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# The use of soil based on sewage sludge from urban wastewater treatment plants in the greening of urban areas

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In a field experiment, the effect of various doses of the agrochemical "Soil Green City", created on the basis of sewage sludge from sewage treatment plants of housing and communal services, on the growth and development of a flower and ornamental culture – *Salvia splendens*, when grown on flower beds in urban areas, was studied. The observations were carried out according to morphological parameters: the height of salvia plants, the number of inflorescences, flowers in the inflorescence. The positive influence of the agrochemical "Soil Green City" on the growth and development of the test flower and ornamental culture (*S. splendens*) has been established. The best results were obtained in the variant with the introduction of an agrochemical at a dose of 4 kg/m$^2$, the variant with the introduction of an agrochemical at a dose of 3 kg/m$^2$, is slightly inferior. When using the tested doses of the agrochemical "Soil Green City", the content of gross forms of heavy metals and arsenic in the soil did not exceed the values established by hygienic standards. In landscaping urban areas and creating favorable conditions for the growth and development of salvia when grown in flower beds and increasing its stress resistance to abiotic factors, it is recommended to use the agrochemical "Soil Green City" at a dose of 3–4 kg/m$^2$.

***Keywords:*** agrochemical, sewage sludge, *Salvia splendens*, heavy metals, urbanized areas, flower and ornamental crops, environmental safety.

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# Применение почвогрунта на основе осадков сточных вод городских очистных сооружений в озеленении городских территорий

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В условиях полевого опыта изучено влияние различных доз внесения агрохимиката «Почвогрунт Зелёный город», созданного на основе осадков сточных вод канализационных очистных сооружений жилищно-коммунального хозяйства, на рост и развитие цветочно-декоративной культуры – сальвии (*Salvia splendens)* при выращивании на клумбах городских территорий. Наблюдения проводились по морфологическим показателям: высота растений сальвии, количество соцветий, цветков в соцветии. Установлено положительное влияние агрохимиката «Почвогрунт Зелёный город» на рост и развитие тестовой цветочно-декоративной культуры (*S. splendens*). Наилучшие результаты

получены в варианте с внесением агрохимиката в дозе 4 кг/м$^2$, немногим уступает вариант с внесением агрохимиката в дозе 3 кг/м$^2$. При использовании испытуемых доз агрохимиката «Почвогрунт Зелёный город» содержание в почве валовых форм тяжёлых металлов и мышьяка не превысило значений, установленных гигиеническими нормативами. В озеленении городских территорий и создании благоприятных условий для роста и развития сальвии при выращивании на клумбах и повышения её стрессоустойчивости к абиотическим факторам рекомендуется применение агрохимиката «Почвогрунт Зелёный город» в дозе 3–4 кг/м$^2$.

***Ключевые слова:*** агрохимикат, осадки сточных вод, *Salvia splendens*, тяжёлые металлы, урбанизированные территории, цветочно-декоративные культуры, экологическая безопасность.

The development of industry and the growth of urbanization have led to the fact that in cities high levels of pollution of atmospheric air, surface and groundwater, as well as soil cover with pollutants can be recorded, which has a negative impact on the environment and negatively affects the quality of life of the urban population [1–3]. At the same time, landscaping of urban areas plays an important role in stabilizing the ecological situation, the possibility of which directly depends on the quality of soils; urban soils are strongly transformed and differ from natural soils in their structure and chemical composition [4–6]. The soil cover in most large cities experiences a powerful and long-term anthropogenic impact, leading to the development of degradation processes and, ultimately, to its depletion, thereby creating unfavorable conditions for the development of plants involved in urban greening [7–11].

