CROP PRODUCTION

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PHYTOPROTECTIVE ROLE OF HUMUS ACIDS UNDER SALINITY

Research article

Abstract

The investigation of phytoprotective properties of humus acids is of interest nowadays due to the growth of anthropogenic soil salinity. The influence of peat humus acids preparation on wheat (*Triticum aestivum* L.) tolerance to chloridic salinity was studied under vegetational experiment in aquatic culture. The plants were grown on Hoaglond nutrient mixture, the experimental variant of solution being enriched by NaCl in 25, 50, and 100 mmol/l concentrations as well as by humus acids preparation (0.005%) in accordance with the experiment scheme. Under mild salinity - 25 and 50 mmol/l -the protecting function of humus acids was shown to act with Na content increase, while under 100 mmol/l the protecting role of humus acids is caused by the decrease of sodium ions contents in plants shoots. Sodium ions accumulation in plants shoots in the presense humus acids under mild salinity (25 and 50 mmol/l of NaCl) can be used in phytoremediation.

Keywords: humic acids, salinity, wheat.

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ФИТОПРОТЕКТОРНАЯ РОЛЬ ГУМУСОВЫХ КИСЛОТ ПРИ ЗАСОЛЕНИИ

Научная статья

Аннотация

В связи с ростом антропогенного засоления почв представляет интерес изучение фитопротекторных свойств гумусовых кислот. В условиях вегетационного эксперимента в водной культуре исследовали влияние препарата гумусовых кислот торфа на устойчивость пшеницы (*Triticum aestivum* L.) к хлоридному засолению. Растения выращивали на питательной смеси Хогланда, на опытных вариантах в раствор добавляли NaCl в концентрациях 25, 50 и 100 ммоль/л, а также препарат гумусовых кислот (0.005%) в соответствии со схемой опыта. В результате исследований установлено, что при умеренном засолении – 25 и 50 ммоль/л – протекторная функция гумусовых кислот реализуется при увеличении содержания Na, тогда как при 100 ммоль/л NaCl защитная роль гумусовых кислот обусловлена снижением содержания ионов натрия в побегах растений. Усиление накопления ионов натрия в побегах в присутствии гумусовых кислот при невысоком засолении (25 и 50 ммоль/л NaCl) может быть использовано в фиторемедиации.

Ключевые слова: гумусовые кислоты, засоление, пшеница.

1. Introduction

The area of salinated soils covers about 25% of land surface and is consantly growing under the influence of different anthropogenic factors. Secondary salinity caused mainly by irrigation reaches thousands of hectars a year [1]. Technogenic salinity resulting from oil extraction and mineral fertilizers production progresses rapidly [2]. The application of anti-ice mixtures in winter leads to their spread in the form of aerosols to great distances from highways as well as their accumulation in soils. High concentrations of salts cause methabolic disturbances as well as plant physiological processes changes resulting in decreasing of their productivity [3], [4]. The main reason of crops damage is excessing salt ions accumulation [5], [6].

Nowadays there are some experimental proofs of adaptogenic properties of humus acids - humic and fulvic acids (HFA) - to plants under high salt concentration conditions [7]. The solution application of HFA was shown to result in partial salt stress releasing in wheat seedlings [8]. The protecting action of HFA under salinity is attributed to their anti-oxidantic action [9] as well as to cytokinins amount maintenance in plants [10]. HFA seem to act as physiological plant protecting and detoxication systems inductor [11]. HFA are known both to decrease [12], and to increase accumulation of metals in plants [13], [14], due to soluble and insoluble salts formation.

Humic preparations containing watersoluble humus acids salts possess the greatest physiological efficacy. The chief raw material for humats production are brown coal and peat, the latter being the most perspective renewable resource with stores in Russia estimated as high as 160 bil.tons [15]. These reserves are computed to grow by 250-280 mln.tons each year.

The above mentioned data proove the necessity of special researches aimed at the investigating of character and mechanisms of influence of humic preparations on toxity and salinating ions accumulation in plants. Such investigations are necessary both for plant stability processes obviating and for phytoremediational technologies development.

2. Materials and methods

2.1. Materials and conditions of experiments

Peat humus acids preparation in the form of HFA watersoluble salt was chosen on the baisis of preliminary experiments and special literature analysis. Peat HFA preparations are known to show the greatest activity in oxydizing-restoring processes and to have high superficial and antioxidant activity [16]. The preparation was obtained from low-lying land peat of wood-sedge group with decomposition rate 35-40% [17]. Being a relatively new geological formation, low-lying land peat contains a great amount of biologically active substances (aminoacids, carbohydrates, ferments, antibiotics, vitamins and phytohormons), mostly in humic acids. The preparation production technology provides the most complete transformation of all biologically active substances into the state available for plants, humic acids changing into physiologically active watersoluble salts – humats.

