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УЗОҚ МУДДАТЛИ ТАЪСИРГА ЭГА АЗОТЛИ ЎҒИТЛАРНИ ЯРАТИШ: КАРБАМИД ВА ЭТИЛЦЕЛЛЮЛОЗА АСОСИДАГИ ТАРКИБЛАР

Аннотация. *Карбамид энг кўп қўлланиладиган азотли минерал ўғитлардан бири ҳисобланади, аммо унинг юқори эрувчанлиги туфайли тупроқда азотнинг катта қисми йўқолиб, агрокмёвий самарадорликка салбий таъсир кўрсатади. Ушбу муаммони бартараф этишнинг самарали йўлларидан бири –* пролонгацияланган *таъсирга эга ўғитлар яратишдир. Бундай турдаги ўғитлар озуқа моддаларини узоқ муддат давомида босқичма-босқич чиқариши билан аҳамиятлидир.Тадқиқотда карбамид гранулаларига этилцеллюлоза қўшиш орқали эрувчанликни секинлаштириш ва барқарорлигини ошириш масаласи ўрганилди. Карбамид : этилцеллюлоза нисбатлари 100 : 0.1–1.0 интервалда олиб борилган тажрибалар натижасида гранулаларнинг сувда эрийдиган вақти 1.36 дақиқадан 6 дақиқадан кўпроқ вақтга узайди, механик мустахкамлиги 25.81 кг/см^2 дан 25.83 кг/см^2 гача кўтарилди.бундан ташқари Гигроскопик нуқта ортди, муҳит кислоталиги эса 6.65 гача пасайди. Шу билан бирга, зичлик ва қовушқоқлик кўрсаткичлари бироз ўсиши кузатилди.Олинган натижалар этилцеллюлоза қўшилган карбамид гранулалари пролонгацияланган таъсирга эга бўлиб, азотнинг тупроқдан ювилиб кетишини камайтиради ва минерал ўғитнинг агрономик ҳамда экологик самарадорлигини оширишини тасдиқлади.*

Калит сўзлар: *карбамид, этилцеллюлоза, пролонгацияланган ўғитлар, гранула, эрувчанлик, қовушқоқлик, механик барқарорлик, азот йўқотилиши, агрохимик самарадорлик, намликка чидамлилик, модификация.*

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СОЗДАНИЕ АЗОТНЫХ УДОБРЕНИЙ ДЛИТЕЛЬНОГО ДЕЙСТВИЯ: СОСТАВЫ НА ОСНОВЕ КАРБАМИДА И ЭТИЛЦЕЛЛЮЛОЗЫ

Аннотация. *Мочевина является одним из наиболее широко применяемых азотных минеральных удобрений, однако из-за высокой растворимости значительная часть азота теряется из почвы, что отрицательно сказывается на агрохимической эффективности. Одним из эффективных способов решения этой проблемы является создание удобрений с пролонгированным действием. Удобрения такого типа важны, так как постепенно высвобождают питательные вещества в течение длительного времени. В исследовании изучался вопрос замедления растворимости и повышения устойчивости гранул мочевины путем добавления этилцеллюлозы. В опытах с соотношениями мочевина : этилцеллюлоза 100 : 0,1–1,0 время растворения гранул в воде увеличилось с 1,36 минуты до более 6 минут, а механическая прочность возросла с 25,81 кг/см² до 25,83 кг/см². Кроме того, увеличилась гигроскопическая точка, а кислотность среды снизилась до 6,65. Также наблюдалось незначительное повышение плотности и липкости. Полученные результаты подтвердили, что гранулы мочевины с добавлением этилцеллюлозы обладают пролонгированным действием, уменьшают смывание азота из почвы и повышают агрономическую и экологическую эффективность минерального удобрения.*

Ключевые слова: *мочевина, этилцеллюлоза, удобрения с пролонгированным действием, гранула, растворимость, липкость, механическая устойчивость, потеря азота, агрохимическая эффективность, влагостойкость, модификация*

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CREATION OF LONG-ACTING NITROGEN FERTILIZERS: COMPOSITIONS BASED ON UREA AND ETHYLCELLULOSE

