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THE EFFECT OF CADMIUM AND GROWTH REGULATOR "EPIN-EXTRA» ON RICE PLANTS (ORYZA SATIVA L.) GROWTH AND BIOMASS ACCUMULATION

Cadmium is a highly toxic metal. Under certain conditions, cadmium ions, having great mobility in soils, easily pass into plants, accumulate in them and then enter the body of animals and humans. Anthropogenic sources of cadmium entering the environment are industrial complexes producing or using cadmium, as well as thermal power plants and mineral fertilizers. The cadmium that entered the soil is mainly present in it in a mobile form, which has negative ecological significance.

Various strategies are being developed to reduce the toxic effects of cadmium. The use of growth regulators can also affect the phytotoxic effects of cadmium. The aim of this work was to study the effect of the growth of the regulator "Epin-extra" under the action of cadmium on rice plants. The effect of cadmium and the growth of the regulator "Epin-extra" on the growth and biomass of aboveground organs and roots of different varieties of rice in the presence of cadmium ions in the substrate was studied. Variants without cadmium with the use of "Epin-extra" for seed soaking ("Epin1-control") and with the addition to the growing substrate ("Epin2-control") served as a control.

The use of the growth regulator "Epin-extra" led to an increase in the growth parameters of aerial organs and roots in the absence and in the presence of cadmium ions in the growing substrate, increasing the resistance of plants. A different effect was found depending on the form of application of the growth regulator, and varietal differences were also observed, which indicates a genetic difference in plant responses to the action of a toxicant and growth regulators, which is due to various complex mechanisms of the signaling system in different genotypes under stress conditions with the involvement of the hormonal system of plants.

Key words: rice, cadmium, tolerance, growth, growth regulator, "Epin-extra".

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Күріш өсімдігінің (Oryza Sativa L.) өсуі мен биомасса жинақтауына кадмий йондарының және өсу реттегіштерінің әсері

Кадмий – бұл уытты, экспозиция деңгейі өте төмен және өсімдіктердің, жануарлардың, адамдардың және жалпы барлық тіршілік иелерінің денсаулығына зиянды әсер етеді. Өнеркәсіптің деңгейіне байланысты, сондай-ақ жалпы технологияның жоғарылауына байланысты қоршаған ортаға жыл сайын Cd бөлінеді. Сондай-ақ ауылшаруашылық өңірлерде фосфорлы тыңайтқыштардың кесірінен кадмийдің топыраққа таралуы жүреді.

Кадмийдің уытты әсерін төмендетудің түрлі стратегиялары жасалуда. Өсу реттегіштерді қолдану кадмийдің фитотоксикалық әсерін төмендетуі мүмкін. Бұл жұмыстың мақсаты кадмий әсерінен күріш өсімдіктерінің өсуіне «Эпин-экстра» препаратының әсерін зерттеу болды. Кадмий мен «Эпин-экстра» өсу реттегішінің күріш өсімдігінің жер үсті мүшелерінің және тамырларының өсуіне және биомасса жинақтауына әсері зерттелді. Бақылау нұсқалары ретінде кадмийсіз Эпин-экстра препаратының күріш дәндерін алдын ала өсу реттегіш ертіндісінде малынған («Эпин1-бақылау») және өсетін ортаға өсу реттегіші қосылған («Эпин2-бақылау») нұсқалары алынған екі жағдайы қолданылды.

«Эпин-экстра» препаратын қолдану күріш өсімдігінің жерүсті мүшелері мен тамырларының ұзындығы мен биомасса жинақтауын кадмий иондары бар жағдайда да, кадмий иондары ортаға қосылмаған жағдайда да арттырды. Сонымен қатар өсімдіктердің төзімділігі артқаны байқалды.

«Эпин-экстра» препаратын қолдану жағдайына байланысты өзгешелігі бар нәтижелер алынды, сонымен қатар сорттаралық айырмашылықтар да байқалды, оны өсімдіктердің гормональды жүйесі қосылған әр түрлі генотиптерде әртүрлі күрделі сигналды механизмдермен сипатталған токсикант әсеріне жауап реакцияларының генетикалық әртүрлілігімен түсіндіруге болады.

Түйін сөздер: күріш, кадмий, төзімділік, өсу, өсу реттегіші, «Эпин-экстра».

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Влияние ионов кадмия и регулятора роста «Эпин-экстра» на рост и накопление биомассы риса (Oryza sativa L.)

Кадмий – это высокотоксичный металл. В определенных условиях ионы кадмия, обладая большой подвижностью в почвах, легко переходят в растения, накапливаются в них и затем поступают в организм животных и человека. Антропогенными источниками поступления кадмия в окружающую среду являются промышленные комплексы, производящие или использующие кадмий, а также тепловые энергетические установки и минеральные удобрения. Поступивший в почву кадмий в основном присутствует в ней в подвижной форме, что имеет негативное экологическое значение.

Чтобы снизить токсическое влияние кадмия, разрабатываются разные стратегии. Использование рострегуляторов так же может повлиять на фитотоксическое действие кадмия. Целью данной работы было изучение влияния рострегулятора «Эпин-экстра» при действии кадмия на растения риса. Было изучено влияние кадмия и рострегулятора «Эпин-экстра» на рост и биомассу надземных органов и корней разных сортов риса в присутствиии ионов кадмия в среде. Контролем служили варианты без кадмия с применением «Эпин-экстра» для замачивания семян («Эпин1-контроль») и с добавлением в среду выращивания («Эпин2-контроль»).

Применение рострегулятора Эпин-экстра приводило к повышению параметров роста надземных органов и корней в отсутствии и в присутствии ионов кадмия в среде выращивания, повышая устойчивость растений. Обнаружен различный эффект в зависимости от формы применения рострегулятора, а также наблюдались сортовые различия, что указывает на генетические различия в ответных реакциях растений на действие токсиканта и регуляторов роста, что обусловлено различными сложными механизмами сигнальной системы у различных генотипов в условиях стресса с вовлечением гормональной системы растений.

