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Influence of water-absorbing polymers on grain crop yield, disease incidence, and end-use quality

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ABSTRACT

Background: Climate change is reshaping global weather patterns, presenting significant challenges for rain-fed agricultural regions that rely heavily on seasonal rainfall for crop irrigation. The increasing risk of droughts and water scarcity in arid and semi-arid regions underscores the critical role of water-absorbing polymers in agriculture, as they significantly enhance water retention and improve plant nutrient uptake. Grain production mainly relies on rainfall, and soil moisture content significantly affects both the quantity and quality of the harvest.

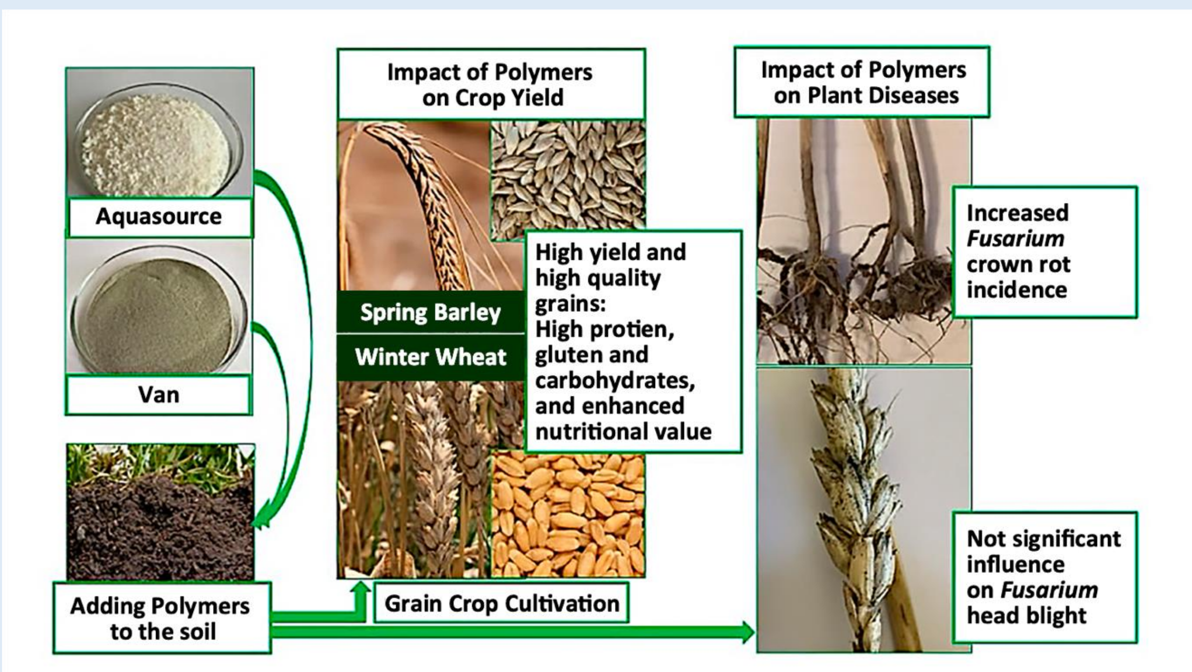
Objective: This study aims to develop strategies for enhancing the productivity and grain yield of cereal crops in rain-fed agricultural conditions by utilizing environmentally safe hydrogel polymers of Armenian origin. Additionally, it seeks to evaluate the effects of these hydrogels on the qualitative indicators of grain as a functional food, and assess their impact on the incidence of fungal diseases and the associated risks.

Methods: This study, conducted during 2022 and 2023, involved field experiments on winter wheat and spring barley. Seven variants, each replicated three times, were established to assess the impact of different doses of water-absorbing polymers (Aquasource at 50, 100, and 150 kg ha^{-1}, and Van at 500, 1000, and 1500 kg ha^{-1}) on grain crop productivity. Each variant, including a control where no polymers were used, was allocated a 30 m^2 area with 0.5 m spacing between plots.

