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BIOMASS ACCUMULATION BY RICE CULTIVARS DEPENDING ON HEAVY METALS SALTS SOLUTIONS CONCENTRATION

Abstract. Heavy metals accumulation in a plant results in significant negative effect on physiological and biochemical processes going on in an organism. In this respect, the present article considers particular features of heavy metal salts solutions (Cuprum - Cu, Zinc - Zn, Cadmium - Cd) of various concentrations on biomass accumulation by Marzhan, AiSaule and Titan rice cultivars. Increase in heavy metal salts content results in significant slowing down the biomass accumulation by rice cultivars in the beginning of vegetation. Solutions of cadmium salts exert significantly greater influence on biomass accumulation by rice cultivars as compared to copper and zinc. Effect of heavy metals on biomass accumulation by rice cultivars is in the following order of sequence: cadmium> copper> zinc. At the low concentrations (5mg/l) of the copper and zinc salts solutions, Marzhan rice cultivar is more stable; nevertheless, at the higher concentrations (10 and 25mg/l) the above named cultivar turned out to be less stable as compared to the AiSaule and Titan cultivars. *The research results obtained may be used in the process of morpho-physiological modelling of future new cultivars of rice that are more resistant (tolerant) to stressful influence of ecological factors (for example, heavy metal salt solutions).*

Key words: rice, varieties, heavy metals: copper, zinc, cadmium; effect of heavy metals on biomass accumulation by rice cultivars.

Introduction. In modern conditions as a result of intensification of industry and agriculture, mining, fuel burning by all types of vehicles, obtaining and using fertilizers, pesticides for agriculture, improper recycling of waste, the amount of heavy metals emitted into the environment, which pollute the atmosphere, hydrosphere and soils increased dramatically [1,2,9]. Gas and aerosol emissions from industry, cars and transport vehicles are oxidized and react with water vapor and as a result acid rain drops into the soil. Most of these harmful gases are sulphuric and nitrogen oxides. In summer, these aerosol and dustlike substances settle on the surface of plant leaves and penetrate through the mouths inside the tissue and have adverse effects. In autumn, these substances, together with the leaves, enter the soil when they fall down. The contamination of soil in such ways causes worries to scientists and specialists of agricultural enterprises. Soils of agricultural lands and pastures of Kazakhstan on large areas are polluted in such ways. Then, through trophic connections these substances enter into human organism and have negative influence on health of population [3-10]. Many heavy metals are highly toxic to all organisms, including plants. They accumulate in the environment and do not decompose.

The majority (60-80%) of heavy metals such as zinc, copper, nickel and others are trace elements and some of them are part of pigments, enzyme systems and physiologically active substances. However, the accumulation of heavy metals in plants, animals and humans have an adverse effect on physiological and biochemical processes in their bodies, and other metals, such as cadmium, are potentially toxic in any concentration. Therefore, the content of heavy metals in soils, water reservoirs and the atmosphere should not exceed the permissible (harmless) level. Otherwise, through a trophic connection through plant and animal products enter the human body and have a negative impact. Therefore, study of the regularities of their intake and accumulation in plant organisms and their influence on biomass formation contributes to correct assessment of heavy metals impact [3-9]. According to many researchers, as a result of the influence of heavy metals, especially cadmium, photosynthesis and other physiological processes are disturbed, absorption of trace elements and nutrients is reduced, enzyme systems are disrupted, plant growth slows down, mass accumulation of roots and aboveground biomass decreases. In toxic concentrations, heavy metal ions can cause significant deviations in cell metabolism. As a result, root growth and branching are slowed down. This leads to a decrease in the total and adsorbing surface of the root, and then the plant gradually dies [11-15]. Therefore, studying the influence of heavy metal salts solutions on rice biomass accumulation has a certain practical interest.