Ключевые слова: рис, кадмий, толерантность, рост, регулятор роста, Эпин-экстра.

Introduction

Cadmium (Cd) does not decompose in nature, so once released into the environment, it remains in the soil. This property, together with its high mobility, bioaccumulation ability and toxicity at very low concentrations, makes it one of the most dangerous heavy metals for living organisms. In the 1960s, environmental contamination with this metal became apparent when more than 100 people in Japan died from a disease called itai-itai, which was caused by high concentrations of Cd in the Jinzu River, in rice (4.2 mg/L), and therefore in the human body. These facts aroused the interest of soil scientists and plant breeders to study and control the effects of this metal on various crops [1].

In agriculture, mainly cadmium gets into the soil due to the use of phosphorus fertilizers or fertilizers with gypsum. An analysis of CIS (Commonwealth of Independent States) fertilizers was carried out at the RIFI (Research Institute for Fertilizers and Insectofungicides named after Professor Ya.V. Samoilov), which showed that during the production of superphosphate from ore concentrates from the Kola and Yegoryevsky deposits, cadmium almost completely remains in the finished product. The "B " grade ammophos from Karatau phosphorites contained 20-30 % more cadmium than the raw material. Depending on the doses and the presence of cadmium in phosphorus fertilizers, cadmium accumulates in different amounts in the soil. With its content in the superphosphate from Kola apatite 0.7 mg/kg and a dose of 100 kg of P2O5, the metal intake level will be 0.35 g/ha, and with the superphosphate from Karatau phosphorite, with a cadmium content of 2.2 mg/kg, at the same dose -1.1 g/ha, and cadmium, in turn, accumulates in the soil [2].

This metal is recognized as one of the most toxic and inhibiting the physiological processes of plants. Studies on several plant species have shown that it reduces growth, photosynthetic activity, transpiration, and chlorophyll content [3-6]. In addition, it causes chlorosis, oxidative stress, and nutritional imbalances, as well as alters the activity of enzymes involved in organic acid metabolism and in the Krebs cycle [7-10]. Some plants, due to strong pronounced changes in physiological processes due to exposure to cadmium, cannot resist cadmium stress and soon die. High Cd concentrations can lead to plant death, and this depends, among other factors, like as time of exposure, the metal content in the plant organs, and the specific adaptations they develop [11].

The specific adaptation of plants to Cd stress is based on two main mechanisms. Some prevent or regulate the intake and transport of cadmium [11], while others transport a certain amount of Cd by detoxifying it by chelating it in intracellular organelles [12]. Based on these tolerance mechanisms, several research groups have proposed different strategies for reducing the effects of Cd on plants. Most strategies involve making changes to power management. One of the strategies for reducing the toxic effects of cadmium is the use of phytohormones and growth regulators based on them [13]. However, other methods such as inoculation with beneficial bacteria have shown good results in reducing the toxic effect of cadmium [14].

There are many studies in which brassinosteroids are used as growth regulators. Brassinosteroids have been shown to perform many physiological functions in plants under normal and stressful conditions [15]. For example, the use of 24-epibrassinolide and 28-homobrassinolide showed changes in plant metabolism, as well as an increase in crop yields. Brassinosteroids increase the resistance of plants to abiotic stress by increasing the stability of membranes, regulating osmotic pressure and the normal course of photosynthesis [16].

Brassinosteroids (BRS) are a group of polyhydroxylated plant steroid hormones that play an important role in plant growth and development by regulating various processes such as cell elongation, cell division, photomorphogenesis, xylem differentiation, endoproduction, and plant responses to stress [16, 17].

Initially, BRS was found to promote cell elongation, but it has now been discovered that they play an important role in growth, development, and response of plants to various stresses. Recent studies suggest that BRS interact with other phytohormones, such as auxin, cytokinin, ethylene, gibberellin, jasmonic acid, abscisic acid, salicylic acid, and polyamines, regulating a wide range of physiological and plant development processes [17].

Modern multifunctional growth regulators can simultaneously stimulate the growth, development and physiological processes of plants, and increase their ability to adapt to adverse factors [18, 19].

Modern plant growth regulators are indispensable for increasing plant resistance to various diseases, and they also increase seed germination, help to combat adverse conditions and stressful situations, as well as accelerate flowering and increase yield [19]. One of the well-known and modern growth regulator of natural origin is «Epin-extra». The same PGRs (plant growth regulators) obtained data, both positive and negative, that is, under the effects of the «Epin-extra», the yield of spring wheat increased, and Epin determined the death of wheat seedlings [20].

In connection with the above, the aim of this work was to study the effect of the growth regulator «Epin-extra» on the growth parameters of 7-days rice seedlings of different varieties under the action of cadmium [20].

Materials and methods

The objects of the study were 12 rice varieties – Bakanas, Madina, KazEr6, Aisaule, Baikonur, KazNIIR5, Marzhan, Aikerim, Salima, Syr-Suluy, Tugysken, Kazvetta. Varieties Madina, Bakanas and Kazvetta are cultivated in Almaty region, varieties KazEr6, Aysaule, Baykonyr, KazNIIR5, Marzhan, Aikerim, Salima, Syr-Suluy, Tugysken were taken from the collection of "Kazakh Research Institute of Rice Growing named after Ibray Zhakhayev" LLP, Kyzylorda, Kazakhstan.

Biometric indicators were measured using generally accepted methods. The plants were divided into aboveground parts and roots. The length of roots and aboveground organs were measured. To determine the dry biomass, the plants were placed in a drying cabinet and dried at t-105^0 C to a constant weight, cooled to room temperature, and weighed [21].

