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# QUALITY OF GARDEN STRAWBERRY FRUIT GROWN UNDER CONDITIONS OF TECHNOGENIC POLLUTION

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**Abstract.** The quality of fruit of garden strawberries grown on technogenically contaminated soils has been assessed. The highest level of copper and zinc in the fruit was recorded after broadcasting the recommended quantity of the fertiliser $N_{90}P_{60}K_{30}$. Introduction of the sorbent ameliorant GREENODIN GRAY reduced the content of copper and zinc in the strawberries by 39 and 59% respectively. Researching the early-ripening strawberry cultivars Olviya and Rozana Kyivska has revealed varietal differences in the fruit's trace element composition. Thus, it can be considered that selection of the proper cultivar is another effective method of obtaining environmentally safe products. Both strawberry cultivars under study were characterised by intense translocation of Cu and Zn into fruit. However, the Rozana Kyivska fruit contained 3 times more copper than the cultivar Olviya did. The zinc level, too, was higher in the Rozana Kyivska fruit (by 1.5 times). When introducing the recommended quantity of the fertiliser $N_{90}P_{60}K_{30}$, the following criteria for the potential storability and transportability of the Olviya berries were recorded: resistance to phytopathogens, dense consistency of a berry, and the dry matter content 10.08%. As a result, the Olviya berries had the longest shelf life – 7 days, when stored in cooling chambers at 0.5°C and relative air humidity 90%. The sugar-acid index in these samples had the maximum value 6.9%, but the amount of vitamin C was at a minimum. This research has become the basis for practical application of a technology of growing strawberries of the cultivar Olviya. The technology involves broadcasting the fertiliser $N_{90}P_{60}K_{30}$ together with the sorbent ameliorant GREENODIN GRAY (500 kg/ha) during the primary tillage, and introduction of $N_{45}P_{30}K_{15}$ with irrigation water. The resulting Olviya berries are resistant to diseases and phytopathogenic damage during storage, have high nutritional value, and are less likely to accumulate ecotoxicants. The yield of berries in the first year of using the plantation was 6,200–6,500kg/ha. The content of nitrates and heavy metals in the berries did not exceed the maximum permissible concentration.

**Key words:** garden strawberry, cultivar, heavy metals, nutritional value, environmentally safe product.

## Introduction. Formulation of the problem

In the world, production of berries is steadily tending to grow. The global import of berries is only increasing with years, being now over 6.5 million tonnes. Of them, the most widely grown species is the garden strawberry. It makes about 70 per cent of the world production of berries, followed by currants and raspberry, which run second and third respectively. Its high sensory qualities, rich complex of bioactive substances, high disease-preventive capacity have made this berry one of the most popular with consumers. That is why producers of these berries find it so important to improve their quality and nutritional value and to increase their storability in the course of commercial exchange and processing. In a number of European countries, measures to protect strawberries during their growing season include ten pesticide treatments. The last of the treatments is allowed 3–5 days before harvesting [1].

In our country, industrial strawberry plantations are still protected with substances containing heavy metals. Besides, strawberry is a crop highly popular with home gardeners, who often have their garden plots near highways or industrial centres where the risk of heavy metal accumulation in berries is high. This proves the importance of studying the ways through which toxins enter strawberry plants and of developing effective methods to reduce heavy metal accumulation in fruit caused by technogenic pollution.

## Analysis of recent research and publications

Heavy metals are chemical elements with the atomic mass over 40 and density higher than 5g/cm$^3$, having the properties of metals [2]. The term 'heavy metals' is but vague: this group includes copper, zinc, and other elements, called trace elements. They are of positive biological value, but when accumulated over a certain threshold limit, they can become toxic and activate or, conversely, hinder biochemical processes in living organisms. Of special interest are such heavy metals as zinc, copper, lead, and cadmium. Strawberry plants do not need most heavy metals, but can actively absorb and accumulate them and pass them on into the human body along food chains. This is because strawberries have a shallow root system and is more sensitive to pollution of soils than other berries are.

