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IMPACT OF THE APPLICATION RATE OF THE "PMM" AMELIORANT ON FERTILITY AND YIELD STRUCTURE OF WINTER WHEAT UNDER RAINFARMED CONDITIONS

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Abstract

Rain fed lands (rain fed fields, rain fed agriculture) – are lands in the zone of irrigated agriculture on which crops are cultivated without artificial irrigation, i.e. they mainly use moisture which the soil gets in spring. Mostly these lands are located in foothill plains and margins of oases where drought-resistant corn, food and garden plants are grown.

Over the past seven years, the authors of this article have been conducting research on the use of polymer-mineral material (PMM) to increase soil moisture and the ability to retain sufficient additional water collected from precipitation and groundwater.

Over the past seven years, research has been conducted to increase soil moisture and maintain a sufficient supply of additional moisture collected from precipitation and groundwater through the use of the PMM ameliorant.

A number of technologies for increasing crop yields using the PMM ameliorant have been developed. Numerous laboratory studies have been conducted.

Based on the results of laboratory tests, field studies were conducted in 2024–2025 in the Tsaghkahovit community of the Republic of Armenia under rainfed farming conditions to determine the effect of the PMM ameliorant on winter wheat yield under real-world conditions. At a PMM ameliorant application rate of 0.3 kg/m² (3 g PMM/kg of soil), the average winter wheat yield exceeded the control by 48.2%.

Keywords: water, irrigation, plant, ground, filtration, polymer.

Introduction

When growing crops under rainfed conditions, water shortages are the main cause of low yields. In regions of Armenia with annual precipitation of 250-450 mm, agriculture is carried out with artificial irrigation, while in the foothill and mid-mountain zones, where average annual precipitation is 450-650 mm, it is mostly carried out without artificial irrigation. Furthermore, frequent droughts cause serious damage to agriculture, creating the risk of desertification. In rainfed conditions, where crops are grown without artificial irrigation, spring moisture from melted snow and groundwater is primarily used, as well as rainfall during the spring, summer, and fall growing seasons, which is absorbed by the soil.

Water-swelling polymer additives, which increase their volume many times over when swollen, can be effectively used in agriculture, including growing ornamental plants, vegetable gardening, and horticulture. Polymer additives are particularly effective for growing lawn grasses and grain crops in under rainfarmed conditions. The artificial ameliorant «Hydrogel» is widely used for this purpose. However, hydrogel is ineffective: it degrades when exposed to sunlight and negatively impacts the plant's root system [1].

In the territories of land where crops are cultivated without artificial irrigation, the use of polymer-mineral material (PMM) will improve the water regime which may lead to increased yields by reducing the root system of grown plants and reducing the coefficients of filtration and soil evaporation. In particular, the use of polymer-mineral material in soil under rainfed conditions will ensure the rapid growth of trees and increase their viability [2].

At the field capacity of the soil (in early spring or after full irrigation), approximately 30 liters of water can accumulate in a 10 cm soil layer over an area of 1 m². Some of this water will be used by the plant as nutrition, while some will remain in the soil (approximately 13 liters – 13%), which will not be used by the plant under any natural circumstances (wilting capacity). It is known that out of 30% - 30 liters of water in a 10 cm soil layer, plants cannot use 13 liters of water, they consume another 7 liters with difficulty, practically surviving and not developing, and only 10 liters of water - a third of the accumulated - they easily absorb and assimilate for growth and development.

Thus, most of the moisture accumulated in the soil evaporates from the soil surface during the growing season under the influence of sunlight and warm weather. Therefore, to increase the water reserves in the soil required for plant consumption, two options are possible: reducing water evaporation from the soil surface (for example, by covering it with a thin film, which creates a greenhouse effect and significantly reduces evaporation from the soil surface), or increasing the soil's water holding capacity using a «PMM» (for example, to 40%-45%), which allows for the accumulation of 40-45 liters of water per square meter in a 10-cm soil layer, where the roots of many plants, including winter wheat, are primarily located. An additional 10-15 liters of water accumulated in the soil will provide plants with the water they need for favorable development and growth for a significant period.