The preparation «Epin-extra» – a solution of epibrassinolide in alcohol 0.025 g/L. (NNPP «NEST M», Russia, Moscow) was used for soaking seeds and adding them to the growing medium

In the soaking variants, rice seeds were soaked in a solution of 10 μl per 100 ml of water for 60 seeds, with an exposure time of 18-20 hours. Plants were grown in 6 variants: 1- control («-Cd-Epin» – without Cd and without phytohormones), 2- a variant with 150 μM Cd – «Cd – 150 μM», 3 – soaking in a solution of «Epin-extra» without Cd (+Epin1 – Cd)– «Epin1-control», soaking in a solution of «Epin-extra» with Cd – «Epin1+ Cd 150 μM», 4 – a variant with «Epin-extra» in the growth medium «Epin2-control», 5 – a variant with «Epin-extra» and 150 μM Cd in the growth medium – «Epin 2+Cd 150 μM «. The plants were grown during the day at a temperature of 22^{0}C, at night 18^{0}C, with a 14-hour light period. Cadmium exposure and growth regulators were evaluated on 7-day-old rice seedlings.

Results and discussion

1. The effect of cadmium in the presence of growth regulator "Epin-extra" on the linear growth of aboveground organs of rice varieties.

In the presence of "Epin-extra" (in variants "Epin1+Cd 150 μM" and "Epin2 +Cd 150 μM") the level of inhibition of rice growth parameters from cadmium stress were lower as compared to variants without growth regulator (in variant "Cd 150 μM").

In variant "Cd 150 μM", the length of the aboveground organs of 7-days seedlings decreased markedly. In Tugysken and KazEr6 varieties, a slight inhibition of the growth of aboveground organs was observed, compared with the control, the length of aboveground organs decreased by 29%, and in KazEr6 variety – by 33%. The greatest inhibition of the growth of aboveground organs was found in varieties Salima and Aikerim, in comparison with the control: in variety Salima – by 62%, in variety Aikerim – by 68%.

In "Epin1-control" variant, there was a noticeable increase in the length of the aboveground organs of 7 – days seedlings compared to the control without phytohormone and cadmium.

For example, in the Tugysken variety, compared to the control without phytohormone and cadmium, the length of aboveground organs increased by 29%. The average means of this indicator were in varieties Syr sulu and Madina, compared with the control without phytohormone and cadmium, the length of the aboveground organs increased by 3%. No increase in growth parameters was observed in the more sensitive varieties Salima and Aikerim (Figure 1).

In the variant "Epin1+Cd 150 μM", the suppression of aboveground organs growth in 7-days seedlings was observed to a lesser extent than in variant "Cd-150 μM". Thus, in Tugysken variety, the shoot growth decreased by 22%, and in KazEr6 variety – by 23%, while in "Cd-150 μM" variant in Tugysken and KazEr6 varieties, this indicator decreased by 29 and 33%, respectively (Fig. 1).

The data obtained may be constructed as a number of varietal resistance to the influence of cadmium and growth regulator on the length of above-ground organs (% to control):

Epin1-control – Tugysken (129) > Bakanas (122) > Kazvetta (119) > Aisaule (115) > Marzhan (107) > KazNIIR5 (104) = Baikonur (104) > Syr Sulu (103) = Madina (103) > KazEr6 (102) > Salima (100) > Aikerim (99);

Epin2-control – Bakanas (125) > Aisaule (114) > Syr Sulu (113) = Kazvetta (113) > Tugysken (105) = KazNIIR5 (105) > Baikonur (104) = Marzhan (104) = Aikerim (104) > KazEr6 (102) = Madina (102) > Salima (101) ;

Cd 150 μM – Tugysken (71) > KazEr6 (67) > KazNIIR5 (65) > Kazvetta (58) > Madina (54) > Aisaule (49) > Baikonur (46) > Syr Sulu (44) >Marzhan (43) > Bakanas (41) > Salima (38) > Aikerim (32);

Epin1+ Cd 150 μM – Tugysken (78) > KazEr6 (77) > KazNIIR5 (76) > Madina (64) > Kazvetta (60) > Baikonur (58) > Bakanas (52) > Aisaule (50) > Syr Sulu (49) > Marzhan (46) > Salima (40) = Aikerim (40);

Epin2 + Cd 150 μM – Tugysken (72) > KazEr6 (70) > KazNIIR5 (69) > Madina (68) > Kazvetta (59) > Aisaule (57) = Bakanas (57) > Baikonur (50) = Syr Sulu (50) > Marzhan (44) > Salima (39) = Aikerim (39).

Specific differences in the impact on the change in the length of the aerial varieties of rice when comparing different forms of application of growth regulator "Epin-extra" in most varieties were observed.

Only in Tugysken variety, when comparing the two forms of use of the growth regulator, it was found that at seed soaking ("Epin1-control"), the length of the aboveground organs significantly increased relative to the control ("-Cd-Epin"-by 29%) compared to the variant of adding Epin to the growth medium ("Epin2-control" – by 5%).

In some varieties, such as Bakanas, Kazvetta and Aisaule, the use of the growth regulator in both forms (seed soaking and adding to the growth medium) the length of the aboveground organs in variants without cadmium significantly increased ("Epin1-control", "Epin2-control"). For example, it was found that in variants with seed pretreatment in a Epin growth regulator solution and addition it to the growth medium without Cd, the length of aboveground organs increased in varieties Bakanas (by 22 and 25%, respectively), Kazvetta (by 19 and 13%, respectively), Aisaule (by 15 and 14%, respectively). But no significant differences were found between the two forms of application.

In the remaining varieties, a slight excess or comparable to the control means of this indicator were observed in variants with growth regulator ("Epin1-control", "Epin2-control") as compared to variant without it ("control without "Epin-extra"). This indicates genetic differences in the responses to the use of the growth regulator in different genotypes.