Sewage sludge waste (SSW) from sewage treatment facilities of housing and communal services (HCS) can serve as a source of organic matter for the soil, as well as macro- and microelements such as nitrogen, phosphorus, potassium, calcium, magnesium, copper, zinc, etc., necessary for the normal course of physiological and biochemical processes in plants [12–16]. The introduction of additional organomineral components into the degraded soil of urban areas obtained from the waste of sewage treatment facilities of city HCS can be a promising method for ensuring the ecological comfort of urban areas during landscaping, planting trees, shrubs, flower beds, laying out lawns, grassing road slopes and landfills [17–19]. Regional features and the specifics of the work of specific sewage treatment plants have a significant impact on the concentration of pollutants in the SSW, bringing them closer to the limits of permissible concentrations [13, 14, 20]. Lead, nickel and arsenic are more actively concentrated in the wastewater treatment plants of the housing and communal services of the Ryazan region. The empirical series of pollutant accumulation in SSW, built on the basis of the results of estimating the concentration coefficients of elements, has the following form: Pb > Ni > As > Cu > Zn > Cr > Cd > Hg [13]. The use of such wastes as the basis for complex long-acting ameliorants also serves as a priority for their disposal [13, 19, 21]. In this regard, the use of organomineral ameliorants obtained on the basis of sewage sludge to improve the environmental sustainability of degraded and man-made urban lands, use in floriculture and landfill reclamation, has a high social, economic and environmental attractiveness in the implementation of nature restoration projects. This requires scientific substantiation and confirmation by the results of experimental studies [20, 22, 23].

The purpose of the research is to study the effect of various doses of the agrochemical "Soil Green City" obtained on the basis of SSW of sewage treatment facilities of the housing and communal services on the growth and development of a test flower-decorative crop (*Salvia splendens*), as well as assessing soil contamination with heavy metals and arsenic when using an agrochemical.

## Objects and methods of research

The composition of the agrochemical includes a composted mixture of dehydrated sewage sludge with pine sawdust, with a moisture content of 70–80%. According to toxicological and agrochemical indicators, the agrochemical "Soil Green City" meets the standards for soils and their mixtures used for the improvement of populated areas (sanitary regulations SanPiN 1.2.3685-21, SanPiN 1.2.3684-21), fertilizers (State Standard GOST R 54651-2011) based on SSW group I, and is registered in the State Catalog of Pesticides and Agrochemicals Permitted for Use on the Territory of the Russian Federation in the section "Soils" (as of December 29, 2021).

The field experiment was laid in 2021 on the territory of the village of Solotcha in the city of Ryazan, Ryazan Region, located in the southern taiga subzone of soddy-podzolic soils. Scheme of laying and conducting a field experiment: option 1 (control) – without the use of agrochemicals

and fertilizers; option 2 – the agrochemical "Soil Green City" was introduced into the flower bed, at a dose of 2.0 kg/m$^2$; option 3 – the agrochemical "Soil Green City" was introduced into the flower bed at a dose of 3.0 kg/m$^2$; option 4 – the agrochemical "Soil Green City" was introduced into the flower bed at a dose of 4.0 kg/m$^2$. The field experiment included a randomized placement of variants in quadruple replication, the area of each plot was 9 m$^2$. The application doses are set taking into account the requirements of the standard (GOST 54651–2011): in green building it is allowed to apply organic fertilizers produced on the basis of sewage sludge, ensuring the introduction of the total nitrogen contained in them in the amount of 250–300 kg/ha. The content of nutrients in the agrochemical "Soil Green City" in terms of total nitrogen is 0.69% in dry matter, which corresponds to the application of 3.62–4.35 kg/m$^2$ of soil. The maximum recommended dose of 4 kg/m$^2$ of soil and two smaller doses, 2 and 3 kg/m$^2$ of soil in dry matter, were used for the field experiment.

The introduction of the agrochemical "Soil Green City" with a uniform distribution over the surface of the flower beds and subsequent mechanized incorporation (with motor-cultivator) into the soil to a depth of 20 cm was carried out on May 11, 2021. *Salvia splendens* (sparkling sage), which is actively used to create flower beds and lay lawns in the Ryazan region, was used as a test flower and decorative culture in the experiment. Seedlings of salvia flowers were planted on flowerbeds by municipal enterprise "ZhKU-22" on May 26, 2021, planting density was 54 pcs/m$^2$. Plant height measurements were carried out on the 8th, 22nd, 33rd, 51st, 85th and 100th days after planting seedlings in flower beds. On the 51st and 85th days, the number of inflorescences and the number of flowers in the salvia inflorescence were also measured. For each variant of the experiment, measurements were taken on 50 plants, then they were statistically processed using the Excel program.

