; also, they can be used at the biological stage when reclaiming disturbed lands.

4. Conclusions
The developed artificial soil mixes reduce the harmful impact on the environment due to eliminating the industrial waste storage, allow their recycling that contributes to creating low- and waste-free technologies, and are not inferior to the reference sample, i.e. typical soil of Belgorod Region by chemical composition.

The artificial soil mix compositions have been prepared and toxicity tested before use. All samples are non-toxic since their toxicity does not exceed 20% and can be used in commercial production.

The artificial soil mixes developed using industrial waste and organic waste digested by black soldier fly larvae are not inferior in chemical composition to soil and promote plant growth without additional fertilization.

The results obtained indicate the possibility of using the soil mixes studied to grow plants.

5. References
[1] Solovichenko V D, Navolneva E V, Stupakov A G, Kulikova M A 2015 Reproduction of soil fertility is the basis for the growth of productivity of agricultural crops Agroecological problems of soil science and agriculture Collection of reports of the scientific-practical conference of the Kursk branch of the MOO "Society of Soil Scientists named after V V Dokuchaev" (Kursk) pp190–194
[2] Cairns J Jr 2005 Biological monitoring part I Early warning systems Water Research 14 pp 1179-1196
[3] Konstantinova K A 2015 Reclamation, reclamation and conservation of disturbed lands Rational use of natural resources: specificity and economic conditions of formation: Materials of the scientific-practical conference (Kemerovo) pp 19–23
[4] Babakova O B, Artemenko S E, Tarkhanova L A 2006 Polymer-containing artificial soil for restoration and creation of landscapes Ecology and Industry of Russia 2 pp 22-24
[5] Gurina I V, Ivanova N A, Mikheev P A 2012 Theoretical substantiation of biological reclamation of ash dumps by the method of plant reclamation Prirodooobustroystvo 4 pp 26–29
[6] Sabitov M M, Karpovich K I, Kuzina E V 2012 Soil tillage - an affordable, effective agrotechnological method for preserving and restoring soil fertility Agromir of the Volga region 2(6) pp 14-18
[7] Morozov D O, Rudakov V O, Epishina G P, Berezina N V Artificial soil Patent RU No 2345518 published 10.02.2009 Bul 4
[8] Ermakov E I, Zheltov Yu I, Surgutanov Yu P Soil for growing plants Patent RU No 2067969 published 10.08.2000 Bul No 22
[9] Artificial soil mixture based on biocompost Black Lion patent application No 2020113762/10 (023240)
[10] Bashkin V 2002 Modern biogeochemistry (New-York: Kluwer Academic publishers) 561 p
[11] Substantiation of the hazard class of production and consumption waste by phytotoxicity Methodical recommendations MP 2.1.7.2297-07 Electronic resource: http://www.infosait.ru/norma_doc/52/52957/index.htm/ (Date of access 1.10.2018)
[12] Pendyurin E A, Smolenskaya L M, Rybin V G, Rybina S Yu 2013 Evaluation of the suitability of technogenic soils for reclamation of disturbed territories Bulletin of BSTU im. V.G. Shukhov 3 pp 151–153

Acknowledgments
The study has been performed with financial support from the Ministry of Science and Higher Education of the Russian Federation (Unique Project No. 07519SU2000000) at V.G. Shukhov BSTU.