CROP PRODUCTION

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Adimale F.*

St. Petersburg State Agrarian University, Saint Petersburg, Russia

* Correspodning author (felicianoad[at]mail.ru)

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THE EFFECT OF A HUMIC PREPARATION ON THE ACCUMULATION OF CADMIUM AND LEAD BY AMARANTH FROM SOD –CARBONATE SOIL

Research article

Abstract

The current study conducts a vegetation experiment in order to study the effectiveness of foliar application for amaranth with a solution of humic substances on the accumulation of cadmium and lead in plants from calcareous soil. The experiment utilizes a humic preparation (HP) made from vermicompost. In the experiment, the calcareous soil had a neutral reaction of the medium, it is rich in organic matter with a high content of mobile phosphorus and medium content of mobile potassium. The variants of the experiment differed in the concentration of the humic preparation (0.002 and 0.0002 mg/l) and the number of plant treatments with the drug. The humic preparation was applied against the background of mineral fertilizers and separately. The treatment of amaranth with a humic preparation was carried out on 17th, 27th, 37th days after sowing. The foliar fertilization of amaranth with the solution of humic substances contributed to an increase in plant biomass when using mineral fertilizer and without it. This significantly reduced the lead content in plants when mineral fertilizers were not used; this effect was not observed when using mineral fertilizers When treating amaranth with a solution of humic substances, a decrease in the content of cadmium and its accumulation coefficients in plants was observed both against the background of the use of mineral fertilizers and in their absence. The cadmium content in amaranth plants on calcareous soil, in which mineral fertilizers were applied, was on average 2.8 times less than in the variants without fertilizers. The use of mineral fertilizers contributed to an increase in the removal of lead and cadmium by amaranth from calcareous soil.

Keywords: humic prepparate, foliar fertilization, amaranth plants, cadmium and lead, calcareous soil.

Адимале Ф.*

Санкт–Петербургский государственный аграрный университет, Санкт–Петербург, Россия

* Корреспондирующий автор (felicianoad[at]mail.ru)

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ВЛИЯНИЕ ГУМИНОВОГО ПРЕПАРАТА НА НАКОПЛЕНИЕ КАДМИЯ И СВИНЦА АМАРАНТОМ ИЗ ДЕРНОВО –КАРБОНАТНОЙ ПОЧВЫ

Научная статья

Аннотация

С целью исследования эффективности некорневой подкормки амаранта раствором гуминовых веществ на накопление кадмия и свинца в растениях из дерново-подзолистой почвы был проведен вегетационный опыт. В опыте использовали гуминовый препарат, приготовленный из вермикомпоста . Дерново-карбонатная почва опыта имела нейтральную реакцию среды, богата органическим веществом, с высоким содержанием подвижного фосфора и средним – подвижного калия. Варианты опыта отличались концентрацией раствора гуминового препарата (0,002 и 0,0002 мг/л) и количеством обработок растений препаратом. Гуминовый препарат был применен на фоне минеральных удобрений и отдельно. Обработка амаранта гуминовым препаратом была проведена через 17, 27, 37 суток после посева. Некорневая подкормка амаранта раствором гуминовых веществ способствовала увеличению биомассы растений при применении минерального удобрения и без него. Некорневые подкормки посевов амаранта раствором гуминовых веществ значительно снижали содержания свинца в растениях, когда минеральные удобрения не применялись. При применении минеральных удобрений этот эффект не отмечен. При обработке амаранта раствором гуминовых веществ наблюдалось снижение содержания кадмия и его коэффициентов накопления в растениях, как на фоне применения минеральных удобрений, так и при их отсутствии. Содержание кадмия в растениях амаранта на дерново –карбонатной почве, в которую были внесены минеральные удобрения, были в среднем в 2,8 раза меньше, чем в вариантах без удобрений. Применение минеральных удобрений способствовало увеличению выноса свинца и кадмия амарантом из дерново-карбонатной почвы.

Ключевые слова: еловые насаждения, динамика, абсолютная полнота, сухостой, запас древесины, сукцессия, устойчивость, танины.

1. Introduction

Today, the world's global task is to meet the needs of the population with clean food products. Fertilizing plants with humic preparations helps increase productivity, plant resistance, and improve the quality of crop production.

Humic substances (HS) are dark brown natural organic formations that are widespread in various natural objects such as soils and peat, coal, shale, marine and lake sediments, as well as the waters of rivers and lakes. Humic substances are the most natural and thermodynamically stable form of preservation of organic substances in the biosphere. They significantly accelerate the growth and development of plants, positively affect all phases of the mitotic cycle of cells and cause an increase in the values of the mitotic index by 1.5 times [1].