Therefore, if the volume of water in the soil decreases by 30-35% of its field moisture capacity, additional water is required for plant growth and development – from artificial irrigation, precipitation, or additionally collected water using a «PMM», increasing field moisture capacity by up to 40% – by 10 liters per square meter.

It should be noted that adding PMM to the soil not only increases its water holding capacity, and therefore doubles the amount of water readily absorbed by plant roots, but also reduces the rate of evaporation under the same conditions, compared to soils without PMM. Therefore, plants easily develop for a period of time that is twice or more longer than without PMM, in the absence of rain and artificial irrigation.

Conflict Setting

A number of technologies have been developed to increase crop yields using the PMM ameliorant. A large number of joint laboratory studies have been conducted by the I.V. Yegiazarov Institute of Water Problems and Hydraulic Engineering and the Lomonosov Moscow State University Research Institute of Mechanics. Laboratory experiments, growing plants in small plots and the most recent field experiment on an area of 1 hectare have shown that the application of PMM to the soil at a rate of 100-300 grams per square meter leads to a significant increase in winter wheat yields [3]. During the research, biometric calculations and measurements were carried out, according to which the ameliorant "PMM" had a significant impact on the growth dynamics of winter crop stems (Fig. 1).

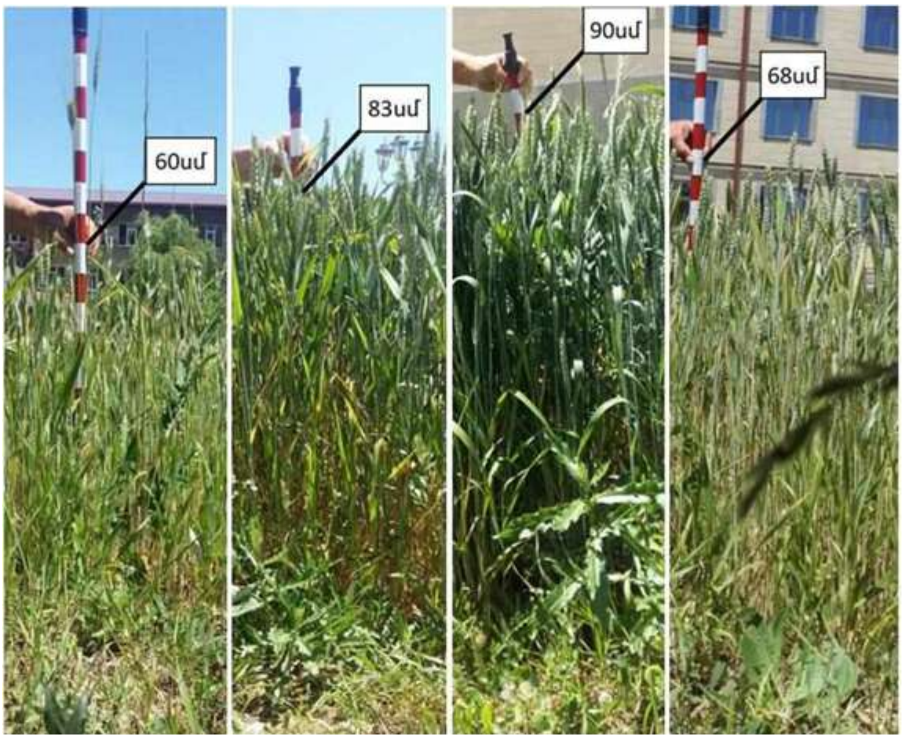

Fig. 1 Biometric observation data [3]

The following four conditions were studied in 1 m² plots under natural conditions:
1. Without PMM and fertilizers (control); 2. Without PMM with fertilizer (P60N90);
3. With P60N90 fertilizer, a 0.5 cm thick layer of PMM was applied to a depth of 10 cm;
4. A 0.5 cm thick layer of PMM without fertilizer was applied to a depth of 10 cm

Based on the laboratory test results, a task was set to conduct natural (field) studies in 2024-2025 in the Tsaghkahovit community of the Republic of Armenia, under rainfed conditions, to determine the real-world impact of the "PMM" material on winter wheat yields. The application rate of the "PMM" ameliorant is 0.3 kg/m² (3 g_{PMM}/1 kg_{soil}).