When comparing the effect of cadmium on the growth of aboveground organs in the presence of a growth regulator in various forms, it was found that in some varieties, such as Tugysken, KazEr6, KazNIIR5, Baykonur, when using a growth regulator as seeds pretreatment (Epin1+Cd 150 mkM), the length of aboveground organs decreased to a lesser extent compared to the variant when the growth reg-

ulator was added to the growth medium (Epin2+Cd 150 μM): by 6, 7, 7 and 8%, respectively. On the contrary, in Madina, Bakanas, Aysaule varieties, there was a tendency to increase this indicator when adding a growth regulator to the growth medium (Epin2+Cd 150 μM) compared to the seeds pretreatment variant (Epin1+Cd 150 μM) (by 4, 3 and 7%, respectively).

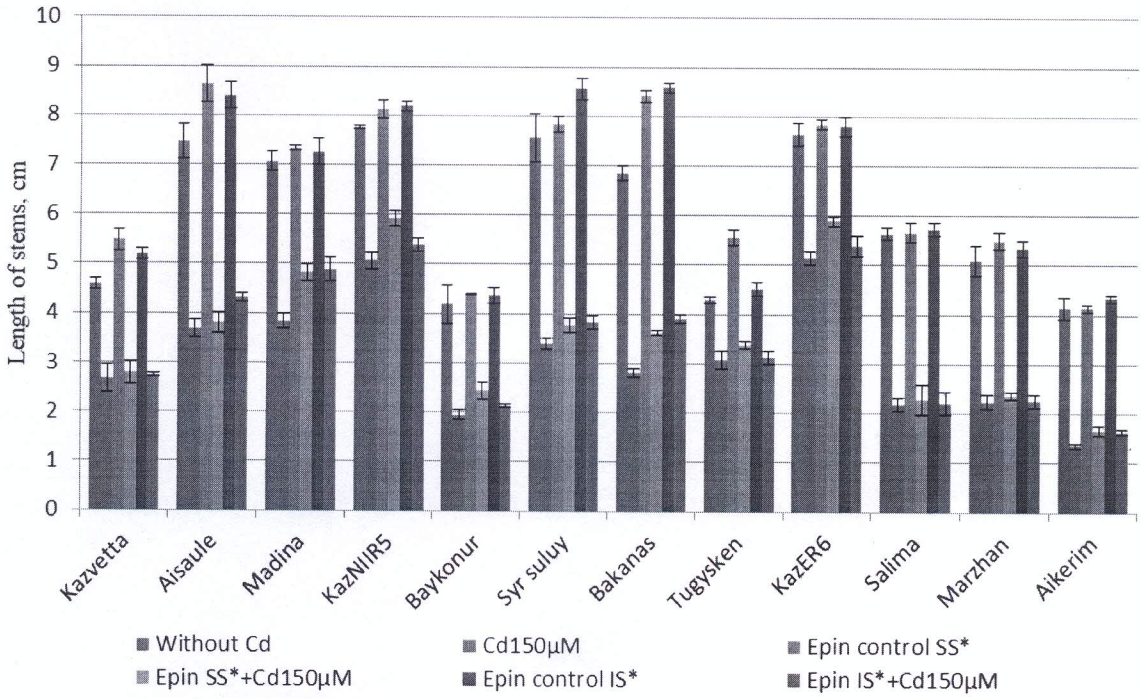

Figure 1 – The effect of Cd and growth regulator "Epin-extra" on the growth of aboveground organs of 7-days rice seedlings.
* Note: SS* (soaked in solution) "Control 1" – seeds pretreatment by "Epin-extra",
IS* (in solution) "Control 2" – addition of "Epin-extra" directly to the growth medium

Thus, the range of tolerance by the length of aboveground organs under cadmium stress in the absence of a growth regulator and in variants with various application forms of the "Epin-extra" is headed by the following varieties: Tugysken, KazEr6, KazNIIR5, Kazvetta, Madina. The least tolerant varieties were Salima and Aikerim, while the other varieties occupied an intermediate position.

2. The effect of cadmium in the presence of growth regulator "Epin-extra" on the biomass accumulation by aboveground organs of rice varieties.

In cadmium free variants with seeds pretreatment by growth regulator Aikerim, Kazvetta and KazEr6 varieties have biomass of above-ground organs higher than in variants with addition "Epin-extra" in the medium growth, on the contrary, the biomass accumulation by shoots of KazNIIR5, Salima, Madina, Aisaule, Baikonur, Bakanas varieties was higher in variants with the addition of growth regulator in growth medium by 11, 7, 6, 6, 4, and 3%, respectively (Fig. 2).

It was found that in variants with cadmium and growth regulator in growth medium, the biomass accumulation of shoots of varieties KazEr6, Madina, KazNIIR5 Marzhan, Aikerim, Baykonur, biomass was higher as compared to the variants with Cd and seeds pretreatment by "Epin-extra" by 4, 22, 21, 19, 6, 4, 2 %, accordingly.

