How to Cite: Mussabayeva, B.Kh., Kassymova, Zh.S., Orazzhanova, L.K., Klivenko, A.N., Sabitova, A.N., & Bayakhmetova, B.B. (2022) Interpolyelectrolyte Complex Chitosan – Alginate for Soil Structuring. *Bulletin of the University of Karaganda – Chemistry, 107(3), 102-114.* https://doi.org/10.31489/2022Ch3/3-22-11

Article Received: 27 May 2022 ǀ Revised: 17 June 2022 ǀ Accepted: 27 June 2022 ǀ Published online: 21 July 2022

UDC 541.6:547.39:636.597 https://doi.org/10.31489/2022Ch3/3-22-11

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Interpolyelectrolyte Complex Chitosan – Alginate for Soil Structuring

The interpolyelectrolyte complex of the composition [chitosan]:[alginate] = [1]:[4] was prepared by mixing a hydrochloric acid solution of cationic polyelectrolyte chitosan and an aqueous solution of anionic polyelectrolyte sodium alginate. The complex of chitosan and sodium alginate biopolymers was first used as a soil structurizer. Due to low humus and light mechanical composition, the dark chestnut soil of the dry-steppe zone of the East Kazakhstan region is subjected to erosion. Introducing a polymer complex into the specified soil contributed to the improvement of wind resistance, an increase in humidity, and a decrease in water permeability. The soil surface treated with a complex of biopolymers showed pronounced resistance to the action of planar and trickle water erosion due to aggregation of particles with a diameter of < 0.01 mm. The fraction of soil particles obtained by mechanical destruction of structured aggregates with a diameter of 3-1 mm has a well-expressed ability to self-aggregate during the humidification - drying process. The results of the vegetation and field experience in tillage with an interpolyelectrolyte complex showed a positive effect of the complex on the growth and development of radish of the Rubin variety and, as a result, an increase in radish yield by 2 times was achieved. The obtained results indicate the effectiveness of the structuring action of the chitosan-alginate complex for poorly structured soils.

Keywords: biopolymers, polysaccharides, interpolymer complex, vegetation experience, dark chestnut soil, radish.

Introduction

The physical and mechanical properties of soil, in particular its structure, are important conditions for the demonstration of soil fertility. The most complete provision of plants with moisture, air, and mineral nutrition occurs precisely on structural soils [1]. Such a valuable agroecological property of the soil as the degree of resistance to water and wind erosion is closely related to the structural state of the soil.

One of the modern and promising ways to improve the structural and aggregate state of the soil is the treatment of the surface soil layer with interpolyelectrolyte complexes (IPECs), which promote the gluing and aggregation of dusty particles into macro aggregates [2–4], thereby preventing wind and water transfer of poorly structured soils. The introduction of IPEC into the soil improves the water and air regimes of the soil, increasing its fertility and contributing to the improvement of plant growth and development [5].

Kabanov et al. [6] selected qualitative and quantitative compositions of polymer mixtures of variously charged synthetic and natural polymers suitable for the production of polymer binders. Moreover, special attention of the authors is paid to the search for ways of applying various polymer coatings to the surface layer of the soil.

There are two methods of introducing IPEC into the soil. In the sprinkling method [3], an IPEC solution is prepared by mixing aqueous solutions of anionic and cationic polyelectrolytes in the presence of a water-soluble alkali metal salt, ammonium, calcium, or magnesium. The resulting water-salt solution of IPEC is simultaneously applied to the soil surface, followed by washing out the salt with water. In the two-solution method, aqueous solutions of polyelectrolytes are prepared separately, while observing the total equimolar charge-charge ratio [4]. The soil is infused with a solution of the first polyelectrolyte until full saturation and then treated with the second. The insoluble complex is formed directly in the surface layer of the soil after applying a solution of the second polyelectrolyte.

To protect soils from erosion, separate synthetic polymers were used, for example, modified polyacrylamide [7], which attaches well to negatively charged soil particles. However, cationic polyelectrolytes

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are easily washed off the soil surface by rain or irrigation water [3]. Nonetheless, the IPECs of synthetic polymers proved to be effective structure-forming agents of longer-acting soils [3, 5, 6].

IPECs of synthetic polymers with natural ones, such as a complex of sodium carboxymethylcellulose (Na-CMC) with urea–formaldehyde oligomers (UFOs) [8], poly(dimethyldiallylammonium chloride) with potassium humates [9], were also used to consolidate soils. We studied the structuring of the soil of IPEC chitosan with polyacrylic acid and obtained positive results [10].