Overconcentration of heavy metals (HM) in fruit and berries grown under conditions of man-caused impact is shown in studies by O. Vetrova et al. [3], T. Sennovska et al. [4], C. G. Kowalenko [5], N. Bağdatlıoğlu et al [6], M. Hamurcu [7], A. Siedlecka [8], W. Treder, G. Cieslinski [9]. Thus, N. Bağdatlıoğlu and her co-authors note that lead finds its way into strawberry plants and is transported into their above-ground organs more slowly than other heavy metals. C. G. Kowalenko [5] studied the distribution of trace elements (boron, zinc, manganese, and iron) in the above-ground organs of raspberry plants (the cultivar Willamette). M. Hamurcu, M.M. Özcan, N.Dursun, S. Gezgin analysed strawberries for the presence of heavy metals and found that none of the samples contained cadmium and lead, but in seven samples, nickel exceeded the maximum contamination threshold. Many researchers established that this element was weakly fixed in the roots and more evenly (compared to other HM) distributed in the organs of strawberry plants [3,8]. W. Treder and G. Cieslinski from Poland report that silicon, in the form of potassium silicate, introduced directly into the soil when planting Elsanta strawberries reduced absorption of cadmium by plants and mitigated its toxic effect on them [9].

There is little information on how much zinc is contained in vegetative organs of berry crops, and practically all the data are only about its content in leaves [4,6]. According to the results obtained by the Russian researchers [10], blackcurrant leaves contained 20 times as much zinc as berries did, and gooseberry and raspberry leaves 4-5 times as much. It is, though, not easy to estimate these authors' results, because their data on the HM content are given on a wet weight basis. So, it is quite a problem to compare their results with data on other crops normally presented as mg/kg of dry matter. However, fruit of berry crops contain several-fold more water than their leaves do, thus the difference these authors established in the amounts of zinc contained in raspberry and gooseberry leaves and fruit may be but insignificant.

Accumulation of copper in vegetative organs of the strawberry of the variety Red Gauntlet is considered in detail by B. K. Tsilu [11]. In the course of these greenhouse experiments, the amounts of copper (in the form of $CuSO_4$) introduced into the soil were 40 and 60mg/kg. These levels of copper contamination of soil are comparable to that of our experimental field. According to the researcher, on the soil with no contamination, copper accumulation in the plants followed the path leaves>fruit>roots. On the contaminated soils, no matter how high their contamination level was, the following path was observed: leaves>roots>fruit.

The most environmentally significant HM in the soil are loosely-bonded compounds, because they get into plants and migrate to other adjacent media. Ion exchange and adsorption are the processes essential for fixation of active forms of HM by the soil. Agricultural measures that intensify these processes in the soil can reduce the level of the HM forms most available to plants. As sorbent ameliorants, one can use waste from local mining enterprises and preparation plants, residues of processing mineral raw materials, and many naturally occurring minerals, such as shungite, bentonite, glauconite, perlite, diatomite, vermiculite, zeolite, etc. Organic sorbents can be used, too: manure, peat, sapropel, vermicompost. How effectively these fertilisers reduce the risk of HM contamination of berry and fruit crops is shown by B. K. Tsilu [11], S. Babel et al. [12], A. Abd-Elfaltah and K.Wada [13], E. Boros [14], and other scientists [15,16]. However, practical aspects of applying organic sorbents in strawberry cultivation still remain underdeveloped.

Soil humidity, too, has a significant effect on HM accumulation in fruit of berry plants [17-19]. The researchers [4] observed that in the year when the soil humidity was higher, blackcurrant berries were heavier and contained far less nickel, zinc, iron, and copper. Therefore, when growing berry plants on soils high in heavy metals, irrigation can have a positive effect.

Thus, to control the level of toxic agents in strawberry fruit, such methods can prove effective as selecting cultivars that resist HM accumulation and using natural adsorbents to raise agricultural crops under conditions of irrigation. It has already been shown how important it is to study distribution of heavy metals in plant organs and tissues depending on the species and cultivar [3,4,10,11,16], but there is still a lack of similar research considering domestic varieties of the garden strawberry. All the above proves the novelty of this research carried out with two cultivars of the garden strawberry under conditions of real contamination.