Humic acid contains molecules of polyphenolic and quinoid grouping, which are used by plants to enhance the phenolase oxidative system, resulting in the general activation of respiration and metabolism. [2]

2. Material and methods

For the purposes of the research, the authors used a humic preparation made from humus manure (vermicompost) at the St. Petersburg State University.

In order to study the effectiveness of foliar fertilization of amaranth with a solution of humic substances on the accumulation of cadmium and lead in plants from calcareous soil, the authors conducted a greenhouse experiment [3]. The experiment was conducted in 2018 in the greenhouse of an agrarian university.

For the experiment, calcareous soils were used, in which humus was determined by the Tyurin method, PH by the Ph were determined via the metric method, while mobile phosphorus and potassium were determined via the Kirsanov method, and the sum of absorbed bases — by the Kappen-Gilkovitz method [3]. To determine the content of heavy metals in the soil (by acid-soluble forms) and in plants (by wet digestion), the authors used the atomic absorption spectrometer AA-7000 [4], [5].

The soil under study showed a neutral reaction of the medium, while also being rich in organic matter with a high content of mobile phosphorus and medium content of mobile potassium. According to agrochemical indicators, the soil can be classified as well-cultivated (Table 1).

The background gross content of cadmium and lead in the soil is comparable to the values typical for this region [6].

Table 1 – Agrochemical characteristics of calcareous medium loam soil

Total organic carbon, %	pH_{KCl}	Hr	S	V,%	Mobile and exchange forms, mg/100 g of soil		Nitrogen, mg/100g of soil		Gross content of heavy metals, mg/kg of soil	
		mmol/100 g			P_2O_5	K_2O	NH_4^+	NO_3^-	Pb	Cd
9,72	6,76	0,53	49,2	98,94	45,5	9,5	36,25	7,40	18,58	0,50

Amaranth, (Latin name *Amaranthus*) – dicotyledonous, annual a herbaceous plant with small flowers collected in dense spike-like paniculate inflorescences [7].

Amaranth growth requires a relatively thick layer of well-drained fertile soil with a pH of 5.5-7 and medium or high nitrogen content.

The scheme of the experiment consisted of two blocks (Table 2). The first block doesn't include applying mineral fertilizers, while the second does include this process. Nutrients N 0,15 P 0,1 K 0,1 were introduced into the soil in the form of salts NH 4 NO 3 and KH 2 PO 4.

Table 2 – Scheme of the experiment

Option	Block 1	Block 2
1	Pb +Cd background	Pb + Cd +NPK - background
2	Background + Humic Preparation (HP) 0.0002	Background + Humic Preparation (HP) 0.0002
3	Background + HP 0,002×1	Background + HP 0,002×1
4	Background + HP 0,002×2	Background + HP 0,002×2
5	Background + HP 0,002×3	Background + HP 0,002×3

The scheme of the experiment included 5 variants and 4 replicates. The experiment was carried out in plastic vessels, the mass of soil in each vessel amounted to 5 kg. Soil contamination was created via the introduction of Pb(NO 3)2 and Na 2 HAsO 3 solutions. The gross content of lead and cadmium in the soil after contamination increased by 32 mg/kg (1 threshold limit value) and 2 mg/kg (1 approximate permissible concentration), respectively.

Each vessel contained 12 seeds of amaranth. When 3 real leaves appeared 17 days after sowing, all variants were treated with the humic preparation with the exception of the first control variants. The plants in the second variant were treated with the humic preparation with a concentration of 0.0002 mg/l. All other variants were treated with the humic preparation with a

concentration of 0.002 mg/l. According to the literature, this dose of humic preparation is optimal for such a vegetable crop as amaranth [8], [9].

27 days after sowing, the second treatment of plants was carried out in the fourth and fifth variants of both blocks of the experiment with the humic preparation with a concentration of 0.002 mg / l. The remaining variants were treated with water.

37 days after sowing, the third treatment of plants with the humic preparation with a concentration of 0.002 mg / l in the 5th variant was carried out. All the other variants were treated with water.

During the growing season of plants in the experiment, the optimal soil moisture was maintained at the level of 70% of its maximum field moisture capacity. Harvesting was carried out 48 days after sowing. After harvesting and evaluation of the crops, a combined plant sample was compiled from each variant to determine the content of lead and cadmium. Measurements of Cd and Pb concentrations in solutions after wet digestion of plants (in a mixture of nitric and perchloric acids) were carried out on the atomic absorption spectrometer "Shimadzu AA-7000".