The purpose of scientific research. To study the influence of different saline concentrations of copper-Cz, zinc-Zn, cadmium-Cd on the accumulation of dry biomass of types of rice Marzhan, AiSaule, Titan and the reaction of these varieties.

Materials and methods of research. The object of research are varieties of rice Marzhan (standard), AiSaule (newly zoned variety of Kazakhstan selection), Titan (variety of Russian selection). Various saline concentrations of copper ($CuSO_4$), zinc ($ZnNO_3$), cadmium ($CdCl_2$) - (5 mg/l, 10 mg/l, 25 mg/l) were used as heavy metals. Experience was conducted on 30 variants by variety. Scheme of experience:

For variety Marzhan: 1 - *control* (without applying saline of heavy metals); 2 *variant* - 5 mg/l solution of copper salt; 3 *variant* - 10 mg/l solution of copper salt; 4 *variant* - 25 mg/l solution of copper salt; 5 *variant* - 5 mg/l solution of zinc salt; 6 *variant* - 10 mg/l zinc salt solution; 7 *variant* - 25 mg/l zinc salt solution; 8 *variant* - 5 mg/l cadmium salt solution; 9 *variant* - 10 mg/l cadmium salt solution; 10 *variant* - 25 mg/l cadmium salt solution.

For variety AiSaule: 11 - *control* (without applying saline of heavy metals salts); 12 - *variant* - 5 mg/l of copper salt solution; 13 *variant* - 10 mg/l of copper salt solution; 14 *variant* - 25 mg/l of copper salt solution; 15 *variant* - 5 mg/l of zinc salt solution; 16 *variant* - 10 mg/l zinc salt solution; 17 *variant* - 25 mg/l zinc solution; 18 *variant* - 5 mg/l cadmium salt solution; 19 *variant* - 10 mg/l cadmium salt solution; 20 *variant* - 25 mg/l cadmium salt solution;

For variety Titan: *21 variant - control* (without making solutions of heavy metals salts; *22 variant* - 5 mg/l of copper salt solution; *23 variant* - 10 mg/l of copper salt solution; *24 variant* - 25 mg/l of copper salt solution; *25 variant* - 5 mg/l of zinc salt solution; *26 variant* - 10 mg/l zinc salt solution; *27 variant* - 25 mg/l zinc salt solution; *28 variant* - 5 mg/l cadmium salt solution; *29 variant* - 10 mg/l cadmium salt solution; *30 variant* - 25 mg/l cadmium salt solution. Experience is repeated three times. Full seeds of the named rice varieties were washed 3-4 times with household soap, then several times treated with 16% hydrogen peroxide solution, then several times washed with distilled water. Seeds were grown according to the above mentioned variants.

Results of research and discussion. As shown in table 1 and figure 1, 2 on the variant without heavy metals (control) the accumulation of dry biomass of Marzhan varieties will be considered 100%.

With low (5 mg/l) concentration of copper salts, the accumulation of dry biomass of Marzhan rice varieties was 57.7% of the control, i.e. the weight reduction of plants was 42.3%. At the same concentration of zinc salts solutions, the accumulation of dry weight of plants was 43.9% of the control, i.e. the reduction of dry biomass accumulation was 56.1%. At the same concentration of solutions of cadmium salts the accumulation of dry biomass was 17.8% of control, i.e. the weight reduction of Marzhan variety plants was the greatest - 82.2%, compared to solutions of copper and zinc salts (table 1, figure 1, 2). When applying the average (10 mg/l) concentration of solutions of copper salt, the accumulation of dry biomass of Marzhan rice was 39.4% of the control, i.e. the weight loss of plants was 60.6%. With the same concentration of zinc salt solutions, the weight of plants was 29.3%, i.e. the decrease in rice biomass was 70.7%. At the same concentration of solutions of cadmium salt, the dry biomass of plants was 14.4% of the control, i.e. the weight reduction of plants was 85.5% (table 1, figure 1, 2).