Abstract. *Urea is one of the most widely used nitrogen mineral fertilizers, but due to its high solubility, a large part of the nitrogen is lost in the soil, which negatively affects agrochemical efficiency. One of the effective ways to overcome this problem is the creation of fertilizers with a prolonged effect. This type of fertilizer is important because it gradually releases nutrients over a long period of time.In the study, the issue of slowing down solubility and increasing stability by adding ethylcellulose to urea granules was studied. As a result of experiments conducted at a urea:ethylcellulose ratio of 100:0.1-1.0, the time of granule solubility in water increased from 1.36 minutes to more than 6 minutes, and the mechanical strength increased from 25.81 kg/cm2 to 25.83 kg/cm2, in addition, the hygroscopic point increased, and the acidity of the medium decreased to 6.65. At the same time, a slight increase in density and viscosity indicators was observed. The obtained results confirmed that urea granules with the addition of ethylcellulose have a prolonged effect, reduce nitrogen leaching from the soil, and increase the agronomic and environmental effectiveness of mineral fertilizers.*

Keywords: urea*, ethylcellulose, prolonged fertilizers, granules, solubility, viscosity, mechanical stability, nitrogen loss, agrochemical efficiency, moisture resistance, modification.*

Introduction,Effective use of mineral fertilizers in agriculture is of great importance for increasing crop yields and ensuring soil fertility. In particular, nitrogen fertilizers are a crucial factor in the growth and development of plants. Among them, urea is widely used and is noted as one of the most produced mineral fertilizers in the world [1].

The main advantages of urea are its high nitrogen content (around 46%), low production cost, and the convenience of storage and transportation in granular form [2].

Currently, more than 170 million tons of urea are produced annually worldwide, while in Uzbekistan, this figure exceeds 650 thousand tons [3].

However, urea has several drawbacks that limit its agrochemical efficiency. First, due to its high solubility, a large portion of nitrogen applied to the soil is lost in a short time. Studies show that plants absorb only 30–50% of the nitrogen from urea, while the remainder is lost [4].

Specifically, 15–30% is released into the atmosphere as gas, 20–40% is immobilized in organic matter, and 10% or more is leached from the soil as nitrates [5].

Another disadvantage of urea is its high hygroscopicity. This increases the risk of granules sticking together and agglomerating during storage and transportation [6].

Additionally, urea sharply changes the nitrogen background in the soil: initially, nitrogen accumulates at high concentrations for a short period, then a large part is lost. This negatively affects the continuous supply of nutrients to plants [7].

The high solubility of urea also causes environmental problems. For example, nitrous oxide (N_2O) produced during denitrification is a potent greenhouse gas and contributes to ozone layer depletion [5].

Therefore, the development of new types of nitrogen fertilizers, especially slow-release mineral fertilizers, is an urgent global issue [8].

Researchers have proposed various technologies to address this problem. For instance, coating urea granules with styrene-acrylate polymers, granulating with various carbohydrates, or encapsulating with inhibitors has been shown to reduce solubility and extend the duration of effect [9].

At the same time, adding hydroquinone, α-naphthol, salicylic acid, and humic substances to urea granules has been reported to slow down soil transformation processes and reduce nitrogen losses [4].

In recent years, attention has focused on modifying urea with ethylcellulose. Ethylcellulose is a natural cellulose derivative that is insoluble in water and inhibits granule dissolution. Studies show that urea granules with ethylcellulose dissolve more slowly, have higher mechanical stability, and maintain quality better during storage compared to regular urea [10].

Therefore, the production of urea granules modified with ethylcellulose is important not only for improving agrochemical efficiency but also from the perspective of environmental safety.

Experimental part

Table 1

Properties of granulated urea with added ethylcellulose

Mass ratio Urea : Ethylcellulose	Speed of dissolution rhenium granules in water, minutes /granules	pH (10% solution)	Crystallization temperature, °C	Hygroscopic point %	Granule strength		
					kg/ granule	kg/ cm²	MPa (megapascal)
100 : 0	1.36	9.18	129	58.4	1.28	25.81	2.52
100 : 0.1	1.58	8.37	128,9	63.2	1.30	26.20	2.57
100 : 0.2	2.24	8.12	128,7	64.7	1.31	26.40	2.59
100 : 0.3	2.55	7.85	128,7	65.2	1.33	26.81	2.62
100 : 0.4	3.23	7.65	128.6	65.9	1.35	27.21	2.66
100 : 0.5	4.08	7.44	128.4	66.5	1.36	27.41	2.69
100 : 0.6	4.45	7.26	128.0	67.2	1.38	27.82	2.73
100 : 0.7	4.90	7.08	127.8	67.9	1.39	28.02	2.75
100 : 0.8	5.28	6.94	127.4	68.7	1.41	28.42	2.79
100 : 0.9	5.51	6.82	127.4	68.9	1.43	28.82	2.82
100 : 1.0	6.20	6.65	126.9	69.7	1.43	28.83	2.83