Results: The productivity analysis revealed a significant impact of water-absorbing polymers on the morphological characteristics and overall yield of winter wheat and spring barley. The most effective doses under rain-fed conditions were 100 kg ha^{-1} of Aquasource and 1000 kg ha^{-1} of Van. Chemical analysis of wheat grains revealed that using these polymers increased the concentrations of carbohydrates, proteins, and gluten, thereby enhancing the nutritional value and functionality of the grains. However, polymer applications were associated with increased *Fusarium* crown rot incidence, with higher disease occurrence observed in polymer-utilizing plots compared to the control. Additionally, polymer applications did not significantly influence the development of *Fusarium* head blight, largely due to its dependence on climatic conditions.

Conclusion: The use of Aquasource and Van polymers enhances the efficiency indicators of the structural elements of spikes in winter wheat and spring barley. This promotes grain yield and improves grain quality by increasing the concentrations of protein, gluten, and carbohydrates in the grains, thereby enhancing their end-use quality as functional foods. Polymer applications were associated with an increased incidence of *Fusarium* crown rot, but they did not significantly influence the development of *Fusarium* head blight.

Keywords: polymer, winter wheat, spring barley, productivity, functional food, disease.



INTRODUCTION

Agriculture, the most water-demanding sector, consumes over 85% of human water consumption [1]. The anticipated effects of global warming pose a significant threat to rain-fed crops, which sustain about 60% of global food production. These agricultural systems are especially susceptible to fluctuations in temperature and precipitation patterns, increasingly intensified by climate change [2]. With a forecasted 50% increase in global water consumption by 2030 [3], the necessity of developing and adopting water-saving technologies such as water-absorbing polymers becomes evident [4-5].

Wheat (*Triticum* L.) and barley (*Hordeum* L.) are the most valuable crops globally and are cultivated extensively. According to STATISTA [6], in the marketing year of 2023/2024, the global production volume of wheat amounted to almost 785 million metric tons, a decrease compared to the previous marketing year. Worldwide, wheat production is influenced by various factors, including climate change, water stress, environmental conditions, pest and disease outbreaks, and improper crop management practices.

The demand for functional foods, which offer health benefits beyond basic nutrition, is increasing globally as consumers seek to improve their health without drastically altering their dietary habits [7-9]. Functional foods primarily aim to promote health and reduce disease risks by containing bioactive compounds in small quantities that can modulate physiological functions and improve overall health. Most food bioactive compounds (FBCs) are found in plant foods, such as whole grains, fruits, vegetables, herbs, mushrooms, and animal sources [10-12]. These sources are rich in various phytochemicals and antioxidants contributing to their health-promoting properties.

Wheat and barley play integral roles in the development of functional foods. Wheat grain's chemical composition makes it a staple crop with versatile applications globally. Wheat grain contains carbohydrates (70–75%), protein (10–15%), fats (1–2%), vitamins, minerals, fiber, and water [13]. Dietary fiber is linked to reduced risks of specific chronic diseases [14], such as cardiovascular disease, type 2 diabetes, and certain cancers [15]. Fiber also promotes healthy digestion and aids in weight management. Wheat grain protein content is a major source of vegetable protein in human diets, particularly where animal protein is scarce [16]. Protein-energy malnutrition contributes to secondary immunity deficiencies, leading to infections in humans [17]. Additionally, wheat contains bioactive compounds like polyphenols and phytosterols, which help reduce oxidative stress and inflammation [18]. Despite potential issues for some individuals, such as gluten sensitivity, wheat's constituents enhance its status as a crucial functional food, significantly contributing to its nutritional value and associated health benefits.

Barley is renowned for its high beta-glucan content, aiding in reducing cholesterol levels and regulating blood sugar. Its beneficial role in insulin resistance, dyslipidemia, hypertension, and obesity is continuously documented [19]. Additionally, barley boasts antioxidants, which safeguard cells from damage and mitigate the risk of chronic diseases. Its high fiber content promotes digestive health and supports heart health. Incorporating wheat and barley into functional foods enhances their nutritional value, providing essential vitamins, minerals, and fibers. Thus, it is significant to increase grain crop production [20].

The production of grain (wheat and barley) is of strategic importance for ensuring both the food and national security of the Republic of Armenia (RA). Arable land in Armenia spans 442.7 thousand hectares, with approximately 70% allocated to rain-fed agricultural cultivation. Grain production mainly relies on rainfall, and soil moisture content significantly affects both the quantity and quality of the harvest.