When applying a relatively high (25 mg/l) concentration of copper salt solutions, the accumulation of biomass was 24.7% of the control, i.e. the decrease was 75.3%. With the same concentration of zinc salt solutions, the accumulation of dry biomass was 13.9% of the control, i.e. the biomass decrease was 86.1%. At the same concentration of cadmium solutions, the accumulation of dry weight of Marzhan rice was 7.2% of control, i.e., the negative influence of cadmium salt solutions was strong in comparison with solutions of copper and zinc salts, and the weight reduction of plants was 92.8% (figure 1, 2). As shown in table 2 and figure 3, 4, the indicator of rice biomass weight of AiSaule variety in the control version (without heavy metals) is 100%.

Table 1 – Influence of heavy metals on biomass accumulation for 10 day seedlings of Marzhan rice variety

Experimental Options	Average dry biomass, (Cu)		Average dry biomass, (Zn)		Average dry biomass, (Cd)	
	mg	%	mg	%	mg	%
Control	1,516	100	1,505	100	1, 579	100
5 mg/l	0,874	57,7	0,660	43,9	0,281	17,8
10 mg/l	0,598	39,4	0,442	29,3	0,227	14,4
25 mg/l	0,374	24,7	0,209	13,9	0,113	7,2

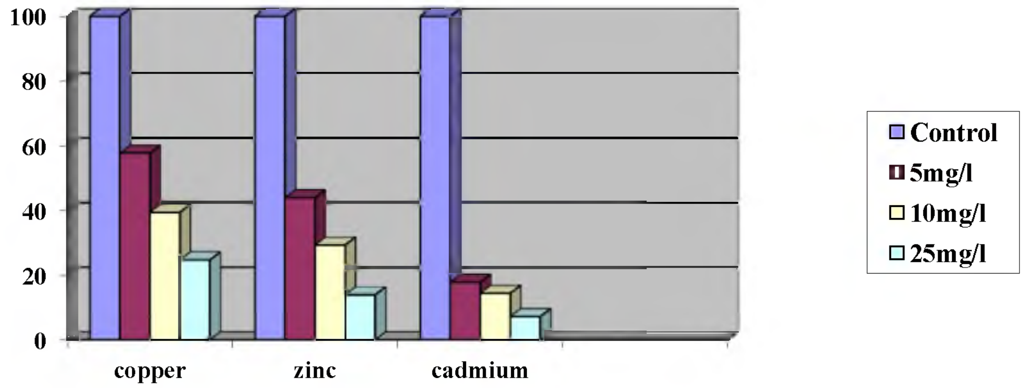

Figure 1 – Influence of heavy metals on biomass accumulation for 10 day seedlings of Marzhan rice variety

Figure 2 – Influence of heavy metals on the variety Marzhan: cadmium - $CdCl_2$ (left side) and zinc - $ZnNO_3$ (right side)

At a *low* concentration (5 ml/l) of copper salt solutions, the weight of AiSaule rice biomass was 45.7% of the control, i.e. a 54.3% decrease in the weight of plants compared to the control. With the same concentration of zinc salts, the weight of the plants was 58.8% of the control, i.e. the biomass decrease was 41.1%. At the same concentration of cadmium salts, the weight of biomass was 22.7% of the control, i.e. the weight reduction of plants was 77.3% (table 2, figure 3, 4).

At an *average* (10 mg/l) concentration of copper salts, the weight of AiSaule rice biomass was 37.1% of the control, i.e. the weight reduction of plants was 62.0%. At the same concentration of zinc salts, the weight of rice plants was 26.2% of the control, i.e. the decrease in dry biomass was 73.8%. At the same concentration of cadmium salts the weight of rice plants was 18,9%, i.e. the decrease of dry rice biomass in comparison with the control was significant - 81,1% of table 2, figure 3, 4.