Spring wheat (*Triticum aestivum* L.) of Priokskaya variety was chosen as the object of investigation. As it is known from special literature, cereals are responsive to HFA stimulating application [18]. The aim of the research work was also the study of HFA influence on the salinating ions accumulation by a typical plant- root ions "excluder". Wheat can be used in phytoremediation due to its high growth rate and ability to absorb and accumulate contaminating ions.

The vegetational experiments were carried out on aquatic culture which allowed to create proper concentration of both humic acids and sodium chloride as well as to observe the plant root system. The seeds were germinated on filter paper with NaCl solutions (25, 50, 100 and 200 mmol/l) with and without HFA addition. Humic preparation was used in concentration 0.01% which is considered to be the most physiologically effective in seeds germination. In 7days the seedlings were moved into 1 littre vessels with 0.25 of Hoaglond solution rate [19]. The rate of nutrient mixture was increased to 0.5 and 1 as the plants grew. Plants grown without NaCl and HFA in the medium were used as control. NaCl in concentrations 25, 50 and 100 mmol/l and HFA (0.005 %) in accordance with the scheme were applied in case of experimental plants. The seeds practically didn't germinate at 200 mmol/l so this variant was excluded from the further experiment. The plants were grown with artificial light, the length of light day being 16 hours. The nutrient solution was changed every 7 days. The temperature was kept at 20-22 degrees, the solution pH being 5.3-5.6. The repetition in experiments was 4-times, in observations-3-times.

2.2. Research methods

Phases of plants development, external signs of root and shoot damage were written down in research process. The length of roots and shoots was measured and the dry weight was estimated. Plant reaction on salinating ions and HFA action was estimated by morphological characteristics of shoots on the seventh day of the experiment as well as by biomass accumulation in phases of tillering, stalk shooting and ears formation. The content of ions in plants was determined on atomic absorbtional spectrometre in the Lobachevsky State University Chemistry Research Institute.

The rate of plants salt tolerance was expressed in the form of correlation of plant shoots dry weight [20] (or seedlings root length) of control and experimental variants. The coefficient of HFA protectional action was computed [21]: 1) by plants mass accumulation – correlation of plant shoots dry weight (or seedlings root length) grown with and without HFA was computed 2) by ions accumulation – the correlation of sodium content in plants grown with and without HFA was computed. The correlation of sodium ions accumulation in plants grown with and without HFA (mg/plant) was taken as the coefficient of HFA fitoremediation efficacy. Sodium ions accumulation per one plant was found to reflect the remediational capacity of plants most accurately due to weight decreasing consideration.

The statistical data processing was carried out with the help of Excel program using dispersion and regressive methods of analysis.

3. Results and discussion

High concentrations of NaCl decreased the shoots and roots length of wheat (table 1, figure1). Seedlings salt tolerance rate was high at 25 mmol NaCl, there being practically no difference between control and experimental variants. At 50 mmol shoots length decreased considerably (by 45%), while at 100 mmol the shoots length decreased by as much as 49% and root length by 65% to control. The influence of salinity on seedlings shoots length at 50 and 100, and on roots at 100 mmol NaCl was statistically proved. At 200 mmol NaCl the seeds were not vital.

Table 1 – Seedlings salt tolerance rate (%)

Variants	Shoots	Roots
1. NaCl 25 mmol	96.92	98.02
2. NaCl 25 mmol + HFA	114.71	148.32
3. NaCl 50 mmol	65.60	94.26
4. NaCl 50 mmol + HFA	70.34	137.57
5. NaCl 100 mmol	51.36	35.14
6. NaCl 100 mmol + HFA	54.57	80.62
7. NaCl 200 mmol	-	-
8. NaCl 200 mmol + HFA	26.93	23.07

