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Effects Of Mineral Fertilizers, Hydrogel, And Mulching On The Growth And Development Of Barley Plants In Sandy Desert Soils

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Abstract: This article describes the effects of mineral fertilizers, hydrogel, and mulching on the growth and development of barley plants in sandy desert soils of the Republic of Karakalpakstan. Experimental results showed that agronomic practices applied during the barley growing season had a positive effect on maintaining soil moisture, increasing plant height, and yield. Particularly high barley growth rates and final results were achieved with the use of hydrogel and mulching in combination with mineral fertilizers. The practices recommended in this region contribute to increased barley cultivation efficiency.

Keywords: Desert sandy soils, barley plants, biomass, mineral fertilizers, hydrogel, mulching, agricultural technology, water conservation methods.

Introduction: At present, sandy desert soils occupy 17.4 million hectares across the Republic. However, despite this vast area, their utilization in agriculture has remained largely undeveloped. According to data provided by the Food and Agriculture Organization (FAO), the world population is projected to reach 9 billion by 2050. This, in turn, necessitates more efficient use of sandy desert soils and underscores the importance and relevance of scientific research aimed at improving their productivity.

In the conditions of Karakalpakstan, it is particularly important to cultivate barley using spring, autumn, and winter atmospheric moisture, as well as to study the agrochemical properties of sandy desert soils. Agroecosystems located in desert regions are characterized by complex climatic conditions and harsh environmental factors. The sandy desert zones of the Republic of Karakalpakstan, in particular, are distinguished by low soil fertility, rapid moisture evaporation, and nutrient deficiencies for plants.

In such areas, the application of alternative agrotechnological approaches plays a significant role in enhancing the productivity of agricultural crops, including barley (Hordeum vulgare L.), an important cereal crop. In recent years, the use of hydrogels has shown promising results in meeting plant water requirements by improving soil water retention capacity. Additionally, organic and inorganic mulching materials are recommended as effective tools for conserving soil moisture, regulating temperature, and suppressing weed growth. Mineral fertilizers, on the other hand, directly influence plant biomass by balancing nutrient supply.

According to the findings of J. Akhter, K. Mahmood, K. A. Malik, A. Mardan, M. Ahmad, and M. M. Iqbal [1, pp. 463–469], the application of hydrogel polymers in sandy and loamy soils demonstrated positive effects on moisture retention and on the post-sowing development of crops such as barley and wheat. When hydrogel was applied at concentrations of 0.1–0.3%, soil moisture retention increased significantly, while the growth period of both barley and wheat was prolonged by 4–5 days.

Based on the research of M. K. Wasifhy, J. A. Durrani, and S. M. Barai [2, pp. 283–300], various polymeric hydrogel products (e.g., potassium polyacrylate PH1 and starch–acrylonitrile PH2) were tested for their ability to retain moisture in desert and semi-desert soils of Kazakhstan, where approximately 95% of the soil is sandy. PH1 (potassium polyacrylate) absorbed water up to 174 times its own weight, while PH4 (polyacrylic acid) absorbed 201.1 times its weight. The application of hydrogels considerably increased both the field capacity and the minimum moisture-holding capacity of the soils. In sandy desert soils, hydrogel use enhances soil moisture retention, which is highly beneficial for barley biomass accumulation.

According to A. S. Abdurakhimov and N. B. Usmonov [3, pp. 11–12], studies conducted on sandy soils in the Yozyovon district of Uzbekistan examined the effectiveness of double-row sowing through relay cropping. The investigation focused on soil conditions, the development of the plant root system, and nutrient migration.

B. Jollibekov, B. B. Jollibekov, G. Sharapova, and M. Jollibekov [6, pp. 66–68] measured soil moisture using modern equipment during January, February, March, and April. Their results showed that the moisture content in the 40-cm soil layer was relatively high. In April, the upper layer of sandy desert soil exhibited an estimated moisture value of 8.1, while the humus content increased from the upper to the lower soil layers.

R. Kurvantayev and O. A. Geldiev [7, pp. 157–162] reported that in dryland farming areas of the plain–foothill region, where precipitation levels are moderately low (average 362 mm), the organic matter (humus) content of typical dryland gray soils ranged between 0.925–1.002%. Total nitrogen content varied from 0.08–0.25%, total phosphorus from 0.100–0.105%, and total potassium from 0.900–1.010%. These soils were found to be particularly deficient in readily available nitrogen ($N–NO_3$, $N–NH_4$) and phosphorus.