At *higher* (25 mg/l) concentration of copper salts, the accumulation of dry rice biomass of AiSaule variety was 10.4% of the control, i.e. the weight reduction of plants was 89.6%. At the same concentration of zinc salts, the accumulation of biomass was 18.2% of the control, i.e. the weight loss of biomass was 81.8%. At the same concentration of cadmium salts, biomass accumulation of rice plants was 14.5% of the control, i.e. the weight reduction of plants was the largest in comparison with the control (without heavy metals) - 85.5% (table 2, figure 3, 4).

Table 2 – Influence of heavy metals on biomass accumulation for 10 day seedlings of AiSaule rice variety

Experimental Options	Average dry biomass, (Cu)		Average dry biomass, (Zn)		Average dry biomass, (Cd)	
	mg	%	mg	%	mg	%
Control	1, 613	100	1,297	100	1,133	100
5 mg/l	0,737	45,7	0,762	58,8	0,257	22,7
10 mg/l	0,598	37,1	0,340	26,2	0,214	18,9
25 mg/l	0,168	10,4	0,236	18,2	0,166	14,5

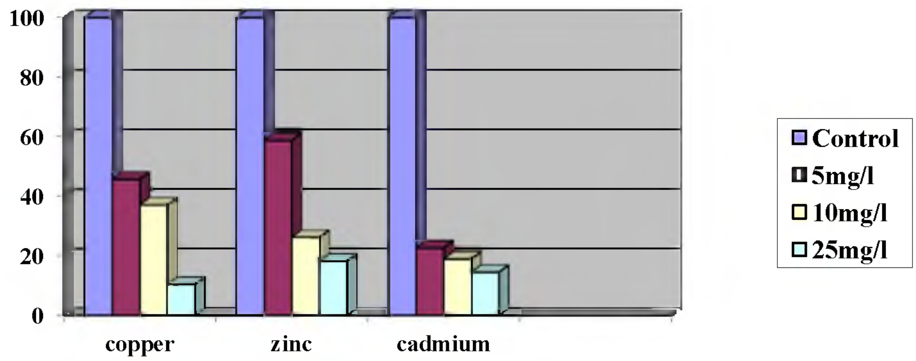

Figure 3– Influence of heavy metals on biomass accumulation for 10 day seedlings of AiSaule rice variety

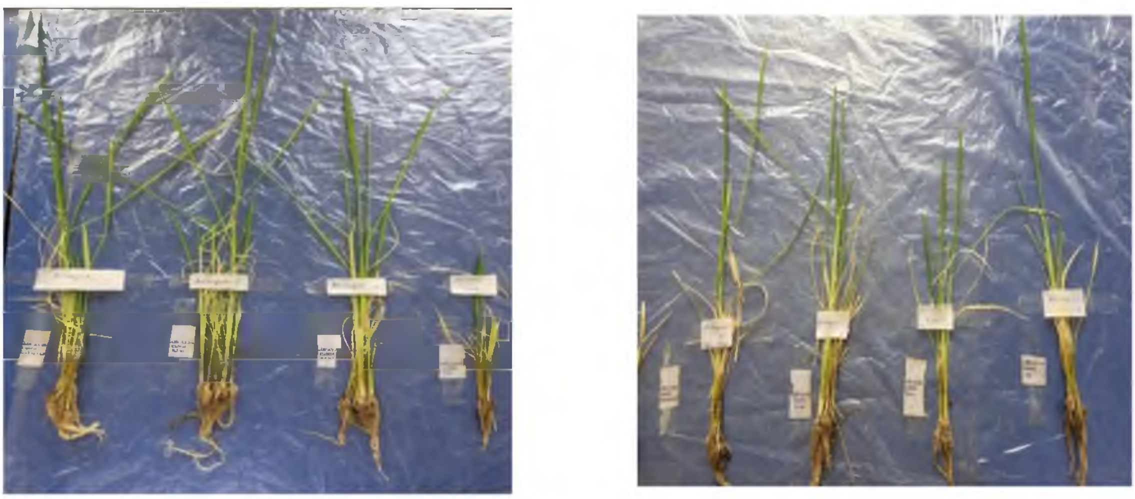

Figure 4 – Influence of heavy metals on AiSaule: copper - $CuSO_4$ (left side) and zinc - $ZnNO_3$ (right side)