Research Results

According to climate change forecasts, the following changes can be expected in the region's agricultural sector in the near future [4]:

- a 10-30% decrease in soil moisture levels;
- a 7-13% decrease in soil moisture availability for various agricultural crops;
- by 2030, a decrease in agricultural yields by 8-14%.

In order to identify the dependence of the structure and yield of winter wheat crops on the volume of the "PMM" ameliorant applied to the soil, field experiments were conducted in 2024-2025 in the mountain chernozem subzone of the mountain-steppe landscape zone of the Republic of Armenia (Tsakhkahovit community), located at an altitude of 2000 m above sea level, where the average annual precipitation is 550 mm, and the average annual air temperature is 4°C.

The experiments were conducted in triplicate. The following treatments were studied:

1. Without "PMM" – control;
2. "PMM" – 2 T/ha;
3. "PMM" – 3 T/ha.

Experimental replicates and treatments were placed systematically, with treatments in all replicates arranged in the same order, without a common boundary. Each experimental plot was surrounded on all sides by a 3-meter-wide protective layer. A 1-meter-wide protective layer was also left between adjacent experimental plots. Thus, each experimental plot had a total length of 60 meters and a width of 18 meters, including the 1-meter-wide protective layer, for a total area of 1,080 m² and a calculated area of 1,000 m².

According to the experimental design, the "PMM" ameliorant was applied to the soil before sowing using an SZ-3.6 grain seeder to the seed placement depth, followed by continuous tillage. All other wheat cultivation procedures were carried out using the technology adopted in the region.

To determine the relationship between winter wheat yield and the amount of "PMM" ameliorant applied to the soil, plants of all treatments and replicates were uprooted from an area of 0.25 m² before harvesting, tied into bundles, labeled, and delivered to the laboratory. Structural elements of the crop and biological yield were determined using the established methodology.

Ten randomly selected plants from each bundle were measured for height, spike length, number of grains per spike, 1,000-grain weight. The number of plants per 1 m² of area, the total number of stems, and the number of effective stems were calculated. The total and effective tillering coefficients were determined.

All the above calculations were carried out both for individual repetitions, and the average value from three repetitions was calculated (Tables 1-4).

Table 1

The structure of the biological yield of winter wheat depending on the amount of introduction of the ameliorant «PMM» into the soil (Repetition 1)

Option	Plant height (cm)	In 1m2			Germination		For 1 ear			Weight of 1000 grains (g)	Biological yield (T/ha)			Straw to grain ratio
		Number of plants	Number of stems		Total	Effective	Length (cm)	Number of grains (pieces)	Grain weight (g)		Total	From which		
			Total amount	Effective								Grain	Straw	
Control plot without the "PMM" ameliorant	48	225	356	240	1,58	1,06	5,6	23,2	0,8	34,48	4,05	1,92	2,13	1,1
PMM 2T/ha	52	251	341	275	1,35	1,09	6,3	27,4	0,9	32,84	4,92	2,47	2,45	0,98
PMM 3T/ha	52	247	335	268	1,35	1,08	6,4	28,6	1,2	41,95	6,37	3,21	3,16	0,98

Table 2

The structure of the biological yield of winter wheat depending on the amount of introduction of the ameliorant «PMM» into the soil (Repetition 2)