However, the low biodegradability of synthetic polymers and their complexes makes them unsuitable for soil structuring. In this connection, to date, complexes of natural polymers and their derivatives are the most promising and environmentally safe for agroecological purposes among IPEC-soil structurizers [11, 12]. They are an affordable alternative to synthetic polymers and can be successfully used for soil structuring. In addition to high aggregating capacity, simple methods of operation, long-term action, biopolymer structure-forming agents have biocompatibility and biodegradability as a result of natural microbiological and biochemical processes, while the soil is not polluted by further polymer decomposition products. The widespread use of biopolymers is also facilitated by certain technological advantages, namely, the presence of a widespread and annually renewable raw material base, cheapness and the availability of production [12].

Polysaccharides and their derivatives — chitosan [4, 13], sodium carboxymethylcellulose [8, 11], gellan [14], alginates [15], etc. — are used in various practical applications from natural complexing polymers that are widely distributed and reproduced in nature.

The natural polymer chitosan (Ch) has proved to be an effective material for reducing water erosion [4, 16] and wind erosion of soils [17]. The introduction of chitosan into clay soil led to an increase in interparticle cohesion, and consequently, an improvement in the mechanical properties of the soil. However, its effect turned out to be short-term in conditions of moist soils [13].

The possibility of using sodium alginate (SA) for the restoration of abandoned lands has been studied [18]. It is shown that alginate easily forms a film on the surface of sandy soil, increases the compressive strength of sand. In addition, the studied polymer has a positive effect on the growth of cyanobacteria, thereby contributing to the restoration of abandoned lands.

Chitosan-alginate complexes are mainly used in medicine as drug delivery systems [19, 20] and for the preparation of wound dressings [21, 22]. In addition, chitosan-alginate complexes can be used in ecology as effective sorbents for water purification from pollutants [23].

Chitosan-alginate IPECs with unique biological properties of both biopolymers are of interest as promising environmentally safe binders of soil dispersions. In addition, experimental data on the restoration of optimal water-resistant and wind-resistant soil structures using the IPEC of these biopolymers are practically absent.

Earlier, we discovered complexation in the chitosan – sodium alginate system of molar composition [Ch]:[SA] = [1]:[4] using a set of physicochemical methods. It was revealed that alginate-chitosan polyionic complexes are formed due to ion-ion interaction between the carboxyl groups of alginate and amino groups of chitosan [24, 25].

In [26], we prepared an IPEC of the composition [Ch]:[SA] = [2]:[3]. To prepare it, chitosan was dissolved in citric acid. Laboratory experiments have shown that this IPEC increases soil resistance to water erosion and has a positive effect on the growth and development of cucumber [26].

This paper presents the results of studying the influence of IPEC Ch-SA on the water-physical and agrochemical properties of the dark chestnut soil of the dry-steppe zone of the East Kazakhstan region, as well as on the growth, development and yield of radishes in the conditions of a vegetation field experiment.

Experimental

The object of the study is the dark chestnut soil of the dry steppe zone of the East Kazakhstan region. The climate of the region is continental and arid. The average annual temperature is 2.5–3 °C, the duration of the warm period is 200 days, and 250–300 mm of precipitation falls per year. The soil sample was taken on a virgin plot located 18.3 km west of Semey (N 50°29’, E 79°56’). The color of the soil is brownish-brownish. The power of the upper horizon is 20–22 cm. Soils are characterized by low humus, mainly light mechanical composition. However, on these soils, when carrying out measures for the accumulation and preservation of moisture, and when applying mineral and organic fertilizers, it is possible to successfully grow a wide range of agricultural crops: cereals (wheat, corn, barley), technical, vegetable, fruit.

Sigma Aldrich chitosan (USA), M = 500 kDa, 85 % deacetylation degree, was used without additional purification.

Sigma Aldrich (USA) sodium alginate, M = 250,000 kDa, was used without additional purification.

The selection of five-point soil samples with a total mass of at least 1 kg was carried out on a 100 m^2 site from the upper layer (0–20 cm) diagonally so that the combined sample was a typical sample for the arable horizon of this genetic soil type. The average sample of air-dry soil was taken by double quartering, the resulting sample was sifted through an appropriate sieve and placed in a jar with a ground stopper.