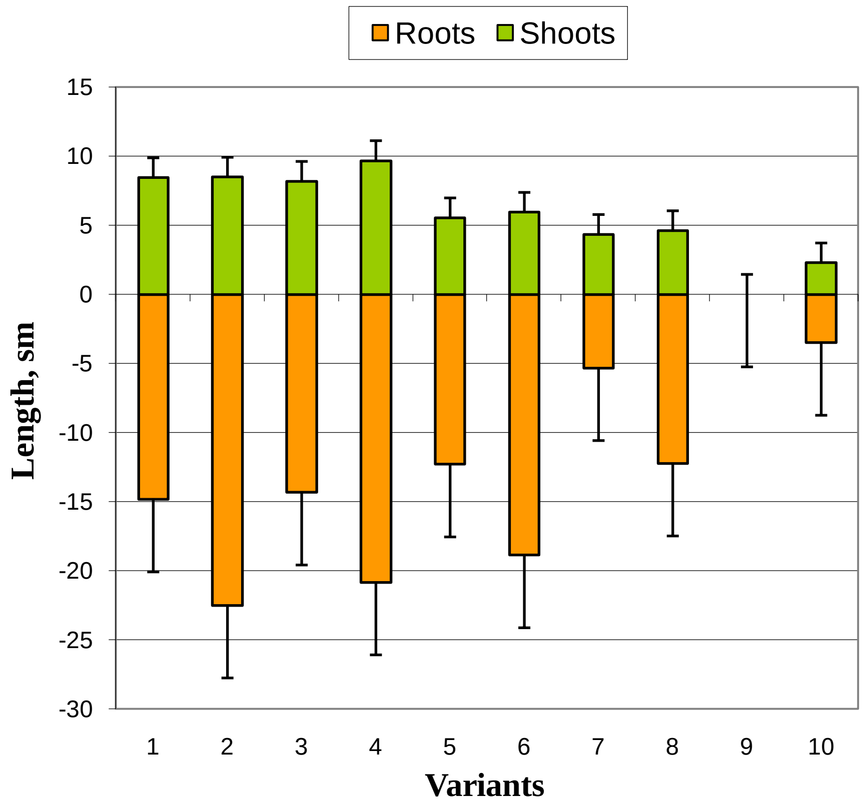

Figure 1 – Influence of salination and HFA on wheat seedlings growth
1.Control 2. HFA 3. NaCl 25 mmol 4. NaCl 25 mmol + HFA 5. NaCl 50 mmol 6. NaCl 50 mmol + HFA 7. NaCl 100 mmol 8. NaCl 100 mmol + HFA 9. NaCl 200 mmol 10. NaCl 200 mmol + HFA. Bars on the diagram show least significant difference for 5% significance level (LSD$_{05}$)

The inverse linea correlation of wheat seedlings root length and NaCl concentration was stated (figure 2)

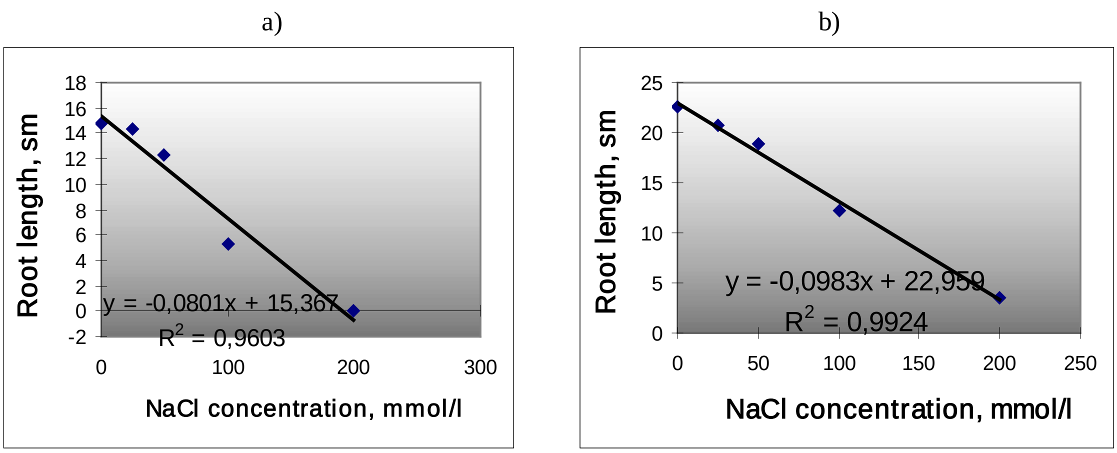

Figure 2 – Correlation of wheat seedlings root length and NaCl concentration
a) without HFA (r=-0.98; p=0.003) *b*) with HFA (r=-1.00; p<0.001)

HFA preparation decreased the damaging action of salinity on wheat seedlings due to 1.5-2.3 times root lengtn increasing as compared with variants withot HFA (table 1, figure 1, 3). In presence of 200 mmol of NaCl HFA preparation stimulated seeds germination. The protecting influence of HFA on seedlings root length was seen in all the variants, on shoots length – in only at NaCl concentration 25 mmol.

Table 2 – HFA protecting action coefficient (by seedlings length)

Variants	**Shoots**	**Roots**
1. HFA	1.01	1.52
2.NaCl 25 mmol	1.18	1.45
3.NaCl 50 mmol	1.07	1.53
4.NaCl 100 mmol	1.06	2.29

Figure 3 – HFA influence on the wheat seedlings root growth in presence of 50 mmol of NaCl
To the left-without HFA, to the right –with HFA

Shoots and roots mass decreased with salt concentration increase (table 3, figure 4). It should be noted that at 25 mmol plants shoots mass to control decreased only in bushing phase, while in tube formation phase and ears formation phase NaCl influence is not proved statistically.