METHODS

This study is dedicated to a comprehensive assessment of the effects of mineral fertilizers, hydrogel, and mulch application on the biomass of barley grown under sandy desert conditions of the Republic of Karakalpakstan. The results obtained will serve as a scientific basis for developing ecologically sustainable and efficient agricultural systems in desert regions. Since the seventeenth century, an agricultural term known as “soil covering” has been in use. At present, this method is still applied, but under a new name “soil mulching,” derived from the English word mulch, meaning “cover” or “protective layer.”

Experimental scheme

Options	Mineral fertilizers kg/ha
1	Control
2	$N_{150} P_{100} K_{70}$
3	$N_{150} P_{100} K_{70}$ + hydrogel
4	$N_{150} P_{100} K_{70}$ Malching
5	$N_{200} P_{150} K_{100}$

Types of Soil Mulching. Soil protection from extreme heat can be achieved through three methods:

1. Traditional mulching,
2. Organic mulching,
3. Inorganic mulching.

Mulching plays an essential role in creating optimal conditions for cultivating vegetable and melon crops. It is a complex agrotechnical method. Mulch slows down moisture evaporation and helps ensure its uniform distribution across the upper and lower soil layers, increasing the moisture content of the root zone by 3–6%. Consequently, soil structure is better preserved, surface crust formation is prevented, and the need for soil loosening is eliminated.

Research activities were conducted under field and laboratory conditions. Soil analyses were performed in accordance with the methodological guidelines “Methods of Conducting Field Experiments” developed by scientists of TATI and UzPITI institutes. Mathematical–statistical analyses of the results were carried out using B.A. Dospekhov’s methodological manual “Methods of Field Experiment” and Microsoft Excel software. Field experiments were conducted based on the following scheme: The experimental design consisted of 5 variants in 3 replications. In Variant 1, no mineral fertilizers were applied. This served as the control group for comparison with other treatments. Variant 2 involved the application of 150 kg of nitrogen, 100 kg of phosphorus, and 70 kg of potassium per hectare. This fertilization rate served as the main technological background under study. Variant 3: N150 P100 K70 + hydrogel. In this treatment, hydrogel was added in addition to the above fertilizer rates. Hydrogel has water-retention properties and is important for maintaining soil moisture in sandy soils. Variant 4: N150 P100 K70 + mulch. In this variant, mulching was applied in addition to the main fertilization. Mulch helps retain soil moisture, stabilize temperature, and reduce weed growth. Variant 5: N200 P150 K100. In this treatment, the amount of mineral fertilizers was increased; that is, 200 kg of nitrogen, 150 kg of phosphorus, and 100 kg of potassium were applied per hectare. This variant makes it possible to determine the productivity of barley under maximum fertilization conditions.

Research Objective. The objective of this study is to determine the optimal mineral fertilizer rates for barley cultivation under sandy desert soil conditions and to develop agrotechnologies for maintaining soil moisture through the use of hydrogel and mulching.

Results Obtained. It is advisable to cultivate barley in sandy desert soils using the mulching method, as the moisture content of these soils is significantly lower and their water permeability much higher compared to meadow–alluvial soils commonly used for irrigation. Furthermore, mulching with plant residues (straw fragments) considerably reduces soil moisture evaporation. Over a four-year period, the average evaporation from mulched plots between May and September was 41 mm, whereas in non-mulched areas this indicator reached 191 mm. The amount of plant residues (straw fragments) on the soil surface plays a decisive role. To maintain sufficient soil moisture reserves, at least 30% of the soil surface must be covered with straw fragments. Under irrigated conditions in light-textured and sandy desert soils, stubble of intermediate crops, which strengthens the upper soil layer and prevents its erosion and wind removal, can also serve as an effective mulch. Mulching is particularly important in areas prone to strong wind erosion and is typically applied in limited zones for maximum effectiveness. Barley was sown in March in sandy desert soil using mulch and hydrogel. The research was conducted during the early spring months. According to the findings, when mulching was applied under sandy desert soil conditions, soil moisture in the control treatment was 35% in March, but decreased to 0% in June and July. In the first and second variants, soil moisture levels were 39% and 40% in March, respectively, while by June and July they decreased to 10% and 5%. When hydrogel (Mojiza polymer) was applied in sandy desert soils, soil moisture levels in the 3rd, 4th, and 5th variants were 35%, 34%, and 28% in March, whereas in June and July field moisture decreased to 6%, 7%, and 6%, respectively. Analysis of the data obtained from studying the effect of different nitrogen fertilizer rates on the germination of Mavlano barley seeds shows that in 2021, in variants where hydrogel was applied—with total nitrogen content ranging from 0.0786 to 0.0448 mg/kg—the average number of seedlings emerging per 1 m² was 303, and field germination reached 75.8%. In contrast, variants 2 (N200P100K70) and 5 (N250P150K100) produced 228.6 and 263.3 seedlings per m², with germination rates of 57.2% and 65.8%, respectively (Table 1).