Option	Plant height (cm)	In 1m2			Germination		For 1 ear			Weight of 1000 grains (g)	Biological yield (T/ha)			Straw to grain ratio
		Number of plants	Number of stems		Total	Effective	Length (cm)	Number of grains (pieces)	Grain weight (g).		Total	From which		
			Total amount	Effective								Grain	Straw	
Control plot without the "PMM" ameliorant	50	201	261	215	1,29	1,06	6,2	26,2	1,0	38,16	4,41	2,15	2,26	1,05
PMM 2T/ha	53	238	296	254	1,24	1,06	6,3	26	1,1	42,30	5,59	2,79	2,8	1,0
PMM 3T/ha	54	293	371	307	1,26	1,04	6,8	28,2	1,0	35,46	6,04	3.07	2,97	0,96

Table 3

The structure of the biological yield of winter wheat depending on the amount of introduction of the ameliorant «PMM» into the soil (Repetition 3)

Option	Plant height (cm)	In 1m2			Germination		For 1 ear			Weight of 1000 grains (g)	Biological yield (T/ha)			Straw to grain ratio
		Number of plants	Number of stems		Total	Effective	Length (cm)	Number of grains (pieces)	Grain weight (g)		Total	From which		
			Total amount	Effective								Grain	Straw	
Control plot without the "PMM" ameliorant	48	254	312	275	1,22	1,08	6,2	21,4	0,8	37,38	4,54	2,20	2,34	1,06
PMM 2T/ha	54	220	303	237	1,08	1,07	6,2	27,2	1,1	40,44	5,29	2,60	2,69	1,03
PMM 3T/ha	55	256	371	281	1,44	1,09	6,4	26,0	1,1	42,30	6,24	3,09	3,15	1,0

Table 4

The structure of the biological yield of winter wheat depending on the amount of introduction of the ameliorant «PMM» into the soil

(Average of 3 repetitions)

Option	Plant height (cm)	In 1m2			Germination		For 1 ear			Weight of 1000 grains (g)	Biological yield (T/ha)			Straw to grain ratio
		Number of plants	Number of stems		Total	Effective	Length (cm)	Number of grains (pieces)	Grain weight (g)		Total	From which		
			Total amount	Effective								Grain	Straw	
Control plot without the "PMM" ameliorant	48,6	226,6	309,6	243,3	1,3	1,06	6,0	23,6	0,86	36,67	4,33	2,09	2,24	1,07
PMM 2T/ha	53,0	236,3	313,3	255,3	1,2	1,07	6,2	26,8	1,03	38,52	5,27	2,64	2,63	1,0
PMM 3T/ha	53,6	265,3	359,0	285,3	1,3	1,07	6,5	27,6	1,1	39,90	6,21	3,12	3,09	0,98

As shown by the averaged data presented in tab. 4, both doses of the ameliorant introduced into the soil had an impact on the height of plants, the total and effective number of stems per unit area, the total and effective tillering coefficient, as well as the length of the ear, the number of grains in the ear, and the weight of 1000 grains. The highest plant height was observed in the variant with a seeding rate of 3 t/ha. This variant also resulted in higher total and effective stem numbers, as well as higher total and effective tillering, on average across three replicates.

Among the most important parameters in the yield structure elements, grain number and 1,000-grain weight were also highest in the PMM 3 t/ha variant. As a result, the highest biological yield of both straw and grain—3.09 and 3.12 t/ha—was observed in the PMM 3 t/ha variant, exceeding the control by 37.9% and 49.2%, respectively, while in the PMM 2 t/ha variant, these yields were 17.4% and 18.1% higher.

Actual yield (arguably the most important indicator) was determined during field harvesting by weighing the yield of each experimental plot across replicates (Table 5). According to the data presented in the table, different rates of soil ameliorant applied to the soil in all replicates significantly impacted the increase in winter wheat grain yield. The highest average yield across three replicates was observed in the PMM 3 T/ha variant – 2.89 T, exceeding the control by 0.94 T, or 48.2%. In the PMM 2 T/ha variant, the deviation from the control was only 0.61 t/ha, or 31.2%.