Table 3 – Shoots and roots dry weight (g)

Variants	Development phases (for control plants)		
	Tillering	Stalk shooting	Ears formation
shoots			
1. Control	0.67	3.00	10.2
2. HFA	**0.80**	**3.50**	11.3
3.NaCl 25mmol	0.60	2.70	9.00
4. NaCl 25mmol + HFA	**0.66**	**3.10**	10.54
5.NaCl 50 mmol	0.27	1.20	4.00
6.NaCl 50 mmol + HFA	**0.53**	**2.77**	**8.20**
7.NaCl 100 mmol	0.05	0.10	0.52
8.NaCl 100 mmol + HFA	**0.09**	0.28	0.98
LSD_{05}	*0.02*	*0.33*	*2.07*
roots			
1. Control	0.10	0.68	2.00
2. HFA	0.11	**0.80**	**2.20**
3.NaCl 25mmol	0.08	0.52	1.50
4. NaCl 25mmol + HFA	0.10	0.64	**1.86**
5.NaCl 50 mmol	0.04	0.30	0.89
6.NaCl 50 mmol + HFA	0.05	0.32	0.97
7.NaCl 100 mmol	0.01	0.08	0.23
8.NaCl 100 mmol + HFA	0.02	0.11	0.32
LSD_{05}	*0.03*	*0.10*	*0.17*

Notes: - statistically proved – HFA influence is printed in bold type;
– LSD_{05} - least significant difference for 5% significance level.

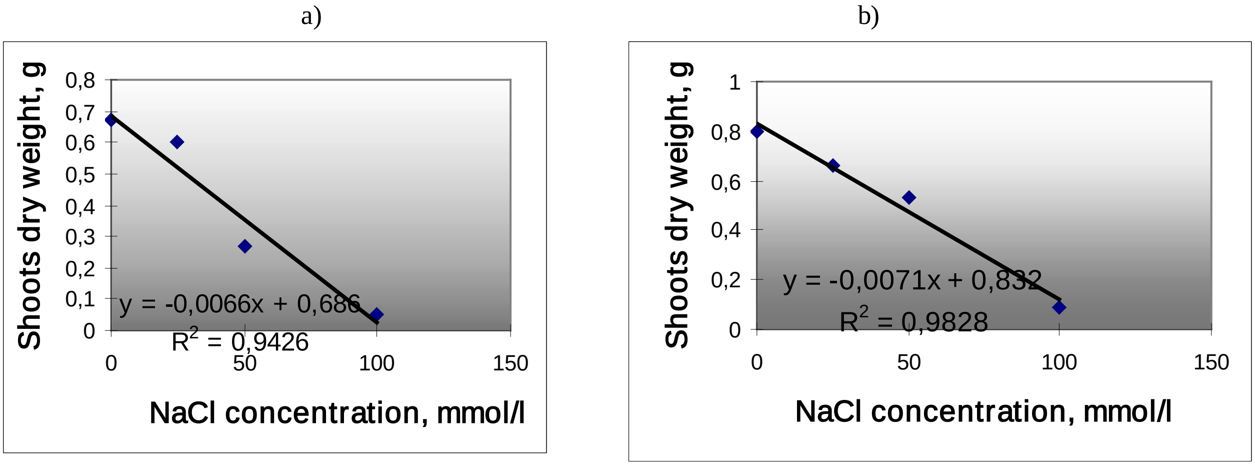

Figure 4 – Correlation of shoots dry weight and NaCl concentration in bushing state: *a*) without HFA (r=-0.97; p=0.029), *b*) with HFA (r=-0.99; p<0.008)

Correspondingly, plants salt resistance rate was high at 25 mmol of NaCl (table 4). At 50 mmol plants saltresistance decreased by 60%, and at 100 mmol was as little as 3-7%.

Table 4 – Plants salt tolerance rate, %

Variants	Development phases (for control plants)		
	Tillering	Stalk shooting	Ears formation
1.NaCl 25mmol	89.55	90.00	88.24
2. $NaCl_{25}$+ HFA	98.51	103.33	103.33
3.NaCl 50mmol	40.30	40.00	39.22
4. $NaCl_{50}$+ HFA	79.10	92.33	80.39
5.NaCl 100mmol	7.46	3.33	5.10
6. $NaCl_{100}$+ HFA	13.43	9.33	9.61

HFA preparation decreased damaging action of NaCl on wheat plants (table 5, figure 5). It should be noted that HFA protecting role increases with salt concentration growth, being the highest in stalk shooting phase (figure 6). HFA contributed to plants weight growth more than two times at 50 and 100 mmol of NaCl as compared with variants without HFA. In presence of 25 mmol of NaCl HFA efficacy was as little as 10-17 % possibly due to low toxity of this salt concentration.