In 2023, under the N150P100K70 treatment, where the total nitrogen content ranged from 0.0384 to 0.0758 mg/kg, the average number of barley seedlings emerging per 1 m² was 160, corresponding to a field germination rate of 40%. In 2024, under the N150P100K70 + Hydrogel treatment, where the total nitrogen content ranged from 0.0436 to 0.0778 mg/kg, the average number of seedlings per 1 m² reached 323.3, with a field germination rate of 80.8%. Under the N150P100K70 + Mulch treatment, 302.2 seedlings per 1 m² (75.6%) emerged. These results clearly indicate that during the 2024 research season, barley germination reached 63.9%.

1-Table.

The Effect of Different Nitrogen Fertilizer Rates on the Field Germination of Barley Seeds, per 1 m² (2022–2024)

Options	2022 yil			2023 yil		2024 yil	
	Number of seeds, piece	Seedlings	Germination	Seedlings	Germination	Seedlings	Germination
Control	400	124	31,1	94	23,5	171,6	42,9
N_{150} P_{100} K_{70}	400	228,6	57,.2	160	40,0	210,7	52,7
N_{150} P_{100} K_{70} + Gidrogel	400	303,3	75,8	234,7	58,6	323,3	80,8
N_{150} P_{100} K_{70} Mulcha	400	192,3	48,0	232,3	58,1	302,3	75,6
N_{200} P_{150} K_{100}	400	263,3	65,8	223,3	55,9	247	61,8

In March, the heights of barley plants in the 3rd, 4th, and 5th variants were 6, 8, and 10 cm, respectively, while in June they reached 42.2, 47.2, and 45 cm. The average plant height in the control treatment was 9.4 cm; however, the application of mulch and hydrogel had a significant effect on soil moisture and, consequently, on barley plant height. In the control treatment, barley height was 3 cm in March but increased to 12 cm by mid-June (Table 2).

2-Table

Lenth of barley cm 2022-2024-year

Variant T/r	Qaytariqlar			O'rtacha	Farqi, ±		
	I	II	III		1-variantga nisbatan	2 va 3 variantga nisbatan	3 va 5 variantga nisbatan
1	51	50,5	49,4	50,3	0,0	00	
2	53,4	52,5	52,6	52,8	+3,1	00	
3	55,1	56,3	55,3	55,5	+4	+0,9	00
4	54	53,8	54,3	54,0	+6	+2	+2
5	52	53	51	52	+9,3	+6,2	+5,3

The table presents the performance results of five experimental variants. Each variant was tested three times, and the average value was calculated. The data show how each variant differs from Variant 1, as well as the comparative differences between Variants 2 and 3, and between Variants 3 and 5. Overall, the measurements indicate progressive changes across the variants, with noticeable increases in the average values and the calculated differences. These comparisons help illustrate the relative performance and variation between the tested conditions.

CONCLUSION

The most effective method for promoting barley growth was mulching (Variant 4), followed by hydrogel application (Variant 3) and mineral fertilizers (Variant 2). Higher doses of mineral fertilizers (Variant 5) did not produce the expected results. The use of hydrogel and mulch significantly preserved soil moisture reserves throughout the growing season. In particular, mulching with straw reduced evaporation from 191 mm to 41 mm. Hydrogel demonstrated the highest efficiency in barley cultivation, while mulching also had a positive effect, especially in areas prone to moisture deficiency. Excessive fertilizer application does not always yield beneficial results; therefore, it is necessary to operate within optimal rates. In the sandy desert regions of Karakalpakstan, the application of N150P100K70 in combination with hydrogel and mulching is recommended as the most effective practice.

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