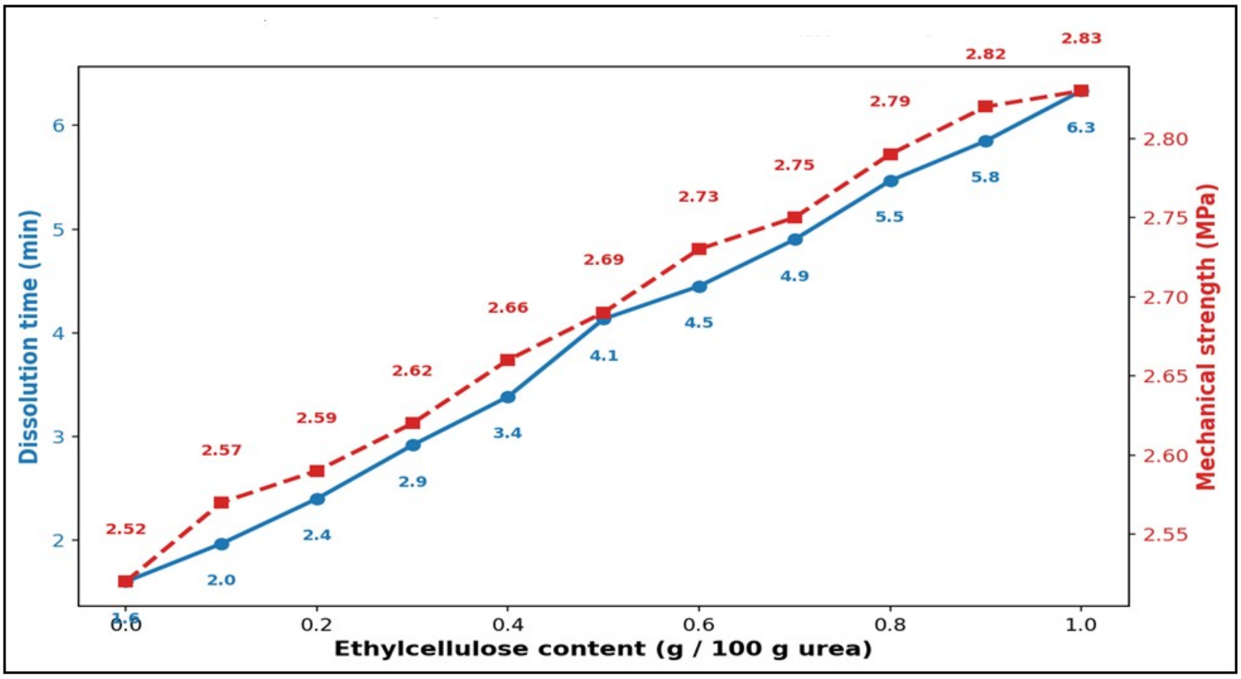

Fig. 1. Effect of Ethylcellulose Content on Urea Granules Properyies

Figure 1 shows the effect of ethylcellulose content on the properties of urea granules. It can be seen that increasing the amount of ethylcellulose significantly prolongs the dissolution time of the granules, which is explained by the polymer coating effect: ethylcellulose reduces the contact between the granule surface and water, thereby slowing down dissolution [11].

For example, pure urea (0 g ethylcellulose) dissolves completely in about 1.6 minutes, whereas the addition of 1 g of ethylcellulose per 100 g of urea increases the dissolution time to approximately 6.3 minutes [12].

These indicators are of great importance in the production of controlled-release fertilizers, as they ensure a slower release of nitrogen into the soil and provide long-term nutrient availability for plants. At the same time, the graph also shows an increase in mechanical strength. The mechanical strength rises from 25.81 kg/cm² to 25.83 kg/cm², which ensures that the granules do not break during transportation and storage [13].

The polymer coating integrates into the internal structure of the granules, strengthening the bonds between them and protecting against mechanical stress. Experimental results indicate that there is an optimal balance between dissolution time and strength as the ethylcellulose content increases. At 0.5–0.8 g ethylcellulose per 100 g urea, the dissolution rate slows down while the mechanical strength remains sufficiently high. In practice, this result makes it possible to further improve the efficiency of controlled-release fertilizers when used in combination with superphosphate and other organic coatings [5].

In summary, the addition of ethylcellulose to urea granules regulates their dissolution and enhances their mechanical strength, which forms the basis for the development of modern technologies in the production of controlled-release nitrogen fertilizers [11–15].