According to the accumulation of biomass by aboveground organs, the following series of resistance of varieties can be compiled (in relation to control):

Epin1-control – Aikerim (111) > Aisaule (108) > Madina (107) = Kazvetta (107) > KazEr6 (106) > Baykonur (100) = Marzhan (100) = Bakanas (100) > KazNIIR5 (98) = Tugysken (98) = Salima (98);

Epin2-control – Madina (113) > Aisaule (112) > KazNIIR5 (109) > Baykonur (106) > Salima (105) > Aikerim (104) > Bakanas (103) > KazEr6 (101) = Kazvetta (101) = Syr Sulu (101) > Marzhan (99) > Tugysken (98);

Cd 150 μM- Aisaule (53) > Marzhan (50) >KazEr6 (47) > Madina (46) =Aikerim (46) > Tugysken (42) = Syr Sulu (42) >KazNIIR5 (37) =Baykonur (37) > Bakanas (30) > Kazvetta (28);

Epin1 + Cd 150 μM Aikerim (64) = Syr Sulu (64) > Aisaule (59) > Salima (57) > Madina (56) > Kazvetta6 (52) = Marzhan (52) > Tugysken (48) >Bakanas (45) = Baykonur (45) > KazNIIR5 (37) > Kazvetta (35);

Epin2 + Cd 150 μM – Madina (77) > KazEr6 (74) > Aikerim (68) > Salima (57) = Aisaule (57) > KazNIIR5 (56) > Tugysken (55) > Marzhan (54) > Baykonur (51) > Bakanas (46) > Syr Sulu (42) > Kazvetta (35).

When treated with the "Epin-extra" growth regulator without Cd, the biomass of aboveground organs in the Aikerim, Kazvetta and KazEr6 varieties was higher than when adding "Epin-extra" to the growth solution as compared to variants of seeds pretreatment: in KazNIIR5, Salima, Madina, Aisaule, Baykonur, Bakanas varieties, this indicator was higher by 11, 7, 6, 6, 4, and 3%,

In the presence of Cd, the growth regulator positively affected on the biomass accumulation by aboveground organs in all forms of using of growth regulator.

In varieties KazEr6, Madina, KazNIIR5 Marzhan, Aikerim, Baykonur, the accumulation of biomass by aboveground organs was higher under the action of cadmium when adding a growth regulator to the growth medium as compared to variants of seeds pretreatment by growth regulator "Epin-extra" by 4, 22, 21, 19, 6, 4, 2 %, accordingly.

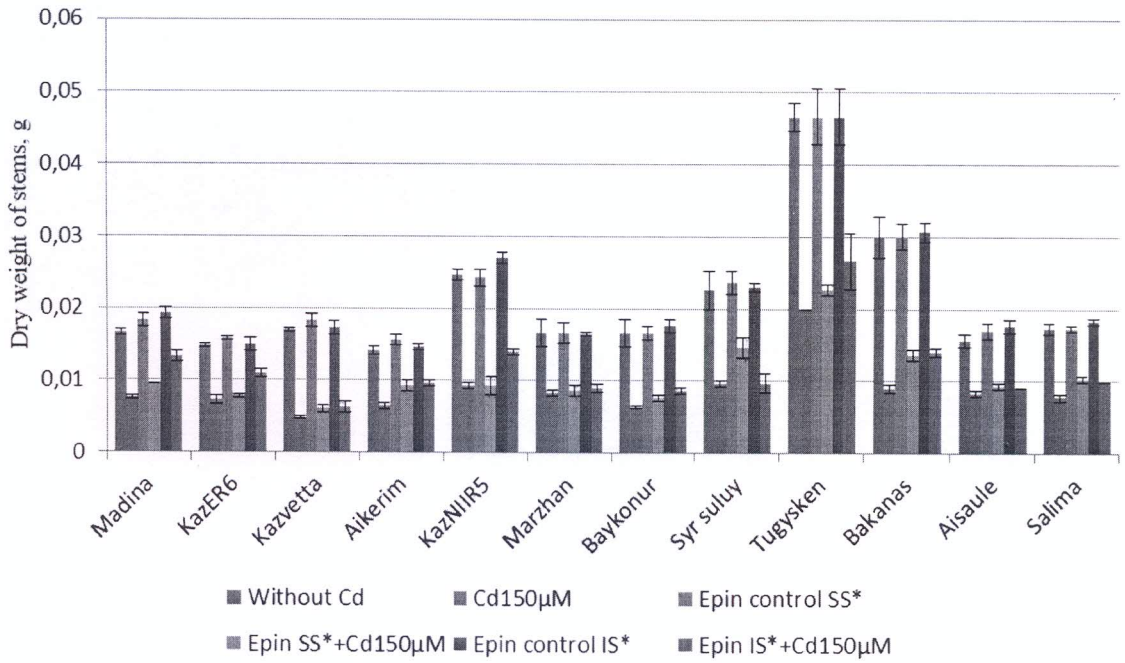

Figure 2 – The effect of Cd and growth regulator "Epin-extra" on biomass accumulation by the aboveground organs of 7-days rice seedlings.
* Note: SS* (soaked in solution) "Control 1" – seeds pretreatment by "Epin-extra", IS* (in solution) "Control 2" – addition of "Epin-extra" directly to the growth medium

It should be noted that the growth regulator "Epin-extra" had the greatest positive effect on the growth of aboveground organs rather than on the accumulation of biomass. The length of aboveground organs in rice varieties with various forms of growth regulator application forms increased as much as possible to 25-29% in variants without Cd, while the accumulation of biomass by aboveground organs increased as much as possible only by 11-13%.

In the presence of Cd, the length of aboveground organs decreased by 32-60% (Epin 1+ Cd) and by 28-61% (Epin2+ Cd) compared to the variant without Epin, where suppression was observed in the range of 29-68% (Cd 150 μM).

And the accumulation of biomass decreased by 36-65% ("Epin 1+ Cd") and by 23-65% ("Epin 2+ Cd"), while without the growth regulator, the decrease was observed in the range of 47-72% ("Cd 150 μM").

3. The effect of cadmium in the presence of growth regulator "Epin-extra" on linear root growth of rice varieties.

According to the results obtained, it is possible to note the inhibition of growth and accumulation of biomass of roots and aboveground organs under cadmium stress.