This study aims to develop strategies for enhancing the productivity and grain yield of cereal crops in rain-fed agricultural conditions, utilizing environmentally safe hydrogel polymers of Armenian origin. Additionally, it seeks to evaluate the effects of these hydrogels on the qualitative indicators of grain as an important functional food, while assessing their impact on the incidence of fungal diseases and associated risks.

MATERIALS AND METHODS

Description of the experimental site: The experiments were conducted during the 2022 and 2023 growing seasons in rain-fed cultivation conditions within the Spitak community (farmer Stepan Shiroyan), situated at an altitude of 1650 meters above sea level in the Spitak region of Lori Marz, Republic of Armenia (RA). The experimental plot features ordinary chernozem soil with a weakly alkaline pH and high humus content in the plow horizon (0-25 cm).

Description of polymers: The experiment involved the application of hydrogel polymers: Aquasource from "EcoTechnology LLC" and the polymer-mineral composition Van from "Yerevan Household Chemicals" factory, RA. Aquasource has a high water-absorption capacity (1:350), whereas 1 gram of Van can absorb 78 grams of water.

Experimental design: The experiment was conducted using the spring barley cultivar "Leon" and the winter wheat cultivar "Bezostaya 1", employing a randomized block design. Each variant, including a control where no polymers were used, was allocated a 30 m² area with 0.5 m spacing between plots. A total of 21 variants, each replicated three times, were tested, with only the seven variants utilizing polymers being presented below:

I. Aquasourse 50 kg ha^{-1}
II. Aquasourse 100 kg ha^{-1}
III. Aquasourse 150 kg ha^{-1}
IV. Van 500 kg ha^{-1}
V. Van 1000 kg ha^{-1}
VI. Van 1500 kg ha^{-1}
VII. Control without using polymers

(Figure 1 highlights 7 of the 21 variants in a randomized block design of the field experiment for both winter wheat and spring barley).

Figure 1. Design of the field experiments: *Aquasource; **50; 100 and 150 kg ha^{-1} application rate of Aquasource, 500; 1000 and 1500 kg ha^{-1} rate of Van polymer.

Application rates of polymers were determined by the companies, and the most promising options were chosen based on prior laboratory investigations.

Before seeding, polymers were evenly distributed over the plots and incorporated into the soil by plowing to a depth of 10-15 cm. Seeds were sown 15 cm apart in rows and buried 3-4 cm deep. Standard agricultural practices, including tillage, residue and weed management, and sowing schedules, were uniformly followed across the experimental field.

Analysis of grain crop productivity: The productivity and structural elements of winter wheat were analyzed using established methods. Plant height, spike length, grain number and weight per spike, grain yield per square meter, and weight of 1000 grains were averaged from 50 sampled plants per variant, while the yield was calculated using the metric method based on three repetitions per variant [21-22].

Assessment of disease development in grain crops: The species composition of diseases was identified through field monitoring and plant sampling. The severity (on a 5-point scale) and incidence, as well as the degree of disease development (DDD), were assessed using widely accepted methods in plant pathology [23-24]. The degree of disease development (DDD) was calculated using the formula: DDD=[∑(disease severity score × number of infected plants (spikes) with corresponding severity score)]/[(total number of calculated plants (spikes)) × (maximal score (4) in the disease severity score scale)] × 100% [25].

Laboratory tests: The chemical composition of the grains was analyzed at the "Standard Dialog" laboratory in RA. The analysis included carbohydrates, proteins, dry matter, and gluten content tests.

Statistical assessment of the experimental results: Statistical assessment was conducted using the single-factor or one-way ANOVA test (analysis of variance). The MS Excel package was used to compare the average data across the experimental options and to represent error bars of standard deviations. The indicator of the least significant difference (*LSD 0.5*) was applied with the lower limit of the permissible significance level set at $p<0.05$.