The climatic conditions for growing grain in the Republic of Armenia are unfavorable. On the other hand, in a country like Armenia, with small, fragmented, and privatized land plots, crop rotation is practically nonexistent, resulting in lower yields. In this case, growing grain is economically infeasible. Will growing grain, then, bring farmers enough profit to encourage them to abandon other crops? According to professional estimates, the profit from growing one hectare of grain does not reach 100,000 drams. In countries like Russia or Canada (where yields are incomparably higher), where millions of hectares of grain are grown, significant profits can be realized by cultivating several hundred or thousands of hectares. In the Republic of Armenia, where the largest areas under wheat cultivation are 20-30 hectares, and mostly 2-3 hectares, this is not economically feasible.

Table 5

Actual yield of winter wheat depending on the rate of application of the «PMM» ameliorant to the soil (average of three repetitions)

N	Option	Grain yield by repetitions (T/ha)			Average grain yield (T/ha)	Deviation of the yield from the control	
		1	2	3		T/ha	%
1	Control plot without the "PMM" ameliorant	1,88	1,96	2,02	1,95	0	0
2	PMM 2T/ha	2,36	2,84	2,60	2,56	0,61	31,2
3	PMM 3T/ha	2,90	2,96	2,82	2,89	0,94	48,2

According to professional estimates, Armenia requires 420,000–450,000 tons of wheat annually. According to experts at the Food Risk Assessment Center, the average daily bread consumption per capita in Armenia is 319 grams. 82.4% of this is high-quality wheat bread, and 16.9% is lavash. Daily pasta consumption per capita is 19.3 grams, and vermicelli consumption is 8.5 grams. According to calculations conducted in the 1980s, annual bakery product consumption in Armenia, calculated as flour, was 130 kg per person. This figure was projected to reach 142 kg per person in the future. Based on the above data, it was calculated that 450,000 tons of wheat per year are needed to ensure food security in Armenia. The list of grain zones in Armenia for 2010–2024 is provided in tab. 6.

Wheat is grown in virtually all regions of the republic. It is cultivated, in particular, in the Shirak Plain (Akhuryan, Ani, Artik), the Sevan River basin (Vardenis, Martuni, Kamo), Sisian, and the Armavir region. Smaller areas are also grown in Ashotsk, Amasia, Tashir, and Tavush. Again, primarily in arid conditions.

Thus, wheat is primarily grown in arid conditions, primarily at altitudes of 1,500-2,000 meters. Irrigation at such an altitude is associated with high costs. Even on the Ararat Plain, with gravity irrigation, the cost of wheat reaches 100-120 drams/kg, which brings virtually no profit to the producer. According to the statistical service, in 2022-23, In the Armavir and Ararat regions, where wheat is grown primarily on irrigated land, the average yield was approximately 4 centners per hectare, reaching 6-7 centners per hectare in some cases. In Syunik, Gegharkunik, and Shirak, where cultivation occurs on rainfed land, the yield is 1.5-2 centners per hectare, and in some cases 2.4 centners per hectare. According to professional estimates, the cost of wheat on irrigated land fluctuates between 75-90 drams per kg. The cost of growing wheat is 110-120 drams per kg. Even with a 5-ton harvest, a farmer's profit is, at best, 100,000 drams per hectare. In rainfed conditions, profits are significantly lower. For this reason, the sown area in the republic is decreasing year after year. In recent years, farmers have been provided with a subsidy of 80,000 drams per hectare of wheat. In this case, the "profit" per hectare approaches 160,000-170,000 drams. Observations show that this significantly stimulates wheat production. Moreover, without subsidies, the area sown to wheat declines year after year, while with subsidies, it grows.

Table 6

Grain crop areas in Armenia 2010-2025 (ha)

Years	Total grain	Wheat	Barley
2010	159307	87585	61160
2012	172206	93710	65291
2014	188695	106365	67637
2016	198148	108738	71600
2018	131400	66680	52460
2020	121656	59393	50294
2021	124929	59110	50632
2022	114409	56757	42110
2023	127091	71360	40074
2024	116400	56520	42035

Experts estimate that investments of one to two billion drams create a significant positive effect in agriculture. Related industries begin to thrive, greater added value is created in rural areas, and population outflow is reduced.