When processing the data obtained, calculated indicators were used: the coefficient of accumulation of heavy metals (accumulation ratio) and their removal by plants.

The accumulation coefficient of heavy metals is the ratio of the concentration of an element in plants to its concentration in the soil. The removal of the element by plants from the soil is calculated as the product of the mass of plants by the concentration of the element in the plant.

3. Results and discussion

The foliar fertilization of amaranth with humic preparation in any concentration under study contributed to a significant increase in the dry biomass of plants in all variants compared to the control variant both against the background of the use of mineral fertilizers and without it (Fig. 1, Table 3). This is confirmed by the results of statistical data processing. The dry weight of amaranth grown on calcareous soil with the introduction of mineral fertilizers, according to the variants, was on average 3.73 times greater than the results obtained without applying NPK to the soil.

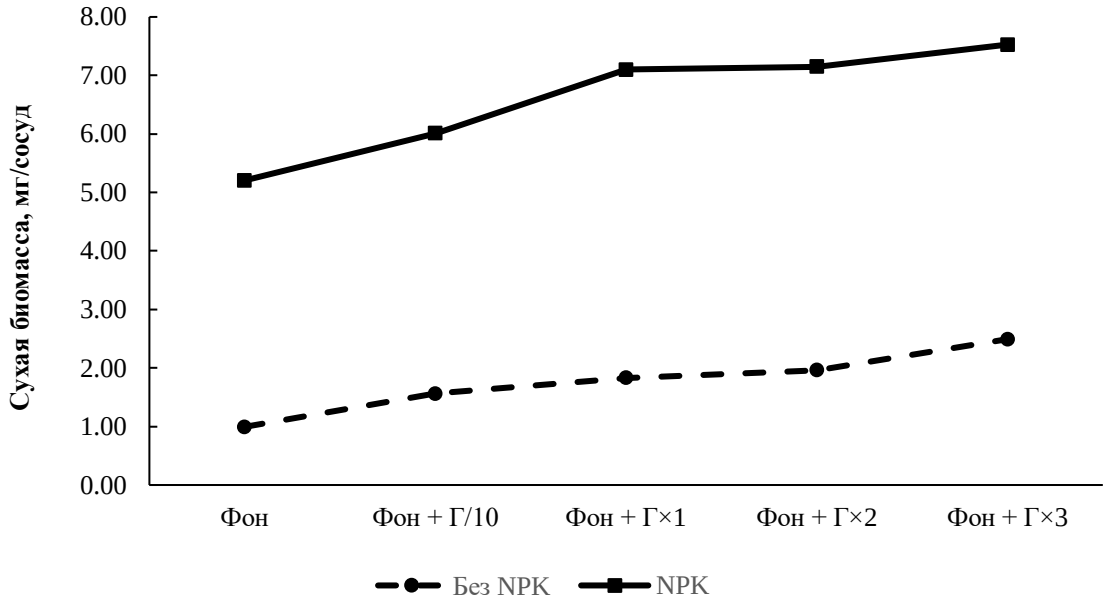

Fig. 1 – The effect of the humic preparation on the biomass of amaranth plants is the following:
H - humic preparation with a concentration of 0.002 mg /l; *H/10* - humic preparation with a concentration of 0.0002 mg/l.

Применение гуминового препарата способствовало возрастанию сухой массы амаранта. Однако на фоне применения минеральных удобрений оно было более эффективным (рис. 1).

Table 3 – Parameters of Pb accumulation by amaranth

Scheme of the experiment	Biomass, mg/vessel	Pb Content, mg/kg	Accumulation ratio	Pb Removal, mg/vessel	Available Pb Share, %
Experiment without the use of mineral fertilizers					
1. Pb + Cd background	0,99	12,10	0,24	12,02	4,75
2. Background + HP 0.0002	1,56	8,58	0,17	13,38	5,29
3. Background + HP 0.002×1	1,83	8,35	0,16	15,28	6,04
4. Background + HP 0.002×2	1,96	6,19	0,12	12,12	4,79
5. Background + HP 0.002×3	2,49	6,92	0,14	17,24	6,82
LSD (Least Significant Difference) 05	**0,78**	**2,08**	–	–	–
Average	1,77±0,55	8,43±2,28	0,17±0,05	14,01±2,23	5,54±0,89
Experiment with the use of mineral fertilizers					
1. Pb+Cd+NPK background	5,21	6,62	0,13	34,47	13,63
2. Background + HP 0.0002	6,01	9,48	0,19	56,96	22,52
3. Background + HP 0.002×1	7,11	6,24	0,12	44,30	17,52
4. Background + HP 0.002×2	7,15	7,47	0,15	53,44	21,13
5. Background + HP 0.002×3	7,53	6,41	0,13	48,24	19,07
LSD (Least Significant Difference) 05	**1,12**	**10,17**	–	–	–
Average	6,60±0,96	7,24±1,34	0,14±0,03	47,42±8,74	18,77±3,45