Radish of the Rubin variety (Ukraine, the Poisk company) is a widely cultivated precocious variety with a growing season of 26–28 days.

The agrochemical properties of the soil before and after the introduction of IPEC were determined according to the generally accepted methods [27].

Preparation of polymer solutions with a concentration of 10^{-3} mol/l

To prepare 1 liter of a solution 0.161 g of dry chitosan was transferred to a 1-liter volumetric flask, filled with a small amount of hydrochloric acid (10^{-1} mol/l) and stirred on a magnetic stirrer until the polymer was completely dissolved. After that, the volume of liquid in the flask was brought to the mark with a solution of hydrochloric acid (10^{-1} mol/l).

To prepare 1 liter of a solution 0.198 g of dry sodium alginate was transferred to a 1-liter volumetric flask, filled with a small amount of distilled water and after complete dissolution of the polymer, the volume of liquid in the flask was brought to the mark with distilled water. Then the solutions were kept at room temperature for 24 hours, after which solutions were used to structure the soil.

The treatment of the surface layer of the soil with biopolymers and IPEC based on them was carried out in a two-solution method by sequentially applying equimolar polymer solutions using a spray gun [6]. The synthesis of IPEC took place directly in the soil at the time of application of a sodium alginate solution to a surface previously saturated with a chitosan solution. At the same time, the volumes of equimolar polymer solutions used contain chitosan and sodium alginate in molar ratios [Ch]:[SA] = [1]:[4] [24, 25].

Investigation of mechanical strength of soil structurates

To obtain the structure, a 0.5 m soil fraction was poured into a Petri dish with a 1.5 cm layer and treated with a two-solution method. The resulting structurates were dried at room temperature for 3 days, then mechanical strength tests were carried out using the TAXT texture analyzer (Stable Micro Systems, UK) in compression mode at a speed of 0.01 mm/sec using the P5/S nozzle.

Determination of resistance to water flushing of soil structurates formed as a result of tillage of IPEC Ch-SA was carried out according to the methodology described in the papers of Panova [9].

The Petri dish was filled with a 50 g soil sample passed through a sieve with holes d = 0.25 mm, the thickness of the soil layer was 0.5 cm. Soil treatment with polymers and IPEC was carried out in the following variants:

1. Control (soil not treated with biopolymers and IPEC);
2. Soil treated with IPEC [Ch]:[SA] = [1]:[4];
3. Soil treated with hydrochloric acid solution Ch (10^{-3} mol/l);
4. Soil treated with an aqueous solution of SA (10^{-3} mol/l).

The treated soil in Petri dishes was dried for 5 days, then cups with soil were installed at an angle of 15° and subjected to flushing by spraying with 100 ml water while collecting the flowing water from the cups. The remaining soil in the cups was dried at room temperature for 5 days, after which it was weighed.

Calculation of soil resistance to flushing was carried out according to the formula (1):

$$R, \% = \frac{m}{M} \cdot 100\,, \qquad (1)$$

where R — the resistance of the soil to flushing, %; m – the mass of the remaining soil after the test, g; M — the mass of the soil sample, g.

The model experiment on trickle water erosion was carried out in the same sequence, while the flushing of soil structures with water was carried out by a drip method on a special installation (Fig. 1).

The ability of soil structurates to self-aggregation was studied after soil treatment with polymers and IPEC [27]. The soil sample was passed through a sieve with a hole diameter of 0.25 mm. 20 g of the obtained fraction of "free particles" (FP) were poured into 4 Petri dishes and 20 ml of water, sodium alginate, chitosan and IPEC were treated, respectively. The treated soil was dried at room temperature for 2 days.

Soil aggregates 3–1 mm were crushed in a mortar and passed through a 0.25 mm sieve. Thus, the so-called fraction of aggregates particles (AP) was obtained. Then the AP fraction was also processed, as well as the FP fraction.

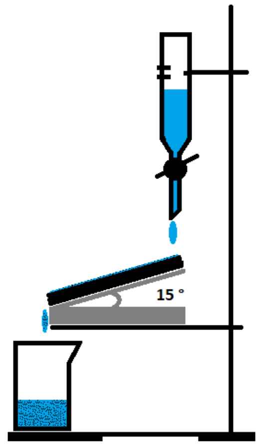


Figure 1. A model laboratory installation for studying trickle water erosion

To separate self-aggregating particles and loosely bonded soil particles, the attachments from Petri dishes were transferred to centrifuge tubes, then shaken on a LOIP LS-110 rotator (Russia) for 90 minutes at 25 rpm, after which the soil was transferred to a 0.25 mm sieve, the remaining soil on the sieve was sifted and weighed.