**Purpose and objectives of the research.** The purpose of the research is to find out whether the garden strawberry grown on technologically contaminated soils can yield environmentally safe products of high quality. To achieve this purpose, the following **objectives** were set:

– to study how using an organic sorbent fertiliser combined with mineral fertilisers effects on accumulation of heavy metals (copper, zinc) and nitrates in garden strawberry fruit;

– to compare the contents of heavy metals in fruit of the cultivars Olviya and Rozana Kyivska, and the biochemical and technological characteristics of their berries.

## Research materials and methods

The material for the research was a triennial plantation of the garden strawberry *Fragaria ananassa* Duch. (the early-season cultivars Olviya and Rozana Kyivska). Both cultivars were developed by selective breeding at the Institute of Horticulture of the National Academy of Agrarian Sciences of Ukraine (IH NAAS). The berries were picked in the period of mass ripening of strawberry fruit (the end of June, the years 2018 and 2019). The research lasted throughout the years 2018–2019 on the premises of Mykolaiv State Agricultural Research Station of the Institute of Irrigated Farming, NAAS, with the use of drip irrigation. The soil of the experimental field was southern chernozem. For three years prior to the research, the field had been used to grow early potato, which had been subjected to heavy treatments with pesticides. As a result, when the plot was pre-examined in autumn, it turned out that the content of some HM in the soil of the ecosystem to be studied exceeded the maximum permissible concentrations (MPC). It was established that the topsoil was mostly contaminated by such HM as copper, cadmium, and zinc: their content was, respectively, by 21.6, 2.2, and 1.3 times higher than the MPC values 3.00, 23.00, and 0.70 mg/kg. (Looking ahead, it should be noted that at the end of vegetation, the adsorptive effect of the ameliorant, washing-out into deeper soil layers, transition of HM into active forms, and absorption by plants reduced the above-mentioned HM in the soil by 2–6 times.)

The agricultural methods were those commonly used to grow garden strawberry, except for certain techniques that were to be studied. From the start of vegetation till the end of the fructification period, the humidity of the soil layer, as deep as 30–40cm, was maintained at 70–80–70% of the minimum moisture-holding capacity (MMHC). The design of the experiment also included the quantities of fertilisers and methods of applying them: no fertilisers (control); $N_{90}P_{60}K_{30}$ introduced by broadcasting (Sample 1); GREENODIN GRAY, 250kg/ha, broadcast (Sample 2); GREENODIN GRAY, 500kg/ha, broadcast + $N_{45}P_{30}K_{15}$ introduced with irrigation water (Sample 3). The sorbent ameliorant GREENODIN GRAY (manufactured by *Sinta*) is an organomineral mixture based on sapropel and silicon-containing minerals. The product is used to recultivate soils contaminated with heavy metals and organic compounds, to reduce soil fatigue caused by planting the same crop for years, and to improve the agrophysical parameters of acidic and toxic soils. The fertilisers were applied before planting, according to the design of the experiment. Fertigation with $N_{45}P_{30}K_{15}$ was carried out in the blooming period.

During mass ripening of strawberries, to assess how effectively the agricultural measures prevented HM from penetrating the plants, fruit samples were picked in all variants of the experiment and analysed for their HM content. The samples were transported to the laboratory in the Mykolaiv affiliate of the Soils Protection Institute of Ukraine (certified as an experimental laboratory, accreditation no. 20830, in accordance with State Standard of Ukraine (DSTU) ISO/IEC 17025:2017). Heavy metals were determined in the samples by atomic absorption spectrophotometry, using the apparatus C-115-M1, according to DSTU ISO 6636-2:2004 and DSTU ISO 7952:2004.

For each variant of the experiment, fruit were harvested separately, by hand, from all over the experimental plot. The products harvested were registered according to the procedure prescribed for agricultural experiments with berry crops [21]. To determine the preservation capacity of the berries, they were packed for storage. Immediately after harvesting, the berries were sorted, cleared of sepals, washed, dried slightly, placed into perforated containers (each sample weighed 600–700 g), and cooled down to 0.5°C in cooling chambers. The storage temperature was 0.5°C, the relative atmospheric humidity 90%. The samples were stored for 7 days. The degree of preservation of the strawberries was checked on the 3$^{rd}$ and 7$^{th}$ days by the change in the weight of the berries (expressed as percentage of their initial weight).