RESULTS AND DISCUSSION

Climatic conditions and grain crop production: Climatic conditions are pivotal in grain crop production, impacting key aspects such as growth, development, and yield formation. During critical growth stages, water stress can profoundly diminish wheat yield [26-28]. The average monthly temperature and precipitation during the growing season play a crucial role in rain-fed grain crop production by significantly influencing soil moisture levels and ultimately impacting grain yield.

Analysis of climatic data for 2022 and 2023 highlights noteworthy trends. Between April and July 2022, the average monthly air temperature in Spitak ranged from 10.5 to 19.7 °C, exceeding the multi-annual monthly averages of 6.4-18.0 °C. Furthermore, precipitation levels during April and July were lower, ranging from 34.8 to 10.5 mm, while May and June experienced higher precipitation, ranging from 111.2 to 90.3 mm. Conversely, in 2023, the average monthly air temperature ranged from 9.3 to 18.8 °C, indicating a decrease compared to 2022 but remaining higher than the multi-annual data. Additionally, the average monthly precipitation for 2023 ranged from 65.6 to 107.9 mm, surpassing the 2022 and the multi-annual monthly averages.

The impact of polymers on grain crop productivity and grain quality: The application of Aquasource polymer in different doses (50, 100, and 150 kg ha^{-1}) demonstrated a notable effect on the morphological features of spring barley, the efficiency indicators of the spikes' structural elements, and the overall yield quantity (see Table 1). Indeed, a noticeable increase in spike length, ranging from 0.5 to 1.0 cm, was observed in the experimental options where Aquasource polymer was applied in different doses compared to the control variant. This increase significantly effected the number of spikelets formed within the spike, thereby affecting the overall grain count as well. Specifically, when the application rate of Aquasource increased from 50 to 100 kg ha^{-1}, there was an observed increase in the number of spikelets per spike by 6.8 to 17.0 compared to the control. Similarly, in the case of grains, the increase ranged from 2.2 to 5.6 grains, respectively. It resulted in a higher weight of grains per spike, with the most significant difference observed during the transition from 50 to 100 kg ha^{-1} version, amounting to 0.06g. Compared to the control group, this increase ranged from 0.12 to 0.26g. It should be noted that when transitioning from 100 to 150 kg ha^{-1} of Aquasource, the difference is insignificant, amounting to only 0.01 g.

A similar pattern is also observed in the case of the weight of grains obtained per 1 square meter, with an increase of 2.8g. When transitioning from 50 to 100 kg ha^{-1} of Aquasource, the difference is noticeable, amounting to 33.4 g. Compared to the control, the difference becomes more pronounced, ranging from 30.9 to 64.3 g. These indicators are influenced by the number of spikes formed in 1 square meter, which increased by 12.0-14.8 compared to the control option. However, in the transition from 100 to 150 kg ha^{-1}, the difference is only one spike.

Table 1. Analysis of productivity indicators and structural elements of spring barley (2022-2023).

Options/variants of the experiment	Height of the stem, cm	Length of the spike, cm	Number of spikelets, pcs.	Number of grains, pcs.	Weight of the grains, g	Number of spikes, pcs.	Weight of the grains, g	Weight of 1000 grains, g	Grain yield, t ha^{-1}
			Per one spike			Per one m^2			
AQS*, 50 kg ha^{-1}	41,1	3,7	34,2	11,4	0,42	227,3	95,5	36,9	0.98
AQS, 100 kg ha^{-1}	38,4	4,0	44,4	14,8	0,56	230,1	128,9	37,8	1,32
AQS, 150 kg ha^{-1}	40,1	4,2	45,0	15,0	0,57	231,1	131,7	38,1	1,38
Control	35,1	3,2	27,4	9,2	0,30	215,3	64,6	34,8	0,66
LSD_{05}	*1,9*	*1,7*	*1,16*	*0,9*	*0,13*	*8,3*	*4,7*	*1,9*	*1,4*
Van, 500 kg ha^{-1}	36,4	3,6	33,0	11,0	0,40	225,8	90,3	36,1	0,93
Van, 1000 kg ha^{-1}	37,1	3,8	38,1	12,7	0,47	229,7	107,9	36,9	1,12
Van, 1500 kg ha^{-1}	38,7	4,7	39,6	13,2	0,49	230,8	113,1	37,2	1,19
Control	35,1	3,2	27,4	9,2	0,30	215,3	64,6	34,8	0,66
LSD_{05}	2,5	0,9	2,8	1,7	0,16	4,7	6,6	2,6	1,9