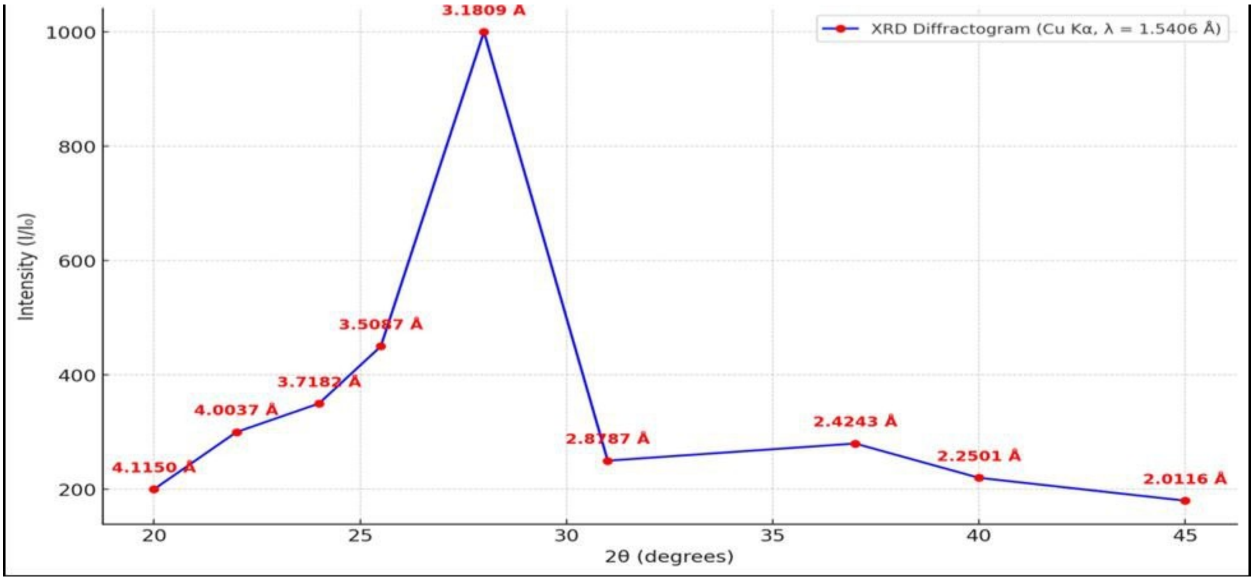

Fig. 2. X-ray Diffraction (XRD) Pattern of Pure Urea Main Diffraction Peak

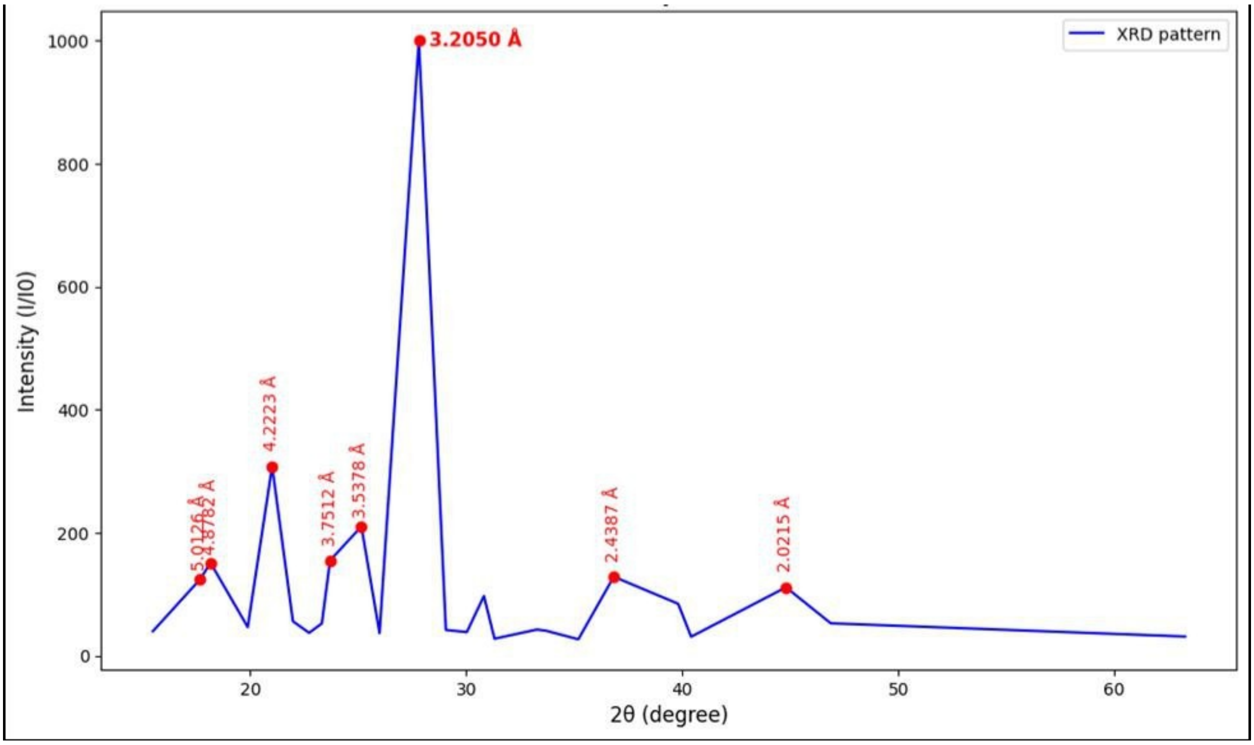

Fig. 3. Urea:Ethylcellulose ratio 100:0.5 Extracted main peaks are shown

X-ray diffractogram analysis of pure urea revealed a high degree of crystallinity. The main reflection was observed at 2θ = 27.81° (d = 3.205 Å), with the highest intensity, confirming the well-defined crystalline structure of urea [16. Patel N., et al., 2022]. In addition, peaks at 21.02° (d = 4.222 Å), 23.70° (d = 3.751 Å), and 25.15° (d = 3.538 Å) were also recorded with high intensity, indicating the stable formation of crystalline domains in different orientations.

For the urea–ethylcellulose (100:0.5) composition, several changes were observed:

- The main peak (27.81°) was retained, but its intensity decreased significantly, and broadening of the peak (increase in FWHM) was noted. This indicates a reduction in crystal domain size and an increase in disorder [17].
- The intensities of the secondary peaks decreased or merged with the background, suggesting partial disruption of order in the crystal orientations.

- The rise in the background confirmed the formation of an amorphous phase in the composition [18].

The addition of ethylcellulose reduces the overall crystallinity of urea. This phenomenon can be explained as follows:

1. Ethylcellulose molecules hinder the formation of the urea crystal lattice, resulting in the generation of smaller crystal domains [17].
2. Due to the amorphous nature of ethylcellulose, the fraction of the amorphous phase in the composition increases, leading to the formation of a crystal–amorphous mixture [18].

Such changes directly affect the physicochemical properties of the composition. In particular, the reduction in crystallinity slows the dissolution of urea in water, ensures long-term stability of the substance, and broadens its application potential [16–18].