The biochemical analysis of fresh and cooled berries included determining the soluble solids content (by refractometry, according to DSTU 28562-90), the total sugars (by photocolourimetry, DSTU 4954:2008), vitamin C (by iodometry, GOST (State Standard) 24556), titrated acidity (by titration with an alkali, DSTU 4957), sugar-acid index (by the ratio of the mass fraction of sugars to organic acids), the nitrate content (ionometrically, DSTU 4948:2008), the content of salts of heavy metals (by atomic adsorption, according to DSTU ISO 6636-2:2004 and DSTU ISO 7952:2004).

## Results of the research and their discussion

The well-balanced combination of sugars and acids, tender pulp, and easy-to-digest nutrients make strawberries a valuable dietetic food product. The main quality parameter determining their superior palatability is their chemical composition: the content of dry matter, sugars, organic acids, and vitamins. To assess the most promising variants of growing the garden strawberry with the use of drip irrigation, a series of biochemical tests has been conducted to determine the content of the main biochemical components of the berries (Table 1).

**Table 1 – Biochemical parameters of fresh garden strawberries (factorial distribution of the experiment 2x4 in quadruplicate)**

| Variants of the experiment | Dry matter, % | Total sugars, % | Titrated acidity*, % | Sugar-acid index | Vitamin C, mg/100g |
|---|---|---|---|---|---|
| Olviya | | | | | |
| 1. Control (no fertilisers) | 8.60 | 4.56 | 0.78 | 5.8 | 62.7 |
| 2. Sample 1 | 10.08 | 6.92 | 1.01 | 6.9 | 55.0 |
| 3. Sample 2 | 9.02 | 5.19 | 0.82 | 6.3 | 60.6 |
| 4. Sample 3 | 9.93 | 6.97 | 1.15 | 6.1 | 71.4 |
| *S (standard deviation)* | *0.71* | *1.22* | *0.17* | *0.46* | *6.81* |
| *X±Sx (standard error)* | *0.36* | *0.61* | *0.09* | *0.23* | *3.40* |
| Rozana Kyivska | | | | | |
| 1. Control (no fertilisers) | 8.11 | 4.12 | 0.75 | 5.4 | 60.0 |
| 2. Sample 1 | 8.85 | 5.62 | 0.87 | 6.5 | 71.9 |
| 3. Sample 2 | 8.72 | 5.07 | 0.80 | 6.3 | 62.4 |
| 4. Sample 3 | 8.61 | 5.94 | 0.94 | 6.3 | 64.3 |
| *S (standard deviation)* | *0.32* | *0.80* | *0.08* | *0.49* | *5.14* |
| *X±Sx (standard error)* | *0.16* | *0.40* | *0.04* | *0.25* | *2.57* |

* in citric acid equivalent.

According to the data from the literature, the most valuable strawberry cultivars are those containing at least 12% of soluble solids (SS) in fresh berries. The SS level required for technological processing should be no lower than 8–10% [11]. These data allow concluding that the dry matter content in the strawberry cultivars considered in our research was above average. Under the influence of the factors under study, this parameter varied from 8.11 to 10.08%. Analysis has shown that using fertilisers increases the dry matter content in berries by 0.42–1.33%, compared to the control. An increase in the dry matter was registered in the variants where mineral fertilisers were broadcast in the recommended quantities (Variant 2). The highest content of the dry matter was recorded when growing the cultivar Olviya, which results in good transportability of berries of this variety. Strawberries mainly contain such sugars as glucose, sucrose, and fructose [9,11]. The sugar content in the Olviya cultivar, too, was by 0.12–1.30% higher than in Rozana Kyivska. Of the nutrition variants analysed, the variant with no fertilisers and the one with only 250kg/ha of GREENODIN GRAY introduced yielded raw materials with the lowest sugar level, 5.07–5.19%. Application of other quantities of fertilisers increased this parameter by 0.63–2.36% compared to the control.