In comparison with aboveground parts under the action of cadmium, there was a noticeable deterioration in root growth and accumulation of root biomass. Metals that enters the plant are inactivated in roots, which is considered the main mechanism of metal resistance of plants. However, with an increase in the concentration of cadmium in the root zone of plants, root growth is inhibited: their length decreases, the number of lateral roots decreases, root hairs die off, and the biomass decreases.

When using the PGRs "Epin-extra", changes can be noted in the variants Epin1+Cd 150 μM and Epin2 +Cd 150 μM compared to the variant Cd 150 μM.

When comparing the two forms of application of growth regulator "Epin-extra" in variants without Cd, it was found that in varieties Kazvetta and Aisaule the root length increased by 8%, when using the growth regulator in the form of addition to the growth medium as compared to variants of seeds pretreatment (in Kazvetta, 121% vs. 113%, in Aisaule, 117% vs. 109%, respectively). No noticeable changes were observed in the other varieties (Fig. 3).

Under cadmium stress, the length of the roots in 7-days seedlings was suppressed to a greater extent than the length of the shoots of the aboveground organs. In the presence of Cd without the growth regulator ("Cd 150 μM»), root growth was least inhibited in the Tugysken, KazEr6, Madina, and Aikerim varieties; in these varieties, the root length decreased by 33, 35, 45, and 46%, respectively, compared to the control. The same varieties lead the row of tolerance by the roots length in both forms of application of growth regulator.

To the greatest extent root growth was inhibited in varieties Aisaule, Salima, Bakanas, Syr suluy, Marzhan under cadmium stress in the absence of growth regulator (by 70, 68, 68, 65 and 64%, respectively) and with the use of a growth regulator ("Epin1+Cd 150 μM" – by 51, 59, 62, 61, 63%, respectively; Epin2+Cd 150 μM – by 63, 51, 60, 64, 63%, respectively).

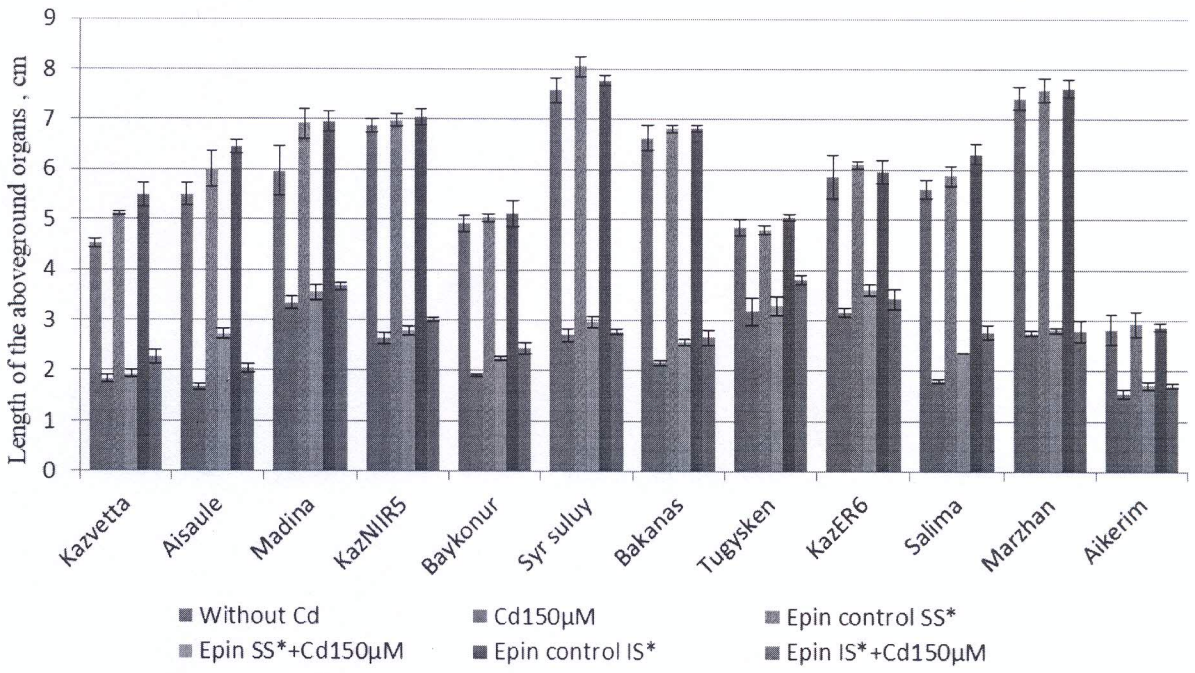

Figure 3 – The effect of Cd and growth regulator "Epin-extra" on root growth of 7-days rice seedlings.
* Note: SS* (soaked in solution) "Control 1" – seeds pretreatment by "Epin-extra",
IS* (in solution) "Control 2" – addition of "Epin-extra" directly to the growth medium

In some varieties (Tugysken, Kazvetta, Baykonur, Salima, KazNIIR5), the greatest effect on root growth from the growth regulator was observed when it was added to the growth medium (variant "Epin2+Cd 150 μM"), possibly due to prolonged direct interaction of the roots with the growing medium containing the growth regulator. The opposite pattern was observed in the varieties KazEr6 and Aisaule (77% vs. 70% in KazEr6 and 49 vs. 37% in Aisaule in variants with seeds pretreatment and addition of the growth regulator "Epin-extra"to the growth medium).

To the greatest extent in all variants in the presence of Cd, root growth was suppressed in varieties Syr suluy, Bakanas, Salima, Aisaule.