* AQS – Aquasource

Aquasource also significantly increased the mass of 1000 grains of spring barley, surpassing the control by 2.1-3.3 g, which contributed to the overall yield improvement. The highest yield was observed with Aquasource at 100 and 150 kg ha^{-1} (1.32-1.38 t ha^{-1}), exceeding the control by 0.66-0.72 t ha^{-1}. Increasing the polymer application rate from 100 to 150 kg ha^{-1} resulted in a non-significant yield increase. Therefore, the most efficient application rate was Aquasource at 100 kg ha^{-1}. This efficacy can be attributed to the hydrogels' role in supplying and retaining essential moisture, thereby mitigating the risks of water stress.

Similar trends were observed with Van polymer at 500, 1000, and 1500 kg ha^{-1} application rates, significantly impacting the morphological characteristics and yield of spring barley. The most effective dose was 1000 kg ha^{-1}.

Under rain-fed conditions, water scarcity reduced grain yield, as evidenced by the experiment's control groups. Specifically, spring barley and winter wheat yields were lower in 2022 compared to 2023, emphasizing the significant impact of weather conditions and water scarcity on crop productivity.

Aquasource and Van polymers were tested on winter wheat using identical application rates (see Table 2). Aquasource increased spike length by 2.1-3.6 cm, with the highest increase observed at the dosage of 100 kg ha^{-1}. Spikelets and grain numbers also increased significantly across all experimental variants. Compared to the control (23.4 grains), the increase ranged from 0.8 to 3.0 grains, with the most significant increase occurring during the transition from 50 to 100 kg ha^{-1}, resulting in an additional 2 grains. However, with further increases in the amount of polymer (up to 150 kg ha^{-1}), the additional increment was only 0.2 grains.

The weight of grains obtained per square meter increased by 22.2-76.0 grams compared to the control, with a minimal increase (3.6 grams) observed from 100 to 150 kg ha^{-1}. The 1000-grain weight showed minor differences of 0.1 grams. In all Aquasource-utilizing options, the actual grain yield differed significantly from the control, with values ranging from 0.21 to 0.8 t ha^{-1}.

Similar patterns were also observed in the experimental options with Van application in winter wheat plots. The option utilizing Van polymer at a dosage of 1000 kg ha^{-1} was considered the most optimal choice.

Table 2. Analysis of productivity indicators and structural elements of winter wheat (2022-2023).

Options/ variants of the experiment	**Height of the stem, cm**	**Length of the spike, cm**	**Number of spikelets, pcs.**	**Number of grains, pcs.**	**Weight of the grains, g**	**Number of spikes, pcs.**	**Weight of the grains, g**	**Weight of 1000 grains, g**	**Grain yield, t ha^{-1}**
			Per one spike			Per one m^2			
AQS*, 50 kg ha^{-1}	70,5	7,8	8,1	24,2	0,93	225,4	209,6	38,4	2,11
AQS, 100 kg ha^{-1}	75,2	9,1	8,7	26,2	1,05	247,4	259,8	40,1	2,69
AQS, 150 kg ha^{-1}	69,3	9,3	8,8	26,4	1,06	248,5	263,4	40,2	2,70
Control	64,2	5,7	7,8	23,4	0,87	215,3	187,4	37,1	1,90
LSD_{05}	*3,8*	*1,0*	*1,4*	*3,5*	*0,1*	*4,1*	*6,9*	*2,98*	*1,57*
Van, 500 kg ha^{-1}	72,2	6,8	7,9	23,8	0,91	216,9	197,4	38,2	2,01
Van, 1000 kg ha^{-1}	75,8	7,4	8,5	25,7	1,01	226,1	228,4	39,2	2,32
Van, 1500 kg ha^{-1}	75,2	7,5	8,7	26,1	1,03	225,3	232,1	39,5	2,41
Control	64,2	5,7	7,8	23,4	0,87	215,3	187,3	37,1	1,90
LSD_{05}	*2,9*	*1,4*	*0,9*	*1,9*	*0,12*	*6,2*	*6,6*	*1,88*	*2,78*