The ratio of sugars and acids determines how strawberries taste when eaten. The higher the sugar-acid index is, the stronger the sensation of the 'sweet taste' of the berry, and the lower this index, the 'sourer' taste is felt. Sweeter berries are more readily eaten fresh, but berries high in acid are less rottable and not so easily get fermented when processed. According to our research data, the sugar-acid index was the lowest in the strawberries grown with no fertilisers, and the highest index (6.9) was in the Olviya strawberries with the recommended dose of mineral fertilisers introduced by broadcasting (Variant 2).

Strawberry is an early crop, so in this period, it is the main source of the antioxidant – vitamin C. In the research, the ascorbic acid content in the strawberries ranged from 55 to 72mg/100g. Its level was a little higher in the Rozana Kyivska berries (an average of 64.7mg/100 g of all the experimental variants), whereas its content in the Olviya fruit was 62.4mg/100g. Assessment of other variants of the experiment (fertilised backgrounds) revealed no other regularities in accumulation of this substance in these cultivars.

Another indicator of the quality of strawberries is the amount of heavy metal ions they accumulate – in particular, copper and zinc (Table 2).

**Table 2 – Content of toxic elements in garden strawberry fruit, mg/kg DM (factorial distribution of the experiment 2x4 in quadruplicate)**

| Variants of the experiment | Cu | Zn | $NO_3$ |
|---|---|---|---|
| Olviya | | | |
| 1. Control (no fertilisers) | 0.60 | 1.42 | 27.2 |
| 2. Sample 1 | 0.68 | 2.87 | 42.5 |
| 3. Sample 2 | 0.62 | 1.69 | 27.5 |
| 4. Sample 3 | 0.63 | 1.75 | 31.7 |
| *S (standard deviation)* | *0.03* | *0.64* | *7.15* |
| *X±Sx (standard error)* | *0.02* | *0.32* | *3.58* |
| Rozana Kyivska | | | |
| 1. Control (no fertilisers) | 1.67 | 2.65 | 27.4 |
| 2. Sample 1 | 2.83 | 3.78 | 43.6 |
| 3. Sample 2 | 1.65 | 2.41 | 31.5 |
| 4. Sample 3 | 1.69 | 2.57 | 33.7 |
| *S (standard deviation)* | *0.58* | *0.63* | *6.88* |
| *X±Sx (standard error)* | *0.29* | *0.31* | *3.44* |
| *MPC, mg/kg [22]* | *5.00* | *10.00* | *60.00* |

Copper, a biogenic element, was the principal contaminant in the environmental conditions of our experiment (its content in the soil exceeded the MPC). Today, there is hardly any doubt that copper plays an important part in metabolism of plants. Copper participates in nitrogen and protein metabolism and activates such important enzymes as nitrate reductase and proteases. The copper-containing protein plastocyanin is an element in the photosynthesis electron transport chain. This accounts for the high Cu level in chloroplasts (75% of its total amount in a leaf). On the other hand, copper is often a pollutant because of its high technophility and due to the wide use of copper-containing fungicides in farming.

In both strawberry cultivars, the lowest Cu level was in the roots (Olviya – 0.58–2.24, Rozana Kyivska – 0.86–1.02mg/kg DM). The leaves accumulated 0.34 to 1.68. Most copper was detected in the fruit. Depending on the fertiliser used, the copper content in the fruit was as follows (mg/kg DM): 0.60–0.68 in Olviya, 1.65–2.83 in Rozana Kyivska. The highest level of copper accumulation was in the Rozana Kyivska berries – 1.96mg/kg DM (an average of fertiliser backgrounds). The Olviya berries accumulated this element in smaller quantities: respectively, 0.63mg/kgDM. Besides, the cultivar Rozana Kyivska was characterised by higher accumulation of this element in the roots.

For the two cultivars, the average content of copper in the fruit was by 1.03–1.69 times lower in the control sample (no fertilisers) than in the fertilised samples. It is worth noting that application of the recommended quantity of $N_{90}P_{60}K_{30}$ caused an increase in copper in the berries, and the use of the recultivant GREENODIN GRAY resulted in its decrease.