The resulting self-assembled aggregates were transferred to a pre-moistened 0.25 mm sieve and waited for the water held between the sieve cells to moisten the suspension of the aggregates, then the sieve with the aggregates was immersed in water for 10 minutes. Next, the aggregates were sifted in water, moving the sieve up and down and left and right 10 times. Water-tight aggregates capable of self-assembly after mechanical destruction remained on the sieve. The obtained water-tight aggregates, as well as the suspension with particles <0.25 mm passed through the sieve, were dried at a temperature of 105°C and weighed.

The number of self-assembling units was calculated according to the formula (2):

$$\eta_c = \frac{m_c}{M} \cdot 100\,\%, \tag{2}$$

where η_c — the number of aggregates capable of self-assembly, %; m_c — the mass of self-assembled soil aggregates, g; M — the mass of the soil sample, g.

The number of water–bearing aggregates capable of self-assembly was calculated by the formula (3):

$$\eta_{в} = \frac{m}{m_c} \cdot 100\,\%, \tag{3}$$

where $\eta_{в}$ — the number of water-bearing aggregates capable of self-assembly, %; m — the mass of water-bearing self-assembled soil aggregates, g.

Investigation of the effect of IPEC on radish yield in vegetation and field conditions. Experiments with radish were carried out in the open ground on microplots measuring 20×20 cm^2 in 3-fold replication. A plot with a homogeneous plain relief is selected. Before laying the experimental plots, the site was dug up, weeds were removed. The marking of the experimental plots was carried out by the randomized square method according to the following scheme (Figure 2):

CONTROL	IPEC	CONTROL
IPEC	CONTROL	IPEC

Figure 2. Layout diagram of experimental plots in the vegetation experiment

The dividing boundaries between the individual plots were 10 cm.

The culture was sown in dry, windless weather. All variants of the experiment were laid down in one day along with planting seeds and making IPEC.

The duration of the experiment from sowing seeds to harvesting was 1 month. Care (watering, weeding from weeds) and recording of biometric and phenological observations were carried out daily for all variants of the experiment while considering the following indicators:

• the appearance of the first shoots of plants according to the experience options;

• the appearance of mass shoots of plants according to the variants of the experiment;

• dynamics of growth and onset of the main phenological phases according to the variants of the experiment;

• evaluation of the yield according to the variants of the experiment (30 days after sowing).

Before weighing, the plants were washed from the soil and dried with filter paper. The determination of the raw biomass of root crops and tops was carried out within 1–2 hours after digging to avoid weight loss during drying.

Statistical processing of the data. Statistical processing of the results was performed automatically using Origin Pro™ Data Analysis and Graphing Software. For mean value and standard deviation determination, the following parameters were used: confidence probability — 0.95; interpolation of quantiles – empirical distribution with averaging.

Results and Discussion

IPEC Ch – SA was successfully used for structuring dark chestnut soil of the dry steppe zone of the East Kazakhstan region.

The main agrochemical parameters of the soil before and after the introduction of IPEC were studied: mechanical composition, moisture capacity, humidity, acidity, water permeability, organic matter content, exchangeable ammonium, and mobile phosphorus.

Table 1 presents the analysis results of the mechanical composition of the dark chestnut soil of the dry steppe zone of the East Kazakhstan region before and after the introduction of IPEC.

Table 1

Content (%) of fractions of soil particles (mm) in untreated soil (control) and after application of IPEC

Variant	Physical Sand			Physical Clay		
	Coarse and medium sand, 0.25–1.0	Fine sand, 0.05–0.25	Coarse dust, 0.01–0.05	Medium dust, 0.005–0.01	Fine dust, 0.001–0.005	Mud, < 0.001
Control	27.95	41.75	19.65	5.04	3.95	1.66
	89.35 %			10.65 %		
IPEC	31.10	45.04	17.85	2.08	2.51	1.42
	93.99 %			6.01 %		

Depending on the content and ratio of various fractions of soil particles, in particular, on the ratio of physical sand (particle diameter >0.01 mm) and physical clay (particle diameter <0.01 mm), according to the agronomic classification of N.A. Kachinsky, a variety of soil is determined by mechanical composition. The studied soil by its mechanical composition belongs to sandy loam soils (in soils of the steppe type of soil formation) since the content of physical clay (10.65 %) is in the range from 10 to 20 %. Such soil is characterized by a low content of moisture and nutrients, is easily exposed to water and wind erosion [11].