Conclusion. The studies showed that the addition of ethylcellulose to urea granules significantly slows their dissolution in water while improving their mechanical and hygroscopic stability. According to the data in Table 1, the dissolution time of pure urea granules (100:0, 0 g ethylcellulose) increased from 1.36 minutes to more than 6 minutes with the addition of ethylcellulose, which is explained by the effect of the polymer coating. As illustrated in Figure 1, the dissolution time consistently increased with higher ethylcellulose content, while mechanical strength improved from 25.81 to 25.83 kg/cm². This ensures the granules do not break during transportation and storage, preserving their quality for a longer period.

Experimental and practical results further indicated that XRD analysis (Figures 2 and 3) revealed a decrease in the intensity of the main peak, broadening of the FWHM, and an increase in the amorphous phase fraction. This suggests that ethylcellulose molecules hinder the formation of the urea crystal lattice and promote the formation of smaller crystal domains. As a result, a crystal–amorphous mixture is formed in the granules, which plays an important role in slowing dissolution and ensuring long-term stability.

The optimal content was determined to be 0.5–0.8 g ethylcellulose per 100 g urea, which provides a balanced improvement in dissolution time and mechanical strength. Under these conditions, the granules act as controlled-release nitrogen fertilizers, reducing nitrogen leaching from the soil and providing plants with a long-term supply of nutrients.

At the same time, an increase in hygroscopicity up to 68.9% reduces interaction with the environment and minimizes the risk of agglomeration during storage. These properties further enhance the efficiency of controlled-release fertilizers, especially when used in combination with superphosphate and other organic coatings.

Overall, urea granules with added ethylcellulose:

- regulate dissolution in water,
- enhance mechanical stability,
- modify the crystal structure,
- reduce nitrogen losses,
- provide controlled-release, environmentally friendly, and agrochemically efficient fertilizers.

Therefore, this composition can be recommended as an effective option for prolonged-release nitrogen fertilizers that meet modern agro-economic and environmental requirements.

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