As shown in table 3, figure 5, 6, if the *control (without heavy metals)* of Titan rice biomass is 100%, then at a concentration of 5 mg/l of *copper* salt solutions the weight of biomass was 48% of the control, i.e., the decrease was 52%. At the same concentration of *zinc* salt solutions, the dry biomass was 67.2% of the control, i.e. 32.8%. At the same concentration of solutions of *cadmium* salts the weight of dry biomass was 37% of the control, the reduction of biomass accumulation was much higher - 63%.

At an *average* concentration (10 mg/l) of copper salt solutions, the weight of dry biomass of the grade Titan was 42% of the controls, i.e., biomass accumulation was reduced by 58%. At the same zincconcentration, the dry biomass was 67% of the control, i.e. the weight reduction was 33%. At the same concentration of cadmium salts the dry biomass was 28% of the control, i.e. the reduction was much higher than the option without heavy metals (control) - 72% (figures 5, 6).

When applying a *higher* concentration (25 mg/l) of copper salts, the dry biomass of Titan rice was 37% of the control (without heavy metals), i.e. the decrease was 63%. At the same concentration of zinc salts, the accumulation of plant dry matter was 37.5% of the control, i.e. the decrease was 62.5%. At the same concentration of cadmium salts, the accumulation of dry rice biomass was 27.7% of the control, i.e. the weight reduction of plants was 72.3% (figure 5, 6).

Table 3 – Influence of heavy metals on biomass accumulation for 10 day seedlings of Titan rice variety

Experimental Options	Average dry biomass, (Cu)		Average dry biomass, (Zn)		Average dry biomass, (Cd)	
	mg	%	mg	%	mg	%
Variety Titan						
Control	1, 543	100	1,493	100	1,576	100
5 mg/l	0,739	48	1,003	67,2	0,583	37
10 mg/l	0,648	42	0,996	67	0,440	28
25 mg/l	0,571	37	0,560	37,5	0,437	28

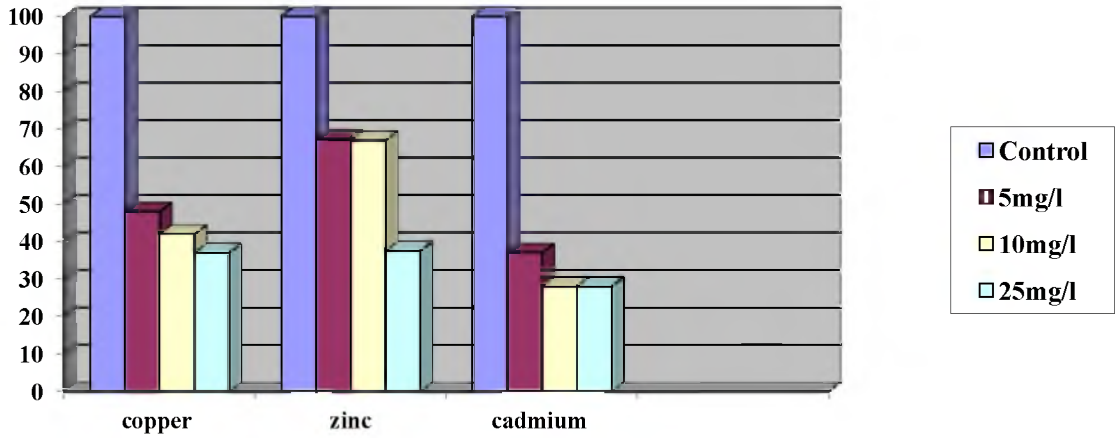

Figure 5 – Influence of heavy metals on biomass accumulation for 10 day seedlings of Titan rice variety

Figure 6 – Influence of heavy metal salts solutions $CuSO_4$ on Titan variety

With the same concentration of cadmium salts, the accumulation of dry rice biomass was 27.7% of control, i.e., the weight reduction of plants was 72.3% (figures 5, 6).