The introduction of IPEC on the soil surface contributed to the aggregation of physical clay (<0.01 mm 6.01 %). The aggregating effect of IPEC when applied to the soil is associated with the formation of a soil-polymer crust due to the interaction of structural fragments (hydrophilic, hydrophobic, positively and negatively charged) of IPEC with particles of the dispersed phase of the soil [14].

Table 2 demonstrates the main agrochemical indicators of dark chestnut soil before and after the introduction of IPEC.

Table 2

Agrochemical indicators of untreated and treated IPEC soil

Variant	Soil moisture, %	Moisture capacity, %	pH_{H_2O}	pH_{KCl}	Content, мg/kg of soil		Organic matter, %	K_{f10}, mm·mn^{-1}
					NH_4^+	exchange P_2O_5		
Control	1.44	40.45	7.16	7.45	28.0	89.2	1.63	1.5
IPEC	1.62	52.60	7.24	7.21	33.9	91.7	1.65	0.4

According to the results of the study of agrochemical indicators of untreated soil, the following agrochemical characteristics were obtained: sandy loam mechanical composition, good water permeability, low organic matter content, slightly alkaline reaction of soil solution, low content of mobile nitrogen and exchangeable phosphorus. The obtained results also indicate a weak structural condition of the soil and a strong susceptibility to deflation and water erosion [11].

When applying chitosan – sodium alginate to the soil surface of IPEC, there is an increase in the content of mobile ammonium nitrogen by ~ 6 % and exchangeable phosphorus by 2.7 %, a relatively small increase in humidity (~ 0.2 %) and moisture capacity (1.3 %), as well as a pronounced decrease in water permeability (by 73%) of the soil after treatment with IPEC. The value of the filtration coefficient is reduced by almost 4 times (Table 2).

The increase in nitrogen and phosphorus content may be due to the presence of amino groups in the chitosan macromolecule, as well as saturation and retention of macronutrients in the surface layer of the soil as a result of gluing soil particles with a polymer complex.

The improvement of the water properties of the treated soil may be a consequence of the enlargement of soil pores and filling them with IPEC, hydrophilic fragments which have the ability to absorb and retain moisture.

Thus, when using IPEC as a structuring agent, the top layer of soil is saturated with water and the moisture necessary for vegetation is preserved, which contributes to the rationalization of the water regime of plants during their growing season.

Mechanical properties of soil-polymer structurators

An important characteristic of the aggregating properties of soil structurators is the mechanical strength of the formed soil structurates. For this purpose, the mechanical properties of soil samples treated with water, chitosan solutions, sodium alginate and IPEC [Ch]:[SA] = [1]:[4] were studied (Figure 3).

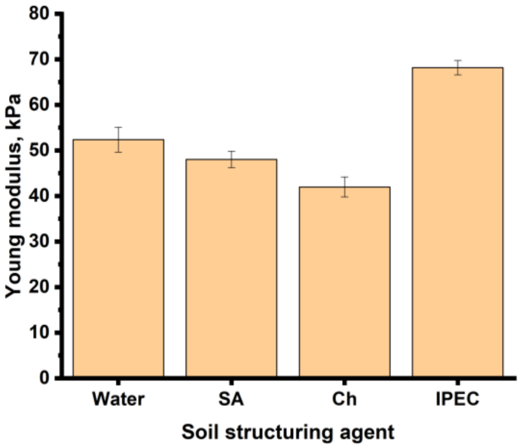


Figure 3. Mechanical properties of soil structurates

As can be seen from Figure 3, structures based on IPEC (68.74 kPa) exhibit the greatest mechanical strength, in comparison with structures treated with individual polymers, as well as water. It is important to note that for a short period of time, water is a good structuring agent [28].

Anti-erosion resistance of soil-polymer structurates

The resistance to planar and trickle erosion of soil structurates formed as a result of tillage with individual polymers and an interpolymer complex of chitosan – sodium alginate has been investigated. Figures 4 and 5 illustrate the results of the resistance of the soil treated with polymers and IPEC to water flushing.