Table 5 – HFA protecting action coefficient (by plants weight)

NaCl concentration, mmol/l	Development phases (for control plants)		
	Tillering	Stalk shooting	Ears formation
1. 25	1.10	1.15	1.17
2. 50	1.96	2.31	2.05
3. 100	1.80	2.80	1.88

Figure 5 – HFA influence on wheat plants growth at 50 mmol/l of NaCl
To the left – without HFA, to the right – with HFA

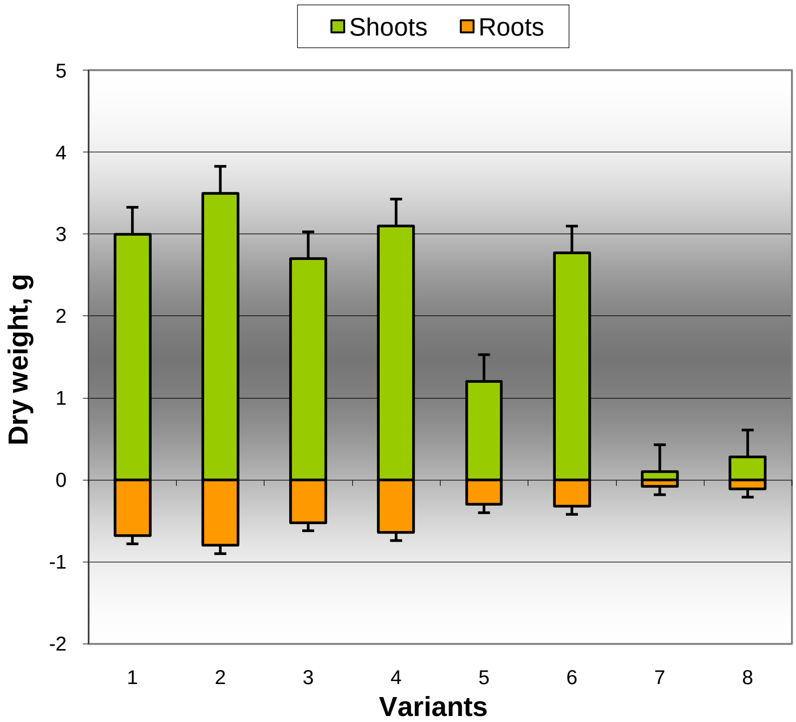

Figure 6 – HFA influence on wheat plants growth under chloride salinity in stalk shooting (tube formation) phase
1. Control 2. HFA 3. NaCl 25 mmol 4. NaCl 25 mmol + HFA 5. NaCl 50 mmol 6. NaCl 50 mmol + HFA 7. NaCl 100 mmol 8. NaCl 100 mmol + HFA . Bars on the diagram show least significant difference for 5% significance level (LSD_{05})

The damaging action of salinity is possibly caused by sodium ions accumulation. The inverse correlation of plants shoots weight and sodium contents coefficient is 0.72, of roots – 0, 84. Sodium ions contents in plants shoots and roots increased with NaCl concentration growth (table 6). At 25 mmol/l of NaCl sodium contents in shoots grew in 7.8 times, at 50 mmol/l – in 17 times, at 100 mmol/l – in 31.5 times to control.

Table 6 – Sodium ions contents, mg/kg of dry weight (Stalk shooting phase)

Variants	Shoots	Roots
1. Control	306.6	2970.8
2. HFA	266.4	**3695.5**
3. NaCl 25 mmol	2400.4	7790.2
4. NaCl 25 mmol + HFA	**2920.3**	***2750.5***
5. NaCl 50 mmol	5220.8	18555.2
6. NaCl 50 mmol + HFA	**6124.8**	***9199.8***
7. NaCl 100 mmol	9646.5	-
8. NaCl 100 mmol + HFA	***3863.6***	-
LSD_{05}	*339.42*	*444.38*

Notes:
- Statistically proved sodium contents growth under HFA influence is printed in bold type;
- Statistically proved sodium contents decrease under HFA influence is printed in bold and italic type;
- LSD_{05} - least significant difference for 5% significance level.

HFA preparation increased sodium contents in shoots in 1.2 times and decreased it in plants roots in 2-2.8 times at 25 and 50 mmol of NaCl (table 7), shoots weight being 92 and 103 % at 50 and 25 mmol correspondingly. At 100 mmol of NaCl the protecting role of HFA increased, which contributed to shoots sodium contents decrease in 2.5 times as well as to plants stability increase in 2.8 times. So the protecting role of HFA was observed at presence of 25 and 50 mmol of NaCl at sodium contents increase, and at 100 mmol of NaCl - at sodium contents decrease.

Table 7 – HFA protecting action coefficient (sodium contents)

NaCl concentration, mmol/l	Shoots	Roots
1. 25	0.82	2.83
2. 50	0.85	2.02
3. 100	2.50	-

The strategy of glycophyts adaptation to excessive salt concentrations on organism level is known to be the regulation of ions concentration in over ground organs and avoiding salinating ions high concentrations in young growing leafs and especially in reproductive organs [22]. Roots are capable of detaining part of absorbed sodium, accumulating it in vacuoli, a certain part being transported to the environment and absorbed in cell walls outside the absorbing zone [23]. So under the condition of salinity 100 mmol of NaCl humus acids strengthened the regulating function of wheat plants root system.