Conclusion. With increasing salt concentrations of heavy metals (copper, zinc, cadmium) the accumulation of rice plant biomass decreases. At the same time, the influence of cadmium salt solutions concentration was stronger compared to the same concentration of copper and zinc salts. The negative influence of solutions of salts of heavy metals on the accumulation of biomass of varieties of rice Marzhan, Titan and AiSaule can be shown in the following sequence: cadmium > copper > zinc. However, Marzhan and AiSaule rice varieties were less resistant than Titan.

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АУЫР МЕТАЛЛ ТҰЗДАРЫНЫҢ КОНЦЕНТРАЦИЯСЫНА БАЙЛАНЫСТЫ КҮРІШ СОРТЫНЫҢ БИОМАССА ЖИЫНТЫҒЫ

Аннотация. Республиканың көп аймағы газ, сұйық және қатты күйдегі өндіріс қалдыгы, транспорт шыгарындысы, сульфат және ауыр металдармен ластануда. Ауыр металдарды жер қыртысының сіңіруі топырақтың орта реакциясына тәуелді. Сонымен қатар, топырақ ерітіндісінің аниондық құрамының да зор маңызы бар. Қышқыл ортада қоргасын, мырыш, мыс, ал сілтілік ортада кадмий мен кобальт сіңдірілген. Ауыр металдар топырақ құрамында органикалық заттармен күрделі комплекс түзуге қабілетті. Өсімдіктер денесінде ауыр металдың жинақталуы организмде жүретін маңызды физиологиялық-биохимиялық үдерістерге айтарлықтай теріс әсер етеді. Сондықтан жогарыда айтылган күрделі экологиялық мәселелер осы зерттеу жұмысының мақсаты мен міндеттерін анықтады.

Зерттеу жұмысының мақсаты. Күріш дақылының Маржан (стандарт) және АйСауле (жаңадан аудандастырылган) сорттарының құргақ биомасса жиынтыгына кадмий, мыс және мырыш металл тұздарының түрлі концентрациясына реакциясын салыстырмалы түрде зерттеу.

Зерттеу жұмысының нысаны және әдістемелері. Зерттеу нысаны ретінде күріш дақылының Маржан және АйСауле сорттарының дәні және ауыр металл ретінде мыс ($CuSO_4$), мырыш ($ZnNO_3$) және кадмий ($CdCl_2$) тұздарының түрлі (5 мг/л, 10 мг/л, 25 мг/л) концентрациялы ерітінділері алынды. Тәжірибе 20 вариант бойынша ылгалды ортада жүргізілді.

АйСауле сорты: 1 – бақылау варианты, 2 вариант – 5 мг/л $CuSO_4$ тұзы ерітіндісі; 3 вариант – 10 мг/л Cu тұз ерітіндісі; 4 вариант – 25 мг/л Cu тұз ерітіндісі; 5 вариант - 5 мг/л $ZnNO_3$ тұз ерітіндісі; 6 вариант – 10 мг/л Zn тұз ерітіндісі; 7 вариант – 25 мг/л Zn түз ерітіндісі; 8 вариант – 5 мг/л $CdCl_2$ тұз ерітіндісі; 9 вариант – 10 мг/л Cd тұз ерітіндісі; 10 вариант – 25 мг/л Cd тұз ерітіндісі;