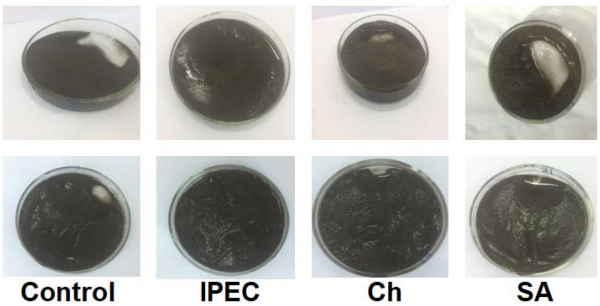


Figure 4. Resistance of soil aggregates to planar (upper row) and trickle erosion (lower row)

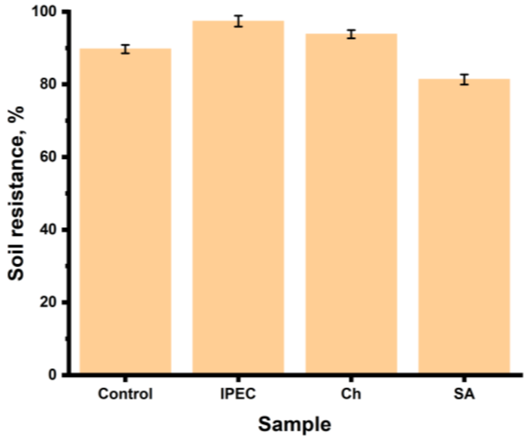


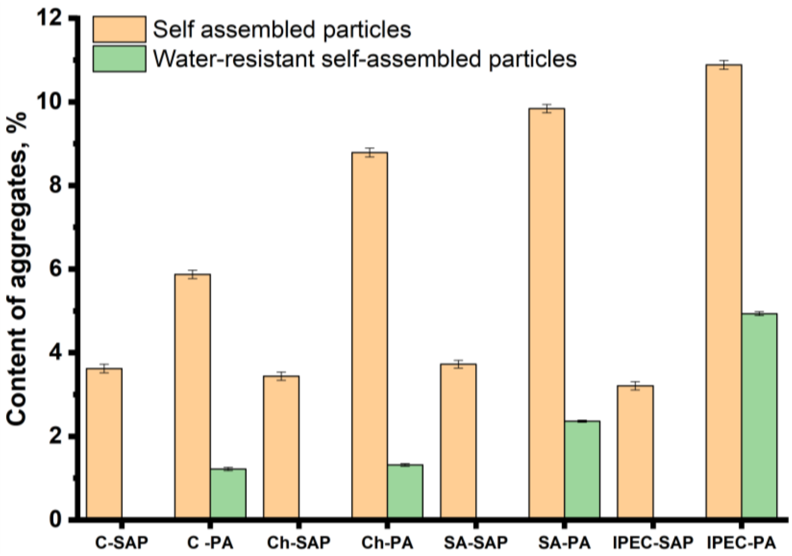
Figure 5. Diagram of soil resistance to trickle erosion

The maximum flushing of soil particles is observed in the variant with control and soil treated with SA. In the sample of soil treated with Ch, the soil washability is lower in comparison with the control and the soil treated with SA. The behavior of Ch in soil is related to its cationic characteristics, which provide electrical interaction between the biopolymer and the diffuse double layer of soil minerals (charged surface and distributed charge in the adjacent phase), which determines the interparticle behavior of the treated soil. It is assumed that upon contact of a negatively charged soil particle with a positively charged chitosan, the distribution of polymer cations concentrates on the surface of the soil particles, which leads to a balance in the overall electrical neutrality of the system. However, the distance from the charged particle leads to a gradual decrease in the concentration of counterions to the same conditions as in the Ch volume. This mechanism leads to an increase in mechanical properties due to the ionic bond between the biopolymer and soil particles.

The greatest soil washout with water in the case of using SA solution is caused by the same charge of SA macromolecules and the surface charge of soil particles [13].

Thus, the introduction of the Ch-SA complex on the soil surface helps to strengthen the upper layer of the soil by aggregating it and increases its resistance to water flushing.

The results of self-assembly of soil aggregates of natural composition <0.25 mm and from predestroyed structural lumps of 3-1 mm treated with polymers and IPEC, after moistening – drying, as well as the values of water-resistant self-assembled aggregates from the above-mentioned fractions are shown in Figure 6.