At the end of the growing season, according to the variants of the field experiment, soil samples were taken from the 0–20 cm layer to determine the content of gross forms of heavy metals (HM) and arsenic. Soil sampling was carried out in accordance with GOST 17.4.3.01-17, GOST 17.4.4.02-17, GOST 28168-89. Analytical determinations of the content of gross forms of HM (copper, zinc, lead, cadmium, and mercury) and arsenic were performed according to standard methods [24–26] in a specialized accredited laboratory.

Meteorological observations performed at the stationary station of the Meshchersky branch of the All-Russian Research Institute of Hydraulic Engineering and Land Reclamation (VNIIGiM), located in the village of Solotcha, showed that the growing season of 2021 is characterized by an uneven distribution of precipitation: for the period May-September, 166.2 mm of precipitation fell, which is 98.8 mm less than the long-term average. This growing season was also characterized by uneven temperature distribution: the average daily air temperature for the growing season in 2021 was +19.1 °C, which is 3.6 °C higher than the long-term average. In general, the growing season of 2021 can be characterized as uncomfortable for plants with stress periods in terms of heat and moisture supply.

## Results and discussion

In the field experiment, we studied the effect of various doses of the agrochemical "Soil Green City" on the dynamics of the height of salvia plants (Table 1).

Studies have shown that on the 8th day after planting salvia seedlings on flowerbeds, the largest increase in plant height was observed in option 2 (55.1% higher than in control); in option 4 the increase in plant height is 33.7% higher than in the control; in the third option the smallest value of the increase in plant height is noted (27.6%). On the 22nd day of the experiment, the largest increase in plant height was also

**Table 1**

The results of the study of the height dynamics of *Salvia splendens* plants in the field experiment, cm (significantly at $P \geq 0.95$)

| Experiment options | Observation period | | | | | |
|---|---|---|---|---|---|---|
| | 8th day | 22nd day | 33rd day | 51st day | 85th day | 100th day |
| Control | 6.06±0.03 | 11.98±0.02 | 16.80±0.04 | 22.04±0.05 | 22.92±0.04 | 23.19±0.04 |
| Option 2 | 9.40±0.04 | 15.17±0.03 | 19.30±0.04 | 22.20±0.04 | 25.62±0.05 | 26.20±0.04 |
| Option 3 | 7.73±0.04 | 13.91±0.03 | 22.20±0.05 | 27.26±0.06 | 31.34±0.06 | 32.38±0.06 |
| Option 4 | 8.10±0.05 | 13.97±0.03 | 22.24±0.04 | 27.60±0.06 | 32.07±0.05 | 33.37±0.06 |

observed in option 2 (26.6% higher than in the control); then option 4 follows with an increase in plant height of 16.6%; in the third option the smallest value of the increase in plant height is noted (16.1%). On the 33rd day, the largest increase in plant height was observed in option 4 (32.4%); then option 3 follows with an increase in plant height (32.1%); the smallest value of the increase in plant height is noted in the second option (14.9%). On the 51st day, the largest increase for salvia was observed in option 4 (25.2%); slightly less – in option 3 (23.7%); the smallest growth value was recorded in the second option (0.7%). On the 85th day, the largest increase in plant height was also noted in the fourth option (39.9%), followed by option 3, in which the increase was 36.7%, the smallest increase was recorded in option 2 (11.8% higher than in control). On the 100th day of the experiment, the largest increase in plant height was recorded in option 4 (43.9%), the average increase was obtained in option 3 (39.6%), the smallest increase was observed in option 2 (13.0% higher than in control).

The results of counting salvia inflorescences and the number of flowers in one inflorescence using the agrochemical "Soil Green City" are shown in Figures 1 and 2.

On the 51st day of the experiment, the largest number of inflorescences on the salvia shrub was observed in option 4 (206% higher than in control), followed by option 3 (138% higher than in control), in the second option and the control option the number of inflorescences is the same and amounted to 1.8 pcs. On the 85th day of the experiment, the largest number of inflorescences on the salvia shrub was also observed in option 4 (175% higher than in control), followed by option 3 (137% higher than in control), the lowest value was recorded in option 2 – 4.4 pieces, which is 10% higher than in the control option.