Маржан сорты: 11 вариант – бақылау; 12 вариант – 5 мг/л $CuSO_4$ тұз ерітіндісі; 13 вариант – 10 мг/л Cu тұз ерітіндісі; 14 вариант – 25 мг/л Cu тұз ерітіндісі; 15 вариант – 5 мг/л $ZnNO_3$ тұз ерітіндісі; 16 вариант – 10 мг/л Zn тұз ерітіндісі; 17 вариант – 25 мг/л Zn тұз ерітіндісі; 18 вариант – 5 мг/л $CdCl_2$ тұз ерітіндісі; 19 вариант – 10 мг/л Cd тұз ерітіндісі; 20 вариант – 25 мг/л $CdCl_2$ (Маржан сорты) тұз ерітіндісіне есептелген. Әр вариант 3 қайталау арқылы жүргізілді.

Зерттеуге алынган өсімдік дәнін өндіруге қоймас бұрын, толық қалыптасқан дәнді іріктеп алып, 3-4 қайтара қара сабынмен жуып, 16% сутегі тотық ерітіндісінде 5-10 минут өндеп, одан кейін бірнеше қайтара дистильденген сумен жуылып, залалсыздандырылды. Тұқымдар өндіруге ауыр металсыз бақылау варианты және 18 вариант ауыр металл тұз ерітінділерінің әртүрлі концентрациялары бойынша қойылды.

Зерттеу нәтижесі. Мақалада Маржан, АйСауле, Титан күріш сорттарының биомасса жиынтығына мыс-Cu, мырыш- Zn, кадмий- Cd ауыр металл тұзының әсері зерттеліп, талқыланган. Ауыр металл тұзының концентрациясы артқан жағдайда күріш сорттарының әдепкідегі биомассасының жиынтыгы тежеледі (азаяды). Аталган күріш сорттарының биомасса жиынтыгына мыс, мырыш тұз ерітінділеріне қараганда кадмий тұзының әсері күштірек болды. Ауыр металдар тұздарының күріш дақылының құргақ биомасса жиынтыгына әсері келесі ретпен жүзеге асады: кадмий > мыс > мырыш. Төмен концентрацияда (5 мг/л) Маржан сортының биомасса жиынтыгы күштірек болғанымен, орташа (10 мг/л) және жогары (25 мг/л) концентрацияда жаңадан аудандастырылган АйСауле және Титан (ресей селекциясы) сорттарына қараганда өсу үдерісі көбірек тежелді. Алынган гылыми нәтижелер болашақ жогары өнімді әрі экологиялық факторлардың (мысалы, ауыр металл тұз ерітіндісіне) төзімді (толерантты) сорттардың морфофизиологиялық моделін дайындағанда пайдалануга болады.

Түйін сөздер: күріш, сорттар, ауыр металдар: мыс, мырыш, кадмий тұздарының күріш сорттары биомассасының жиынтыгына әсері.

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НАКОПЛЕНИЕ БИОМАССЫ СОРТОВ РИСА В ЗАВИСИМОСТИ ОТ КОНЦЕНТРАЦИИ РАСТВОРОВ СОЛЕЙ ТЯЖЕЛЫХ МЕТАЛЛОВ

Аннотация. Большинство территории Казахстана загрязнены газообразными, жидкими и твердыми остатками промышленности, выделениями транспортов, а также сульфатами и тяжелыми металлами. На накопление тяжелых металлов существенное влияние оказывает реакция pH раствора почвы, а также анионный состав почвенного раствора.Так, в кислой среде интенсивно поглощаются свинец, цинк, мед, а в щелочной среде – кадмий и кобальт. Тяжелые металлы с органическими веществами почвы образует сложные комплексные соединения. Поэтому выше изложенные сложные экологические проблемы определил цель и задачи исследования.