Zinc is another important biogenic trace element necessary to synthesise chlorophyll and maintain the respiratory enzyme activity. It is a component of such enzyme as carbonic anhydrase, which catalyses decomposition of carbonic acid into water and $CO_2$, then participates in photosynthesis. Zinc in plants is highly mobile. Unlike lead, nickel, and cadmium, zinc can pass through the plasmalemma of bundle sheath cells and is found not only in cover and conductive tissues of a leaf, but in the mesophyll, too [3].

In the strawberry cultivars analysed, the zinc content in the fruit was significantly higher (5–15 times as much) than in the leaves and roots. Thus, zinc in the roots ranged 0.14–0.56mg/kg DM in Olviya and 0.43–0.84mg/kg DM in Rozana Kyivska. In the leaves, it ranged 0.15–0.26mg/kg DM in Olviya and 0.17–0.29mg/kg DM in Rozana Kyivska. The zinc content in the fruit, depending on the fertiliser, was (mg/kg DM): in Olviya, 1.42-2.87, in Rozana Kyivska, 2.41–3.78.

The highest level of zinc was in the Rozana Kyivska berries, and the Olviya berries accumulated less of it. Besides, the roots and leaves of Rozana Kyivska, too, had the higher content of zinc. The average zinc content in the strawberry fruit was by 0.91–2.02 times lower in the unfertilised control than in the fertilised samples. Like it was with copper, introduction of the recommended dose of $N_{90}P_{60}K_{30}$ increased the zinc content in the berries, and application of the recultivant GREENODIN GRAY decreased it.

Determining the content of nitrates in the strawberries has shown that the techniques under study do not result in nitrate accumulation in quantities exceeding the MPC. The lowest nitrate level was registered in the crop grown on the unfertilised ground. It has also been established how $NO_3$ accumulation in the berries varies with the cultivar. The largest quantities of nitrates were registered for Rozana Kyivska (34.1mg/kg on average for the fertilised backgrounds). Using the cultivar Olviya reduces the nitrate content by 5.3%.

Due to its physiological features, the garden strawberry is classified as a perishable horticultural product. Its high moisture content, thin cover tissues and cell walls, weak moisture-holding capacity of colloids in the cytoplasm, and low mechanical strength results in the poor storability of strawberries. Besides, their storability is greatly affected by the varietal genotype, degree of ripeness, agrotechnological and environmental factors of their cultivation. The storage time of perishable berries increases under conditions when the metabolic activity in berries is reduced. That is why during industrial storage, strawberries are kept in cooling chambers at 0–2°C and air humidity about 95% for 5–7 days. Cooling down allows maximum retention of the natural properties of fruit, but is accompanied by reduction in the total quantity of standard berries (Table 3).

**Table 3 – Degree of preservation of standard strawberries, % of the initial quality (factorial distribution of the experiment 2x4 in quadruplicate)**

| Variants of the experiment | Day of storage | | |
|---|---|---|---|
| | 1st | 3rd | 7th |
| Olviya | | | |
| 1. Control (no fertilisers) | 100 | 96 | 80 |
| 2. Sample 1 | 100 | 100 | 92 |
| 3. Sample 2 | 100 | 100 | 84 |
| 4. Sample 3 | 100 | 100 | 92 |
| *V, % (coefficient of variation)* | – | *2.0* | *6.9* |
| Rozana Kyivska | | | |
| 1. Control (no fertilisers) | 100 | 90 | 75 |
| 2. Sample 1 | 100 | 98 | 82 |
| 3. Sample 2 | 100 | 97 | 81 |
| 4. Sample 3 | 100 | 97 | 81 |
| *V, % (coefficient of variation)* | – | *3.9* | *4.0* |

In the course of the experiment, it was established that the samples of berries with a higher dry matter content were characterised by higher preservation capacity, and for the first 3 days of storage, fully retained their quality and maximum resistance to *Botrytis cinerea* infection (‘grey rot’). Their further storage led to reduction in the number of berries of the standard quality because of natural loss and phytopathogenic damage. The higher degree of preservation was observed in the Olviya berries (92% of standard berries on the seventh day of storage).