Foliar fertilizing of amaranth with the humic preparation contributed to a decrease in the accumulation of lead in all variants without mineral fertilizers compared with the control variant; apparently, this is due to an increase in plant weight and the manifestation of the effect of biological dilution. The lowest concentration of Pb and its minimum accumulation ratio in plants were observed in the fourth variant, with a two-time humic top dressing of plants with a concentration of 0.002 mg/l, although the indicators of this variant do not differ significantly from the results obtained in other variants with the use of the humic preparation.

In the experiment with the use of mineral fertilizers, the concentration of Pb in plants and its accumulation ratio are minimal in the third variant, with one-time HP top dressing of plants with with a concentration of 0.002 mg/l. These indicators are significantly lower than in the variant with the use of amaranth feed with a lower concentration HP (0.0002%); however, they do not significantly differ from the indicators of lead accumulation in the control variant.

Comparing the results of two experiments, with and without the introduction of mineral fertilizers, showed that the coefficient of accumulation of lead by amaranth is slightly less in the experiment with the introduction of mineral fertilizers. When introducing salts into the soil, it is possible to form slightly soluble lead salts (lead phosphate), i.e. chemical embedding of heavy metal in the soil. The noted differences exist only at the level of trends and are not confirmed statistically.

The removal of lead by plants and its available share were significantly higher in the variants with the use of mineral fertilizers.

Table 4 – Parameters of Cd accumulation by amaranth

Scheme of the experiment	Biomass, mg/vessel	Cd Content, mg/kg	Accumulation ratio	Cd removal, mg/vessel	Available Cd content, %
Experiment without the use of mineral fertilizers					
1. Pb + Cd background	0,99	4,92	1,09	4,89	39,14
2. Background + HP 0.0002	1,56	3,63	0,81	5,66	45,32
3. Background + HP 0.002×1	1,83	3,06	0,68	5,61	44,85
4. Background + HP 0.002×2	1,96	2,76	0,61	5,41	43,30
5. Background + HP 0.002×3	2,49	4,39	0,98	10,95	87,58
LSD (Least Significant Difference) 05	**0,78**	**4,79**	–	–	–
Average	1,77±0,55	3,75±0,90	0,83±0,20	6,51±2,50	52,04±20,01
Experiment with the use of mineral fertilizers					
1. Pb+Cd+NPK background	5,21	1,62	0,36	8,42	67,38
2. Background + HP 0.0002	6,01	1,15	0,26	6,91	55,30
3. Background + HP 0.002×1	7,10	1,38	0,31	9,81	78,51
4. Background + HP 0.002×2	7,15	1,51	0,33	10,76	86,10
5. Background + HP 0.002×3	7,53	0,92	0,20	6,89	55,16
LSD (Least Significant Difference) 05	**1,12**	**1,55**	–	–	–
Average	6,60±0,96	1,31±0,28	0,29±0,06	8,56±1,73	68,49±13,81

The cadmium content in plants and its accumulation ratio by amaranth from calcareous soil, to which mineral fertilizers were applied, were on average 2.8 times less than in the first block of the experiment. At the same time, the indicators of metal removal by plants were, on the contrary, slightly higher when fertilizing the soil with NPK than in the control variant without fertilizers.

When processing crops with a humic preparation, a decrease in the content of cadmium and its accumulation ratio in plants was observed. Minimal accumulation ratio of metal in plants were observed in the variants with multiple fertilization of plants with the solution of humic substances, apparently due to the effect of biological dilution.

4. Conclusion

The foliar fertilization of amaranth with the solution of humic substances contributed to an increase in plant biomass when using mineral fertilizer and without it. This significantly reduced the lead content in plants when mineral fertilizers were not used; this effect was not observed when using mineral fertilizers When treating amaranth with the solution of humic substances, a decrease in the content of cadmium and its accumulation ratio in plants was observed both against the background of the use of mineral fertilizers and in their absence. The use of mineral fertilizers contributed to an increase in the removal of lead and cadmium by amaranth from calcareous soil.

5. List of abbreviations

HS – Humic Substance
HP – Humic Preparation
AR – Accumulation Ratio
LDS – Least Significant Difference
APC – Approximate Permissible Concetration
MPC – Maximum Permissible Concentration
MFMC – Maximum Field Moisture Capacity
HM – Heavy Metal

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

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