According to the effect of the growth regulator "Epin-extra" and Cd on the length of the roots of rice plants, the following series of tolerance can be constructed:

"Epin1-control": Kazvetta (113) > Aisaule (109) > Syr suluy (106) > Salima (104) = Aikerim (104) > Madina (103) Baykonur > (102) KazEr6 (102) = Bakanas (102) = Marzhan (102) > KazNIIR5 (101) > Tugysken (99);

"Epin 2-control": Kazvetta (121) > Aisaule (117) > Salima (112) >Baykonur (104) = Tugysken (104) > KazEr6 (102) = Madina (102) = KazNIIR5 (102) = Syr suluy (102) = Bakanas (102) = Marzhan (102) >Aikerim (101);

"150 μM Cd": KazEr6 (67) > Tugysken (65) > Aikerim (55) > Madina (54) > Kazvetta (40) > Baikonur (38) > KazNIIR5 (38) > Marzhan (36) > Syr Sulu (35) > Bakanas (32) = Salima (32) > Aisaule (30);

"Epin 1 +Cd 150 μM": KazEr 6 (77) > Madina (68) > Tugysken (67) > Aigerim (60) > Aisaule (49) > Baikonur (45) > Kazvetta (42) > Salima (41) > KazNIIR5 (40) > Syr Sulu (39) > Bakanas (38) > Marzhan (37);

"Epin 2+Cd 150 μM": Tugysken (78) > KazEr6 (70) > Madina (68) > Aigerim (60) > Kazvetta (50) > Baikonur (49) = Salima (49) > KazNIIR5 (43) > Bakanas (40) > Marzhan (37) = Aisaule (37) > Syr Suluy (36).

4. The effect of cadmium in the presence of growth regulator "Epin-extra" on root biomass of rice varieties

The study of the effect of growth regulator "Epin-extra" on biomass accumulation of roots of rice plants showed that the use of the growth regulator in one form or another, basically, had a positive effect on this parameter.

It is characteristic that in most varieties, when seeds were soaked in "Epin-extra" solution, the accumulation of biomass by roots in the Cd-free variant was higher as compared to the variants with addition of it in growth medium. For example, the varieties Tugysken, Baykonur, Kazvetta, KazNIIR5, Aysaule, Marzhan, Bakanas increased the root mass in variant with seeds pretreatment by 28, 11, 9, 8, 8.4 and 3% against 18, 6, -1 (99%), 3, 4, 0% (100%), accordingly, when adding Epin to the growing medium.

Only in varieties Aikerim, Salima, Madina, the root biomass was higher when adding "Epin-extra" to the growing medium, than seeds pretreatment variant (112% vs110%, 107% vs 104%, 109% vs 100% to the control, accordingly). In other varieties there were no noticeable differences in different forms of use of the growth regulator (Syr suluy, KazEr6).

According to the accumulation of biomass by roots, the following series of varieties ' resistance can be compiled (% to control):

"Epin control 1" – Tugysken (128) > Baykonur (111) > Aikerim (110) >Kazvetta (109) > KazNIIR5 (108) = Aisaule (108) > Marzhan (104) =Salima (104) >Syr suluy (103) = Bakanas (103) > Madina (100) >KazEr6 (96);

"Epin control 2" – Tugysken (118) > Aikerim (112) >Madina (109) >Salima (107) >Baykonur (106) >Aisaule (104) >Syr suluy (103) = KazNIIR5 (103) > KazEr6 (100) = Marzhan (100) > Kazvetta (99) > Bakanas (99);

"Cd 150 μM" – KazNIIR5 (37) > Aisaule (34) = Salima (34) >Tugysken (32) >Madina (31) > Bakanas (27) >Bykonur (25) >KazEr6 (24) > Kazvetta (23) = Aikerim (23) > Syr suluy (20) > Marzhan (16);

"Epin1 + Cd 150 μM" – Salima (42) >KazNIIR5 (40) > Aikerim (38) > Tugysken (35) = Aisaule (35) > Madina (34) > KazEr6 (30) = Baykonur (30) = Bakanas (30) > Kazvetta (28) > Syr suluy (22) > Marzhan (17);

"Epin2 + Cd 150 μM" – KazEr6 (54) > Tugysken (51) > Aikerim (46) > Madina (43) = Salima (43) > KazNIIR5 (40) = Aisaule (40) > Kazvetta (39) > Baykonur (32) > Bakanas (31) > Syr suluy (28) > Marzhan (17).

Under cadmium stress, the use of the growth regulator "Epin-extra " in any form increased the accumulation of roots biomass compared to the variant without a growth regulator (Cd 150 μM).

Soaking seeds in the solution of the growth regulator in comparison with the variant without the growth regulator significantly increased the accumulation of biomass by plant roots in varieties Salima, Baikonur, KazEr6, Kazvetta, Aikerim (by 43% vs. 34%, by 30% vs. 25%, by 30% vs. 24%, by 38% vs. 23%, by 38% vs. 23% relative to control, accordingly). In other varieties, such as Nakaziir5, Tugysken, Madina, Bakanas, Syr suluy, this indicator slightly increased at seeds pretreatment variants by the growth regulator, and in Marzhan variety, no personal effect was observed