## Approbation of results

This research has proved the advantages of the garden strawberry cultivar Olviya: it is resistant to diseases and phytopathogenic damage to its fruit when stored, has high nutritional value, and is less likely to accumulate ecotoxicants. Along with selecting the proper cultivar, application of certain acrotechnological methods allowed reducing the ingress of HM from the environment into plants. So, this technology (cultivation of Olviya strawberries accompanied by broadcasting 500kg/ha of $N_{90}P_{60}K_{30}$ together with the sorbent ameliorant GREENODIN GRAY during the primary tillage, and introduction of $N_{45}P_{30}K_{15}$ with irrigation water) was implemented at the private enterprise *Dvoretsky V.F.* on a 0.5ha field. In the first year of using the plantation, the yield of berries was 6,200–6,500 kg/ha. The nitrate and HM content did not exceed the MPC.

## Conclusion

It has been found how to obtain environmentally safe garden strawberries of high quality by growing them on technogenically polluted soils. In particular, determining the content of the main pollutants, copper and zinc, and of nitrates has shown that their level in the berries did not exceed the MPC. Introduction of the sorbent ameliorant GREENODIN GRAY allows reducing the content of copper and zinc in strawberries by 39 and 59% respectively. The copper and zinc content in the Rozana Kyivska fruit was, respectively, 3 and 1.5 times higher than in the variety Olviya. When the recommended quantity of the fertiliser $N_{90}P_{60}K_{30}$ was introduced, the following parameters of the potential storability and transportability of the Olviya berries were recorded: resistance to phytopathogens, dense consistency of a berry, and the dry matter content 10.08%. As a result, the Olviya berries had the longest shelf life – 7 days, when stored in cooling chambers at 0.5°C and relative air humidity 90%. In these samples, the sugar-acid index had the maximum value 6.9%.

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# ЯКІСТЬ ПЛОДІВ СУНИЦІ САДОВОЇ ПРИ ВИРОЩУВАННІ В УМОВАХ ТЕХНОГЕННОГО ЗАБРУДНЕННЯ

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**Анотація.** Оцінено якість плодів суниці садової, вирощеної на техногенно забруднених ґрунтах. Найбільше Cu і Zn у плодах зафіксовано за внесення рекомендованої дози добрив ($N_{90}P_{60}K_{30}$ врозкид), внесення меліоранту-сорбенту GREENODIN GRAY дозволяє знизити вміст Cu і Zn у ягодах суниці на 39 та 59% відповідно. При вивченні ранньостиглих сортів суниці Ольвія та Розана київська доведеноі сортові розходження в мікроелементному складі плодів, що дозволяє вважати підбір сорту також потенційно ефективним прийомом одержання екологічно безпечної продукції. Для обох досліджуваних сортів суниці характерна інтенсивна транслокація Cu і Zn у плоди. Однак у сорту Розана київська плоди містили Cu відповідно у 3 рази більше, ніж у сорту Ольвія. Вищий вміст Zn у плодах також зазначений по сорту Розанна київська (у 1,5 рази). При внесенні рекомендованої дози добрив $N_{90}P_{60}K_{30}$ у ягодах сорту Ольвія зафіксовано критерії потенціальної лежкості й транспортабельності ягід: стійкість до фітопатогенів, щільна консистенція ягід, вміст сухих речовин 10.08%, внаслідок чого ягоди сорту Ольвія мали максимальний термін зберігання в холодильних камерах при температурі 0,5°С і відносній вологості повітря 90% – 7 діб. У відмічених зразках ягід цукрово-кислотний індекс мав максимальний показник 6,9%, однак вітамін С був у мінімальній кількості. На підставі даних досліджень, у виробництво впроваджено технологію вирощування суниці сорту Ольвія із внесенням $N_{90}P_{60}K_{30}$ разом з меліорантом-сорбентом GREENODIN GRAY, 500 кг/га врозкид під основний обробіток ґрунту та $N_{45}P_{30}K_{15}$ з поливною водою, ягоди якої відрізнялися стійкістю до захворювань і ураження фітопатогенами при зберіганні, високою харчовою цінністю та мали схильність до меншого накопичення екотоксикантів. Урожайність ягід у перший рік використання плантації становила 65 ц/га, вміст нітратів та важких металів у ягодах не перевищував гранично допустиму концентрацію.

**Ключові слова:** суниця садова, сорт, важкі метали, харчова цінність, екологічно безпечна продукція.

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