FP from structureless particles <0.25 mm in natural soil composition;
FA obtained by mechanical destruction of soil fractions 3-1 mm

Figure 6. The ability to self-aggregate FP and AP and the water resistance of self-assembled aggregates

As can be seen from Figure 6, structureless FP, regardless of the polymer composition introduced for structuring, in almost all cases have a minimal aggregation ability and no water-resistant particles were found among them. On the contrary, according to experimental data, AP have a well-expressed ability to self-assemble after the humidification-drying process. When using IPEC, the water resistance index of self-assembled aggregates is the highest, which indicates the structuring of the IPEC soil. After IPEC treatment, self-organized AP of arable dark chestnut soil contain almost 4 times more water-resistant particles compared to AP structured with water.

Thus, when using biopolymers and IPEC, artificially destructured soil aggregates have a greater ability to self-aggregate than natural soil microaggregates. In this regard, polymer structure-forming agents can be recommended for effective use on soils with a destroyed structure.

Influence of the interpolyelectrolyte complex on radish development

From a practical point of view, the impact of IPEC Ch-SA introduced into the soil on the growth and development of plants that grow on it is important. In this work, radish (Raphanus sativus) of the "Ruby" variety was used as a model plant. Figures 7, 8 and Table 3 show data on the growth and development of radishes on dark chestnut soil treated with water and IPEC [Ch]:[SA] = [1]:[4] in a vegetative field experiment.

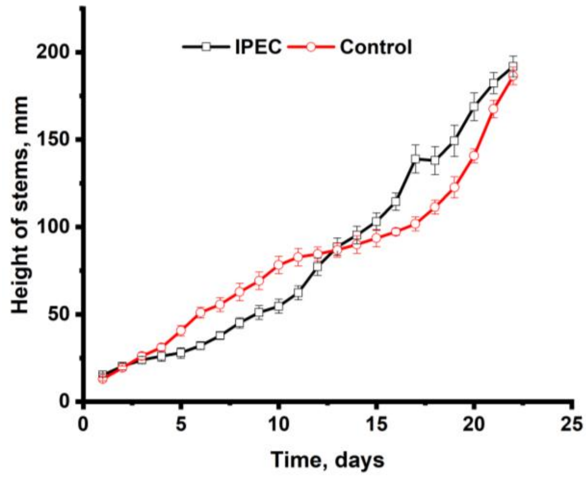


Figure 7. Dynamics of growth and development of radish of the "Rubin" variety

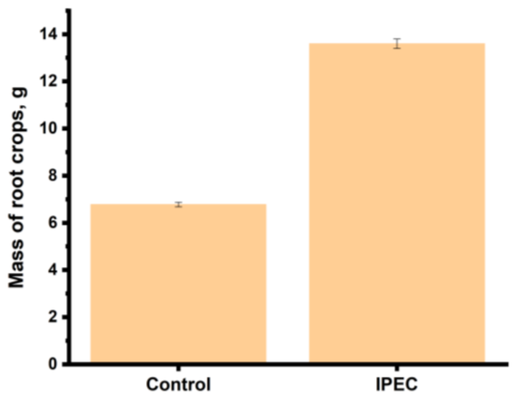


Figure 8. The average weight of the radish variety "Rubin" on the plots, g

Table 3

The influence of IPEC on the development of the radish variety "Rubin"

Parameter	Variant	
	Control	IPEC
Height, cm/vessel	18.50	19.10
Weight of the tops, g	35.13	51.8
Weight of root crops, g	6.43	20.78
Specific weight, g/unit	1.07	3.47
The period before the emergence of seedlings, a day	6	5
Germination, %	60	80

The results of daily monitoring of biometric indicators of radish development showed that the introduction of IPEC into the soil contributed to the best plant growth since radish seedlings were obtained earlier, and the height and weight of plants were more pronounced than in the control variant.

The yield of radish turned out to be 2 times higher than the control in the case of introduction of IPEC into the soil.

The positive effect on the growth and development of radish of the Rubin variety during tillage of IPEC may be due to its effect on the retention of moisture reserves in the soil by reducing evaporation and improving water absorption.