Salinating ions accumulation per one plant better reflects the remedial capacity of plants taking into consideration their mass decrease. Accumulation of sodium by wheat plants was higher in shoots than in roots in 1.3-1.8 times and decreased markedly at 100 mmol of NaCl due to toxicity growth and plants weght decrease (Table 8).

Table 8 – Sodium ions accumulation (mg/plant)

Variants	Shoots	Roots
1. Control	3.127	5.942
2. HFA	3.010	8.130
3. NaCl 25 mmol	21.604	11.685
4. NaCl 25 mmol + HFA	30.780	5.116
5. NaCl 50 mmol	20.883	16.514
6. NaCl 50 mmol + HFA	50.223	8.923
7. NaCl 100 mmol	5.016	-
8. NaCl 100 mmol + HFA	3.786	-

HFA preparation increased sodium ions accumulation by wheat plants shoots at 25 and 50 mmol of NaCl in 1.4 and 2.4 times correspondingly in comparison with variants without HFA having increased their remedic potential (Table 9).

Table 9 – HFA phytoremediation efficacy coefficient

NaCl concentration, mmol/l	Shoots	Roots
1. 25	1.42	0.44
2. 50	2.40	0.54
3. 100	0.75	-

4. Conclusion

So the present investigations proved the suggested phytoprotective role of humic acids under salinity. HFA preparation decreased the damaging action of salinity on wheat seedlings increasing root length in 1.5-2.3 times at 25, 50 and 100 mmol of NaCl as compared with variants without HFA. HFA preparation stimulated seeds germination in presence of 200 mmol of NaCl. In conditions of salinity 100 mmol of NaCl humus acids contributed to plant root system regulating function strengthening – sodium contents in wheat shoots decreased in 2.5 times at plant stability increase in almost 3 times as compared to variant without HFA .

Intensification of sodium ions accumulation by wheat plants shoots in presence of HFA at low salinity (25 and 50 mmol/l of NaCl) prove the perspectiveness of humus acids preparations use in phytoremediation as the effectors of phytoextraction of salinating ions.

Conflict of Interest

None declared.

Конфликт интересов

Не указан.

References

1. Ковда В.А. Проблемы опустынивания и засоления почв аридных регионов мира / В.А. Ковда. - М.: Наука, 2008. - 415 с.

2. Лымарь О.А. Техногенные поверхностные образования зоны солеотвалов и адаптация к ним растений. Дисс… канд. биол.наук. Пермь, 2007. - 208 с.

3. Flowers T.J. Improving crop salt tolerance / T.J. Flowers // Journal Experimental Botany - 2004. - Vol. 55, No. 396. - P. 307-319.

4. Балнокин Ю.В. Ионный гомеостаз и солеустойчивость растений / Ю.В. Балнокин.- М.: Наука, 2012. - 99 с.

5. Строгонов Б.П. Физиологические основы солеустойчивости растений / Б.П. Строгонов. - Изд-во АН СССР, 1962. – 366 с.

6. Петров-Спиридонов А.Е. Реакция растений пшеницы, проса и сорго на внезапное хлоридное засоление / А.Е. Петров-Спиридонов, Т.А.Рыбкина // Известия ТСХА. - 1990.-№ 6.- С.78-84.

7. Христева Л.А. Действие физиологически активных гуминовых кислот на растения при неблагоприятных внешних условиях / Л.А. Христева // Гуминовые удобрения: Теория и практика их применения. - Днепропетровск, 1973. Т.4. – С.15-23.

8. Куликова Н.А Защитное действие гуминовых веществ по отношению к растениям в водной и почвенной средах в условиях абиотических стрессов / Н.А. Куликова. Автореф. дис. … д-ра биол. наук. М.: МГУ, 2008. - 48 с.

9. Кузнецов Вл.В. Роль систем антиоксидантной защиты при адаптации дикорастущих видов растений к солевому стрессу / Вл.В. Кузнецов // Физиология растений. - 2008. - Т. 55. - С. 516–522.

10. Гилязетдинов Ш.Я. Влияние Гуми-М на гормональный статус растений пшеницы при засолении / Ш.Я. Гилязетдинов, Ф.М. Шакирова // Агрохимия. - 2006. - № 8. - С. 25-29.

11. Lu J. Sorption of atrazine onto humic acids (HAs) coated nanoparticles / J. Lu, Y. Li, X.Yan, B.Shi, D.Wang, H.Tang // Colloids and Surfaces. – 2009. - Vol. 347, No. 1. - P. 90-96.