On the 51st day of the experiment, the largest number of flowers in the salvia inflorescence is observed in option 4 (55% higher than in the control), followed by variant 3 with an increase of 49%, the lowest value was recorded in option 2 (20% higher than in the control option). On the 85th day of the experiment, despite unfavorable meteorological conditions for the flowering of salvia in the period from the 51st to the 85th days of the experiment (July to August of the growing season 2021), which led to the fact that the flowers in the salvia inflorescences partially wilted and fell off, a similar trend is observed: the largest number of flowers in the inflorescence was recorded in option 4 – 77.0 pcs., which is 55% higher than in the control, slightly less in option 3 – 71.2 pcs., which is 44% higher than in the control, the lowest value obtained in option 2 – 64.6 pcs., which is 30% higher than in the control.

When using the agrochemical "Soil-Green City" in doses of 2–4 kg/m$^2$, the content of gross forms of heavy metals (Pb, Ni, Cu, Zn,

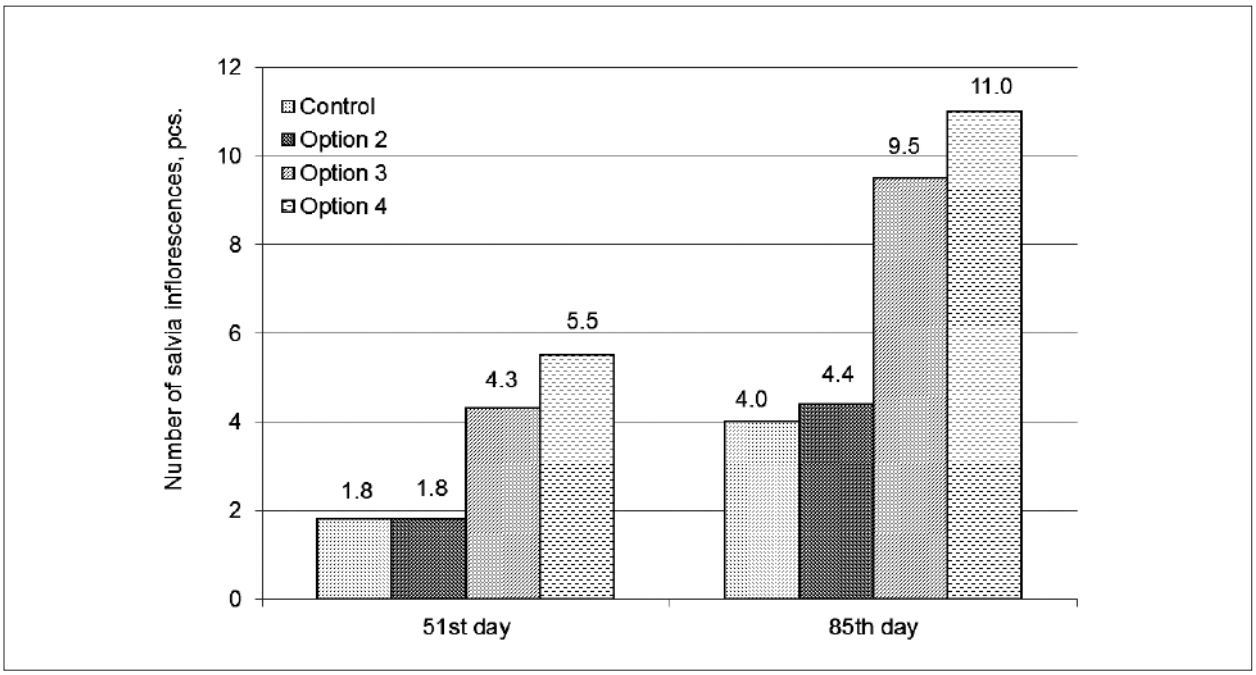


**Fig. 1.** Comparative assessment of the number of salvia inflorescences when using the agrochemical "Soil Green City" on flowerbeds