Материалы и методика исследования. Объектом исследования являются сорта риса *Маржан* (стандарт), *АйСауле* (вновь районированный сорт казахстанской селекции), *Титан* (сорт российской селекции), В качестве тяжелых металлов использовано различные концентрации растворов солей меди ($CuSO_4$), цинка ($ZnNO_3$), кадмия ($CdCl_2$) - (5 мг/л, 10 мг/л, 25 мг/л). Опыт проведен по 30 вариантам по сортам. Схема опыта:

Для сорта риса Маржан: 1 – *контроль* (без внесения растворов солей тяжелых металлов); *2 вариант* – 5 мг/л раствора соли меди; *3 вариант* – 10 мг/л раствора соли меди; *4 вариант* – 25 мг/л раствора соли меди; *5 вариант* – 5 мг/л раствора соли цинка; 6 *вариант* – 10 мг/л раствора соли цинка; 7 вариант – 25 мг/л раствора соли цинка; *8 вариант* – 5 мг/л раствора соли кадмия; 9 вариант – 10 мг/л раствора соли кадмия; 10 вариант – 25 мг/л раствора соли кадмия.

Для сорта АйСауле: *11 – контроль* (без внесения растворов солей тяжелых металлов); *12 – вариант* – 5 мг/л раствора соли меди; *13 вариант* – 10 мг/л раствора соли меди; *14 вариант* – 25 мг/л раствора соли меди; *15 вариант* – 5 мг/л раствора соли цинка; *16 вариант* – 10 мг/л раствора соли цинка; *17 вариант* – 25 мг/л раствора цинка; *18 вариант* – 5 мг/л раствора соли кадмия; *19 вариант* – 10 мг/л раствора соли кадмия; *20 вариант* – 25 мг/л раствора соли кадмия;

Для сорта Титан: *21 вариант – контроль* (без внесения растворов солей тяжелых металлов; *22 вариант* – 5 мг/л раствора соли меди; *23 вариант* – 10 мг/л раствора соли меди; *24 вариант* – 25 мг/л раствора соли меди; *25 вариант – 5* мг/л раствора соли цинка; *26 вариант* – 10 мг/л раствора соли цинка; *27 вариант* – 25 мг/л раствора соли цинка; *28 вариант* – 5 мг/л раствора соли кадмия; *29 вариант* – 10 мг/л раствора соли кадмия; *30 вариант* – 25 мг/л раствора соли кадмия. Повторность опыта трехкратная.

Полноценные семена названных сортов риса и с целью обевреживания их помыли 3-4 раза хозяйственным мылом, затем несколько раз обработали 16%-ным раствором перекиси водорода и несколько раз промыли дистиллированной водой. Семена выращивали согласно вышеуказаным вариантам.

Результаты исследования. Накопление тяжелых металлов в растений оказывают существенное негативное влияние на прохождение физиолого-биохимических процессов в организме. В связи с этим, в статье рассмотрены особенности и влияние растворов солей тяжелых металлов (меди-Cu, цинка-Zn, кадмия-Cd) различной концентрации на накопления биомассы сортов риса Маржан (стандарт), АйСауле (вновь районированный) и Титан (российской селекции). При увеличении концентрации солей тяжелых металлов интенсивность накопления биомассы сортов риса в начале вегетации значительно снижаются. На накопления биомассы сортов риса влияние растворов солей кадмия значительно больше по сравнению с медью и цинком. Влияние тяжелых металлов на накопление биомассы сортов риса осуществляются в следующем порядке: кадмий > медь > цинк. При низких концентрациях (5 мг/л) растворов солей меди и цинка сорт риса Маржан более устойчив, однако при более высоких концентрациях (10 и 25 мг/л) названный сорт оказался менее устойчивым по сравнению с вновь районированным сортом АйСауле и сортом российской селекции Титан. Результаты исследования будут использованы при создании морфофизиологической модели высокоурожайных и устойчивых негативным экологическим факторам (например, влиянию тяжелых металлов).

Ключевые слова: рис, сорта, тяжелые металлы: медь, цинк, кадмий, влияние растворов солей тяжелых металлов на накопление биомассы сортов риса.

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