12. Wu X. Bioaccumulation of cadmium bound to humic acid by the bivalve Meretrix meretirx Linnaeus from solute and particulate pathways / X. Wu, Y. Jia, H. Zhu, H. Wang // J. of Enviromental Sciences-china. - 2010. - Vol. 22, No.2. - P. 198-203.

13. Halim M. Potential availability of heavy metals to phytoextraction from contaminated soils induced by exogenous humic substances / M. Halim, P. Conte, A. Piccolo // Chemosphere/ - 2003. - Vol. 52, No. 1. - P. 265-275.

14. Evangelou M. W. H. The influence of humic acids on the phytoextraction of cadmium from soil / M. W. H. Evangelou, H. Daghan, A. Schaeffer //Chemosphere. -2004. Vol. 57, No 3. - P. 207-213.

15. Чураков А.А. Запасы торфа в России / А.А. Чураков // Лесной вестник. – 2003. - № 3. – С. 22-25.

16. Перминова И.В. Анализ, классификация и прогноз свойств гумусовых кислот / И.В. Перминова. Дис. … д-ра хим. наук. М.: МГУ, 2000. - 359 с.

17. Способ получения жидких торфяных гуматов: пат. 2310633 Рос. Федерация: МПК C05F11/02, C10F7/00/ Калинников Ю.А., Вашурина И.Ю., Кирдей Т.А.; заявитель и патентообладатель ООО Научно-производственная фирма «Недра». № 2006120883/04; заявл. 15.06.2006; опубл. 20.11.2007, Бюл. № 32. - 4 с.

18. Христева Л.А. Стимулирующее влияние гуминовой кислоты на рост высших растений и природа этого влияния / Л.А. Христева // Гуминовые удобрения. Теория и практика их применения. – Харьков. - 1957. - С.75-93.

19. Hoaglond D.R. The water culture method for growing plants without soil / D.R. Hoaglond, D.E. Arnon // Calif. Agric. Expt. Stn. - 1950. - Vol. 347. - P. 1-39.

20. Удовенко Г.В. Солеустойчивость культурных растений / Г.В. Удовенко. – Л.: Колос, 1977. – 215 с.

21. Кирдей Т.А. Защитное действие гумата на проростки пшеницы в присутствии тяжелых металлов / Т.А. Кирдей // Проблемы региональной экологии. - М. - 2014. - № 2. - С. 199-201.

22. Greenway H. Mechanisms of salt tolerance in nonhalophytes / H. Greenway, R. Munns // Ann.Review of Plant Physiol. - 1980. - Vol. 31. - P. 149-190.

23. Захарин А.А. Феномен солерезистентности гликофитов / А.А. Захарин., Л.А. Паничкин // Физиология растений. - 2009. - Т.56. - № 1. - С. 107-116.

References in English

1. Kovda V.A. Problemy opustynivaniya i zasoleniya pochv aridnykh regionov mira [Problems of desertification and salinization of soils in arid regions of the world] / V.A. Kovda. - M.: Nauka. 2008. - 415 p. [in Russian]

2. Lymar O.A. Tekhnogennyye poverkhnostnyye obrazovaniya zony soleotvalov i adaptatsiya k nim rasteniy [Technogenic surface formations of the landfill zone and adaptation of plants to them]: dis… of PhD in Biology. Perm. 2007. - 208 p. [in Russian]

3. Flowers T.J. Improving crop salt tolerance / T.J. Flowers // Journal Experimental Botany - 2004. - Vol. 55, No. 396. - P. 307-319.

4. Balnokin Yu.V. Ionnyy gomeostaz i soleustoychivost rasteniy [Ionic homeostasis and salt tolerance of plants] / Yu.V. Balnokin.- M.: Nauka. 2012. - 99 p. [in Russian]

5. Strogonov B.P. Fiziologicheskiye osnovy soleustoychivosti rasteniy [The physiological basis of salt tolerance of plants] / B.P. Strogonov. - Izd-vo AN SSSR. 1962. – 366 p. [in Russian]

6. Petrov-Spiridonov A.E. Reaktsiya rasteniy pshenitsy. prosa i sorgo na vnezapnoye khloridnoye zasoleniye [The reaction of wheat, millet and sorghum plants to sudden chloride salinization] / A.E. Petrov-Spiridonov. T.A.Rybkina // Izvestiya TSKhA. - 1990. - № 6. - P.78-84. [in Russian]

7. Khristeva L.A. Deystviye fiziologicheski aktivnykh guminovykh kislot na rasteniya pri neblagopriyatnykh vneshnikh usloviyakh [The effect of physiologically active humic acids on plants under adverse environmental conditions] / L.A. Khristeva // Guminovyye udobreniya: Teoriya i praktika ikh primeneniya. - Dnepropetrovsk. 1973. T.4. – P. 15-23. [in Russian]