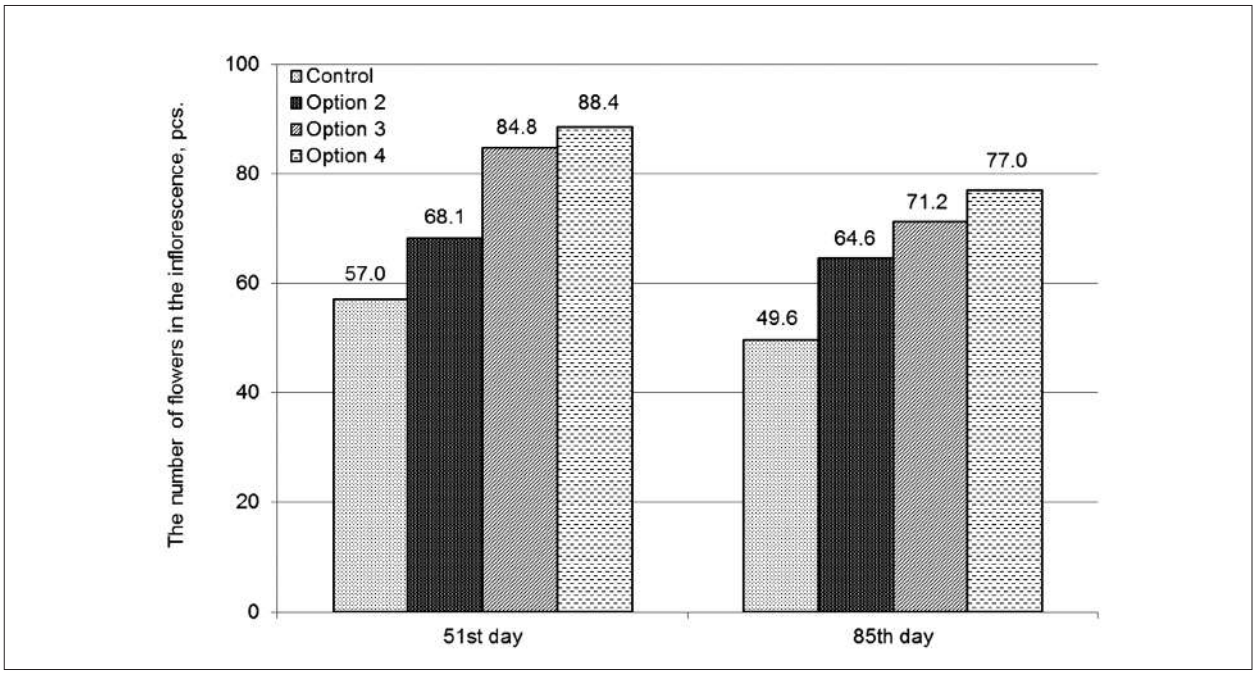


**Fig. 2.** Comparative assessment of the number of flowers in the inflorescence of salvia when using the agrochemical "Soil Green City" in flowerbeds

**Table 2**

The content of gross forms of heavy metals and arsenic in the soil when using the agrochemical "Soil Green City", mg/kg

| No. | Element | Agrochemical application dose, kg/m² | | | Standard content |
|---|---|---|---|---|---|
| | | 2 | 3 | 4 | |
| 1 | Lead | 12.7±3.8 | 13±4 | 14±4 | 32* |
| 2 | Nickel | 6.2±1.9 | 6.4±2.0 | 7.0±2.3 | 20* |
| 3 | Arsenic | 1.53±0.07 | 1.63±0.06 | 1.72±0.08 | 2.0* |
| 4 | Copper | 8.2±2.5 | 9.5±2.8 | 10.6±3.2 | 33* |
| 5 | Zinc | 33±10 | 43±6 | 47±5 | 55* |
| 6 | Chromium | 5.1±2.1 | 6.2±2.3 | 8±5 | 61** |
| 7 | Cadmium | 0.26±0.08 | 0.30±0.09 | 0.33±0.11 | 0.5* |
| 8 | Mercury | 0.033±0.021 | 0.061±0.028 | 0.09±0.05 | 2.1* |

*Note: * – according to SanPiN 1.2.3685-21, ** – background for soils of the Moscow region [27].*

Cr, Cd, Hg) and As in the soil did not exceed the values established by sanitary and hygienic standards.