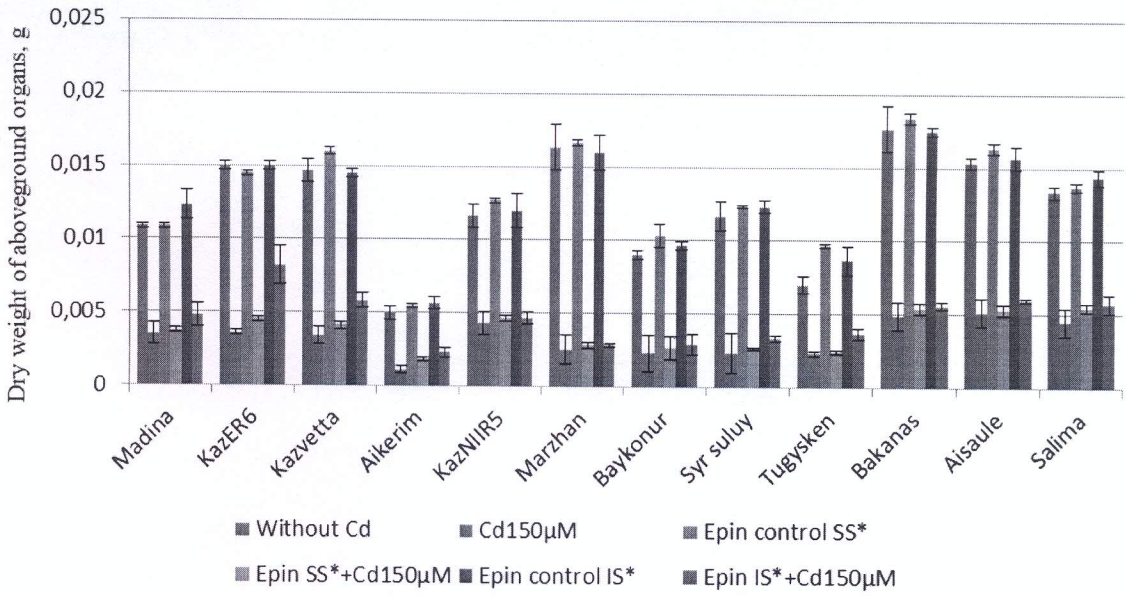

Figure 4 – The effect of Cd and growth regulator "Epin-extra" on root biomass accumualtion of 7-days rice seedlings.
* Note: SS* (soaked in solution) "Control 1" – seeds pretreatment by "Epin-extra",
IS* (in solution) "Control 2" – addition of "Epin-extra" directly to the growth medium

When "Epin-extra" was added to the growth medium in varieties KazEr6, Tugysken, Aikerim, Madina, Salima, Kazvetta, Baykonur, accumulation of root biomass was significantly increased as compared to the variants without the growth regulator and seeds pretreatment by the growth regulator variants – by 24, 30 and 54%; 32, 35 and 51%; 23, 38 and 46%; 31, 34, 43%; 34, 42, 43%; 23, 28 and 38%; 25, 30 and 32% (in variants "Cd 150 μM", "Epin1 + Cd 150μM", "Epin2 + Cd 150 μM", respectively).

The most positive effect on root growth was exerted by growth regulator "Epin-extra" when it was added to the solution compared to the pretreatment by soaking in the Cd-free version, namely, the root length increased as much as possible in some varieties up to 13% when soaking, and when added to the solution – up to 21%. In the presence of Cd, the root length without the growth regulator was suppressed in the range of 33-70% relative to the control, and when using the growth regulator in any form – in the range of 22-64%.

Thus, the use of the growth regulator in one form or another increased the weight of the roots by a maximum of 18-28% compared to the version with Cd without "Epin-extra".

In the presence of Cd without a growth regulator, the accumulation of biomass by roots was suppressed in rice varieties in the range of 83-63% relative to the control. At seeds pretreatment by "Epin-extra" solution roots biomass decreased in the range of 83-58%, in variants with addition of growth regulator to the growth solution – by 83-46% relative to control, which indicates that the use of a growth regulator in one form or another reduces the degree of suppression of biomass accumulation in some varieties by 4-17%.

Conclusion

The results of this study showed that the growth regulator "Epin-extra" reduces to a certain extent the inhibitory effect of Cd cadmium ions on the growth of aboveground organs and roots. The degree of positive effect of the growth regulator to some extent depended on the form of application – seeds pretreatment by soaking or addition of "Epin-extra" to the growth solution.

The most positive effect of a growth regulator "Epin-extra" had on the length of the aboveground organs in comparison with other parameters. Rice varieties also differed in the response to the presence of cadmium when using a growth regulator in one form or another.

Varieties Tugysken, Bakanas, Kazvetta, Aisaule were distinguished by the greatest increase in the growth rate of aboveground organs in comparison with other varieties when using a growth regulator

in any form. The same varieties were more resistant to cadmium in terms of the length of the aboveground organs in the absence of a growth regulator.

There were no special differences in the effect on the change in the length of the aboveground organs of rice varieties when comparing different forms of use of a growth regulator "Epin-extra" in most varieties. The least tolerant varieties were Salima and Aikerim, while the other varieties occupied an intermediate position.

When treated with growth regulator "Epin-extra" without Cd, the weight of aboveground organs in some varieties was higher than when Epin was added to the solution, in others – on the contrary.

In the presence of Cd, growth regulator "Epin-extra" positively affected the accumulation of biomass by aboveground organs in all types of application.

According to the accumulation of biomass, the most resistant to Cd were the varieties Aisaule, Marzhan, KazEr6, Madina, Aikerim, Tugysken, Syr suluy, the least – Bakanas, Kazvetta. In the latter varieties, the degree of reduction in the biomass of aboveground organs was the greatest, although their length decreased to a lesser extent.

Under the action of cadmium (Cd 150 μM") without the growth regulator and in the presence of it, root growth was least inhibited in the varieties Tugysken, KazEr6, Madina and Aikerim. In the greatest extent the roots growth was inhibited in varieties Aisaule, Salima, Bakanas, Syr suluy, and Marzhan.

To the greatest extent in all variants in the presence of Cd, root growth was suppressed in the varieties Syr suluy, Bakanas, Salima, Aisaule. There were differences in varieties in the reaction of plant roots from the form of growth regulator application.

Thus, it can be concluded that the growth stimulator "Epin-extra" helps to increase the resistance of plants under cadmium stress, increasing the growth rates of aboveground organs and roots of rice plants. Differences in changes in growth parameters were found when using a growth stimulator in the presence of Cd stress in different genotypes, which indicates the genetic conditionality of plant responses in the presence of growth regulator belongs to brassinsteroids.

Conflict of interest

All authors have read and are familiar with the content of the article and have no conflicts of interest.

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