The results indicate that the use of environmentally friendly biodegradable IPEC Ch-SA had contributed to the growth of the plant, so seedlings were obtained 1 day earlier, and the height and weight of plants were greater than in the control variant, a 3-fold increase in fruit weight, a 2-fold increase in yield were achieved. Examples of the use of biodegradable polymer as floating row covers in field production of radish based on aliphatic-aromatic polyesters [29] and IPEC based on chitosan and sodium carboxymethylcellulose [30] are known. These systems lead to an increase in fruit weight by 2.9 and 1.45 times, respectively. Thus, the developed technology has significant advantages among known analogues.

Conclusions

To conclude, the analysis of the results of laboratory and vegetation-field studies confirms the possibility of using IPEC chitosan – sodium alginate for aggregation of poorly structured soils to create an erosion-resistant, agronomically valuable soil structure and ensure optimal water and air regimes for the cultivation of agricultural crops. The results of the application of soil treatment technology with biopolymers and IPEC show the need for further research on other agricultural soils and crops.

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Хитозан – альгинат интерполиэлектролитті комплексі топырақты құрылымдау үшін

Құрамы [хитозан]:[альгинат] = [1]:[4] интерполиэлектролитті комплексі катиондық полиэлектролит хитозанның тұз қышқылды ерітіндісін және аниондық полиэлектролиті натрий альгинатының сулы ерітіндісін араластыру арқылы алынды. Хитозан және натрий алгинаты биополимерлерінің комплексі алғаш рет топырақ түзуші ретінде пайдаланылды. Шығыс Қазақстан облысының құрғақ далалы аймағының күңгірт-күрең топырағында қарашіріктің төмен болуынан және жеңіл механикалық құрамның салдарынан эрозияға ұшыраған. Аталған топыраққа полимерлі комплекстің енгізілуі желге төзімділікті жақсартуға, ылғалдылықты арттыруға және су өткізгіштігін төмендетуге ықпал етті. Биополимерлер комплексімен өңделген топырақ беті диаметрі < 0,01 мм бөлшектердің агрегациялануына байланысты жазықтық және ағынды су эрозиясының әсеріне айқын қарсылық көрсетті. Диаметрі 3–1 мм құрылымдалған агрегаттардың механикалық бұзылуымен алынған топырақ бөлшектерінің фракциясы ылғалдандыру–кептіру процесінде өзін–өзі реттеуге жақсы қабілетті. Топырақты интерполиэлектролитті комплекспен өңдеудегі вегетациялық-далалық тәжірибенің нәтижелері комплекстің Рубин сортты шалғамның өсуіне және дамуына оң әсерін көрсеткен, нәтижесінде шалғамның өнімділігі 2 есе артты. Алынған нәтижелер нашар құрылымдалған топырақтарға арналған хитозан-альгинат комплексінің құрылымдық әсерінің тиімділігін көрсетеді.

Кілт сөздер: биополимер, полисахаридтер, интерполимерлі комплекс, вегетациялық тәжірибе, күңгірт-күрең топырақ, шалғам.

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Интерполиэлектролитный комплекс хитозан–альгинат для структурирования почвы

Интерполиэлектролитный комплекс состава [хитозан]:[альгинат] = [1]:[4] получили методом смешения солянокислого раствора катионного полиэлектролита хитозана и водного раствора анионного полиэлектролита альгината натрия. Комплекс биополимеров хитозана и альгината натрия впервые использован в качестве структурообразователя почвы. Вследствие малогумусности и легкого механического состава темно-каштановая почва сухостепной зоны Восточно-Казахстанской области подвержена эрозии. Внесение в указанную почву полимерного комплекса способствовало улучшению ветроустойчивости, увеличению влажности и снижению водопроницаемости. Поверхность почвы, обработанная комплексом биополимеров, проявляла выраженную устойчивость к действию плоскостной и струйчатой водной эрозии за счет агрегирования частиц диаметром < 0,01 мм. Фракция почвенных частиц, полученная механическим разрушением структурированных агрегатов диаметром 3–1 мм, обладает хорошо выраженной способностью самоагрегироваться в процессе увлажнения–высушивания. Результаты вегетационно-полевого опыта по обработке почвы интерполиэлектролитным комплексом показали положительное влияние комплекса на рост и развитие редиса сорта «Рубин» и, как следствие, достигнуто повышение урожайности редиса в 2 раза. Полученные результаты свидетельствуют об эффективности структурирующего действия хитозан-альгинатного комплекса для слабоструктурированных почв.

Ключевые слова: биополимер, полисахариды, интерполимерный комплекс, вегетационный опыт, темно-каштановая почва, редис.

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