8. Kulikova N.A Zashchitnoye deystviye guminovykh veshchestv po otnosheniyu k rasteniyam v vodnoy i pochvennoy sredakh v usloviyakh abioticheskikh stressov [Protective effect of humic substances in relation to plants in aquatic and soil environments under abiotic stress] / N.A. Kulikova. Avtoref. dis. … of PhD in Biology. – M.: MGU. 2008. - 48 p. [in Russian]

9. Kuznetsov Vl.V. Rol sistem antioksidantnoy zashchity pri adaptatsii dikorastushchikh vidov rasteniy k solevomu stress [The role of antioxidant defense systems in the adaptation of wild plant species to salt stress] / Vl.V. Kuznetsov // Fiziologiya rasteniy. - 2008. - Vol. 55. - P. 516–522. [in Russian]

10. Gilyazetdinov Sh.Ya. Vliyaniye Gumi-M na gormonalnyy status rasteniy pshenitsy pri zasolenii [Effect of Gumi-M on the hormonal status of wheat plants during salinization] / Sh.Ya. Gilyazetdinov. F.M. Shakirova // Agrokhimiya. - 2006. - № 8. - P. 25-29. [in Russian]

11. Lu J. Sorption of atrazine onto humic acids (HAs) coated nanoparticles / J. Lu, Y. Li, X.Yan, B.Shi, D.Wang, H.Tang // Colloids and Surfaces. – 2009. - Vol. 347, No. 1. - P. 90-96.

12. Wu X. Bioaccumulation of cadmium bound to humic acid by the bivalve Meretrix meretirx Linnaeus from solute and particulate pathways / X. Wu, Y. Jia, H. Zhu, H. Wang // J. of Enviromental Sciences-china. - 2010. - Vol. 22, No.2. - P. 198-203.

13. Halim M. Potential availability of heavy metals to phytoextraction from contaminated soils induced by exogenous humic substances / M. Halim, P. Conte, A. Piccolo // Chemosphere/ - 2003. - Vol. 52, No. 1. - P. 265-275.

14. Evangelou M. W. H. The influence of humic acids on the phytoextraction of cadmium from soil / M. W. H. Evangelou, H. Daghan, A. Schaeffer //Chemosphere. -2004. Vol. 57, No 3. - P. 207-213.

15. Churakov A.A. Zapasy torfa v Rossii [Peat reserves in Russia] / A.A. Churakov // Lesnoy vestnik. – 2003. - № 3. – P. 22-25. [in Russian]

16. Perminova I.V. Analiz. klassifikatsiya i prognoz svoystv gumusovykh kislot [Analysis, classification and prediction of the properties of humic acids] / I.V. Perminova. Dis. … d-ra khim. nauk. M.: MGU. 2000. - 359 p. [in Russian]

17. Sposob polucheniya zhidkikh torfyanykh gumatov [The method of obtaining liquid peat humates]: pat. 2310633 Russian Federation: MPK S05F11/02. S10F7/00/ Kalinnikov Yu.A.. Vashurina I.Yu.. Kirdey T.A.; the applicant and the patentee Ltd Nauchno-proizvodstvennaya firma «Nedra». № 2006120883/04; appl.. 15.06.2006; publ. 20.11.2007. Bul. № 32. - 4 p. [in Russian]

18. Khristeva L.A. Stimuliruyushcheye vliyaniye guminovoy kisloty na rost vysshikh rasteniy i priroda etogo vliyaniya [The stimulating effect of humic acid on the growth of higher plants and the nature of this effect] / L.A. Khristeva // Guminovyye udobreniya. Teoriya i praktika ikh primeneniya. – Kharkov. - 1957. - P.75-93. [in Russian]

19. Hoaglond D.R. The water culture method for growing plants without soil / D.R. Hoaglond, D.E. Arnon // Calif. Agric. Expt. Stn. - 1950. - Vol. 347. - P. 1-39.

20. Udovenko G.V. Soleustoychivost kulturnykh rasteniy [Salt tolerance of cultivated plants] / G.V. Udovenko. – L.: Kolos. 1977. – 215 p. [in Russian]

21. Kirdey T.A. Zashchitnoye deystviye gumata na prorostki pshenitsy v prisutstvii tyazhelykh metallov [The protective effect of humate on wheat seedlings in the presence of heavy metals] / T.A. Kirdey // Problemy regionalnoy ekologii. - M. - 2014. - № 2. - P. 199-201. [in Russian]

22. Greenway H. Mechanisms of salt tolerance in nonhalophytes / H. Greenway, R. Munns // Ann.Review of Plant Physiol. - 1980. - Vol. 31. - P.149-190.

23. Zakharin A.A. Fenomen solerezistentnosti glikofitov [The phenomenon of salt resistance of glycophytes] / A.A. Zakharin.. L.A. Panichkin // Fiziologiya rasteniy. - 2009. - Vol.56. - № 1. - P. 107-116. [in Russian]