## Conclusion

The positive effect of the test doses of the agrochemical "Soil Green City" on the growth and development of salvia (*S. splendens*) was experimentally confirmed. This flower-decorative culture showed the best results in the variant with the introduction of an agrochemical at a dose of 4 kg/m², slightly inferior to the variant with the introduction of an agrochemical at a dose of 3 kg/m². On the 8th and 22nd day of the experiment, the best results in terms of the height of salvia plants were obtained in the variant with the introduction of an agrochemical at a dose of 2 kg/m². However, starting from the 33rd day of the experiment and until its completion, the best results in terms of plant height were obtained in the variant with the introduction of an agrochemical at a dose of 4 kg/m²; the variant with the introduction of an agrochemical at a dose of 3 kg/m² is slightly inferior to it. This circumstance apparently is associated with the prolonged release of nutrients from the agrochemical into the soil solution and their entry into the plants. When the agrochemical "Soil Green City" was applied in doses of 2–4 kg/m², the content of gross forms of heavy metals in the soil did not exceed the values established

by sanitary and hygienic standards. To create favorable conditions for the growth and development of salvia when grown in flowerbeds and increase its stress resistance to abiotic factors, it is recommended to use the agrochemical "Soil Green City" at a dose of 3–4 kg/m$^2$. In the future, it seems appropriate to continue this field experiment to assess the prolonged impact of the agrochemical "Soil Green City" on flower and ornamental crops and the dynamics of the content of heavy metals in the soil.

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## Проект «Натуральные удобрения пролонгированного действия, полученные на основе «зелёной химии»

Разработка и внедрение зелёных технологий является важнейшим трендом развития мировой экономики на современном этапе. Инновационные разработки и перспективные технологические решения, позволяющие снизить антропогенную нагрузку на окружающую среду и обеспечить рациональное использование природных ресурсов, представляют большой интерес для современного бизнеса как в России, так и за рубежом. К числу соответствующих разработок можно отнести проект «Натуральные удобрения пролонгированного действия, полученные на основе «зелёной химии» из Вятско-Камских фосфоритов и вятского торфа», разработанный учёными научно-исследовательской лаборатории биомониторинга Вятского государственного университета (научный руководитель – к.х.н., доцент Н.В. Сырчина). Соответствующий проект прошёл экспертный отбор в конкурсе стратегических инициатив и вошёл в топ 1000 инициатив для форума «Сильные идеи для нового времени – 2022».

Желваковые фосфориты и торф являются важнейшими полезными ископаемыми Кировской области. На основе соответствующих природных ресурсов может быть налажено производство широкой линейки органоминеральных удобрений (ОМУ) с улучшенными характеристиками, натуральных удобрений для органического земледелия и почвенных мелиорантов. К преимуществам вятских фосфоритов следует отнести низкое содержание токсичных элементов, в частности кадмия, хорошую биодоступность фосфора, наличие в составе руды глауконита, оказывающего положительное влияние на активность почвенных азотфиксирующих микроорганизмов, химический состав и структуру почвы.

В отличие от традиционных растворимых минеральных удобрений, ОМУ на основе фосфоритов Вятско-Камского месторождения характеризуются пролонгированным периодом действия, не вымываются из почвы, способствуют оптимизации pH и детоксикации корнеобитаемого горизонта за счёт сорбции ряда тяжёлых металлов глауконитом. Производство ОМУ ориентировано на безотходную переработку добываемой руды, низкую энергоёмкость производственного процесса и исключение химического воздействия на сырьевые компоненты, что полностью соответствует принципам «зелёной химии».

Организаторами конкурса является Агентство стратегических инициатив. Первый, подготовительный, этап конкурса пройдёт с 1 июня по 4 июля, второй этап – с 5 июля по 20 июля 2022 г. Желаю участникам проекта успешного прохождения всех этапов конкурса и внедрения проекта в практику!

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