Each new, previously uncultivated plot of land is developed, which has a positive impact on soil protection and environmental protection. And "dry water," which effectively increases yields by approximately 50 percent in arid conditions, improves soil structure, which is an important prerequisite for further cultivation and high yields. The area sown to wheat in the republic is 55,000-56,000 hectares. Of these, approximately 40,000 hectares are cultivated under rainfed conditions. With this type of cultivation, the average yield is 1.8-2, and sometimes as high as 2.2-2.3 centners per hectare. Approximately 80,000 tons of wheat will be harvested from 40,000 hectares. Using «Dry irrigation», the yield will reach 120,000 tons, which is 26-27% of the country's food wheat needs. In purely economic terms, this generates an additional income of almost 5 billion drams. Foreign imports will decrease by a similar amount. And this is with the same sown area. Meanwhile, with such an increase in income, the sown area will obviously expand, and this additional income could increase significantly in practice. In any case, from a food security perspective, it is desirable to have locally produced wheat, which is at least slightly more expensive than imported wheat.

In 2023, Armenia imported 343,500 tons of milling wheat worth $62.8 million, as well as 65,500 tons of finished flour worth $10 million. In 2024, 316,000 tons of milling wheat worth $60.7 million and 42,300 tons of flour worth $10.2 million were imported, respectively. Even a modest increase in wheat acreage would reduce imports by millions of dollars.

Regarding food security, it should be noted that bread is a vital commodity, and based on the country's strategic security goals, at least half of the bread consumed should be produced domestically. Meanwhile, Armenia currently produces less than 20% of its milling wheat needs. Some of the 120,000–130,000 tons are produced as feed. Meanwhile, experts estimate that the republic has the potential to produce 200,000–250,000 tons of wheat. More than 200,000 hectares of agricultural land in the republic remain uncultivated due to water shortages and low yields. This problem could be partially solved with dry irrigation. New wheat varieties are currently being introduced that, with more or less appropriate agricultural practices, yield up to 7–8 quintals per hectare under irrigated conditions and 2–3 quintals or more on dry lands. Therefore, production of 200–220,000 tons is certainly feasible. In this case, this would bring the republic additional revenue of up to 8 billion drams, based on purely economic calculations, and, more importantly, would provide a significant incentive to reduce, stop, and stabilize the outflow of population from mountain, foothill, and border villages. During Soviet times, Armenia consumed up to 1.2 million tons of grain annually, of which 450,000 tons were used for bread production and the rest for livestock feed. In Armenia, this figure has been reduced by approximately half. The problem of feed wheat production can be solved by using a "dry irrigation" mechanism.

Conclusions

1. The application of the PMM ameliorant to the soil has a significant impact on increasing winter wheat yields. According to field studies conducted in 2024-2025 in the arid conditions of the Tsaghkahovit community of the Republic of Armenia, with an

ameliorant application rate of 0.3 kg/m² (3 g PMM/kg of soil), the average winter wheat yield exceeded the control by 48.2%.

2. In the same experimental field, it is necessary to re-sow winter wheat (without adding an additional dose of the ameliorant «PMM») to evaluate the residual effect of the ameliorant on reducing yield increase.
3. To improve the effectiveness of the proposed project, it is necessary to establish production of the «PMM» ameliorant in Armenia, as well as conduct research to find a suitable (replacement) polymer-mineral material of natural origin. This will significantly reduce the cost of the ameliorant used (and, if a local substitute is found, several times over).

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ԱՆՋՐԴԻ ԵՐԿՐԱԳՈՐԾՈՒԹՅԱՆ ՊԱՅՄԱՆՆԵՐՈՒՄ «PMM» ՄԵԼԻՈՐԱՆՏԻ ՀՈՂ ՆԵՐՄՈՒԾՄԱՆ ՉԱՓԱՔԱՆԱԿՆԵՐԻ ԱԶԴԵՑՈՒԹՅՈՒՆԸ ԱՇՆԱՆԱՑԱՆ ՑՈՐԵՆԻ ԲԵՐՔԱՏՎՈՒԹՅԱՆ ԵՎ ԲԵՐՔԻ ԿԱՌՈՒՑՎԱԾՔԻ ՎՐԱ

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Բնական պայմաններում, որտեղ մշակաբույսերը աճեցվում են առանց արհեստական ոռոգման, օգտագործվում է հողի կողմից կլանված գարնանային խոնավությունը: Դրանք հիմնականում գտնվում են նախալեռնային հարթավայրերում, որտեղ աճեցվում են

երաշտին դիմացկուն հացահատիկային, սննդամթերքի և բանջարանոցային մշակաբույսեր:

Վերջին յոթ տարիների ընթացքում հետազոտություններ են կատարվել «PMM» բնական ծագման պոլիմերահանքային նյութի կիրառման միջոցով, հողի խոնավությունը բարձրացնելու և տեղումներից ու ստորգետնյա ջրերից հավաքված լրացուցիչ ջրի բավարար քանակություն պահպանելու ուղղությամբ: Մշակվել են «PMM» մելիորանտի կիրառմամբ, մշակաբույսերի բերքատվության բարձրամանն ուղղված մի շարք տեխնոլոգիաներ: Կատարվել են մեծ թվով լաբորատոր հետազոտություններ:

Հաշվի առնելով լաբորատոր փորձարկումների արդյունքները, 2024-2025թթ. Հայաստանի Հանրապետության Ծաղկահովիտ համայնքի անջրդի տարածքում, իրականացվել են բնօրինակ (դաշտային) հետազոտություններ, իրական պայմաններում, աշնանացան ցորենի բերքատվության վրա «PMM» նյութի ազդեցությունը որոշելու համար: «PMM» մելիորանտի 0,3 կգ/մ2 (3 գ$_{PMM}$/կգ$_{հող}$) հող ներմուծման չափաքանակի դեպքում, աշնանացան ցորենի միջին բերքատվությունը ստուգիչ տարբերակին գերազանցել է 48,2%:

Բանալի բառեր. ջուր, ոռոգում, բույս, հող, ֆիլտրացիա, պոլիմեր:

ВЛИЯНИЕ НОРМЫ ВНЕСЕНИЯ МЕЛИОРАНТА «ПММ» НА ПЛОДОРОДИЕ И СТРУКТУРУ УРОЖАЙНОСТИ ОЗИМОЙ ПШЕНИЦЫ В УСЛОВИЯХ БОГАРНОГО ЗЕМЛЕДЕЛИЯ

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В богарных условиях, где сельскохозяйственные культуры выращиваются без искусственного орошения, используется весенняя влага, впитываемая почвой. Эти земли расположены преимущественно на предгорных равнинах, где выращиваются засухоустойчивые зерновые, продовольственные и овощные культуры.

За последние семь лет проводились исследования по повышению влажности почвы и поддержанию достаточного количества дополнительной воды, собранной из атмосферных осадков и грунтовых вод, за счет применения мелиоранта «ПММ».

Разработан ряд технологий по повышению урожайности сельскохозяйственных культур при применении мелиоранта «ПММ». Проведено большое количество лабораторных исследований.

С учетом результатов лабораторных испытаний, в 2024-2025 гг. в общине Цахкаовит Республики Армения, в богарных условиях были проведены натуральные (полевые) исследования для определения в реальных условиях влияния материала «ПММ» на урожайность озимой пшеницы. При норме внесения мелиоранта «ПММ» 0,3 кг/м² (3$г_{ПММ}$/$кг_{почвы}$) средняя урожайность озимой пшеницы превысила контрольный вариант на 48,2%.

Ключевые слова**:** вода, орошение, растение, почва, фильтрация, полимер.

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