* AQS – Aquasource

Our experiments have demonstrated the positive impact of using Aquasource and Van polymers on grain crop yield in rain-fed agricultural conditions, primarily attributed to enhanced soil moisture retention. This finding aligns with multiple studies indicating superior performance of hydrogel application across parameters such as taller plant growth, increased spike count, heavier 1000-grain weight, and higher grain yield [29-31]. Earlier work by Pahlevanyan *et al*. highlighted the positive influence of Aquasource hydrogel on melon cultivation, enhancing plant development and productivity [32]. Hydrogel polymers mitigate water stress and benefit plant growth by enhancing soil moisture availability and improving plant establishment [33-36]. Therefore, the adoption of polymer usage in water-scarce or rain-fed regions is justified.

The grain from the top-performing experimental variants (Aquasource at 100 kg ha^{-1} and Van at 1000 kg ha^{-1}) underwent chemical composition analysis at the "Standard Dialog" laboratory. The application of hydrogels has resulted in an increase in overall yield and enhanced the nutritional quality of the grain , evidenced by higher concentrations of carbohydrates, proteins, and gluten, as shown in Table 3. Among the tested variants, the highest protein content was observed with the application of Aquasource at a rate of 100 kg ha^{-1} (14.6%), followed by Van at 1000 kg ha^{-1} (12.7%). These values exceeded those of the control by 4.5-6.4%. Similarly, significant increases in gluten content were recorded with Aquasource (39.4%) and Van (39.1%), surpassing the control by 19.7-20.0%.

Table 3: Impact of Polymers on wheat grain quality

Options/variants of the experiment	Chemical composition of wheat grains, %			
	proteins	**gluten**	**dry matter**	**carbohydrates**
Aquasource, 100 kg ha^{-1}	14.6	39.4	90.8	62.9
Van, 1000 kg ha^{-1}	12.7	39.1	91.0	63.6
Control	8.2	19.4	91.2	57.36

While the control variant exhibited a slightly higher percentage of dry matter content in grains, the difference from the polymer application options was only 0.2-0.4%. Additionally, the Van and Aquasource application variants recorded the highest carbohydrate content (62.9-63.6), surpassing the control by 5.6-6.3%.

The analysis indicates that hydrogels significantly enhance soil moisture retention, ensuring a consistent and sufficient water supply for wheat plants. This steady hydration facilitates efficient nutrient uptake, essential for synthesizing carbohydrates, proteins, and gluten. By reducing water stress, Aquasource and Van hydrogels promote heightened metabolic activities and robust growth, ultimately leading to grains with higher nutrient content. Additionally, hydrogels enhance the soil's nutrient retention and release capabilities, promoting the availability of essential elements [37-38].

This nutrient-rich environment facilitates optimal photosynthesis, which is crucial for the synthesis of proteins and other vital components in wheat grains. Furthermore, the improved growth conditions enable wheat plants to accumulate more biomass, resulting in higher yields and superior grain quality. These combined benefits contribute to optimizing wheat cultivation practices, enhancing crop productivity and quality. The improved growth conditions ensure the production of grains with elevated protein, gluten, and carbohydrate content, thereby increasing the nutritional and functional value of wheat grains and improving their end-use quality.

The high protein content in wheat provides numerous nutritional benefits that enhance its value as a functional food. These benefits include supporting muscle maintenance and growth, aiding in weight management, regulating blood sugar levels, and contributing to overall metabolic and cardiovascular health. Wheat protein's versatility in various food applications makes it a key component in developing nutritious and functional food [39]. The regulation of human energy balance is intricately connected to the catabolism of primary proteins derived from cereal crops. These proteins are essential for maintaining critical physiological functions necessary for human life.

The high gluten content in wheat also provides multiple nutritional benefits that enhance its value as a functional food in a non-gluten-free diet. It provides a good source of protein, supports digestive health, enhances nutrient absorption, promotes satiety, and contributes to cardiovascular and bone health. The high carbohydrate content in wheat offers numerous health benefits, including sustained energy, brain function support, digestive health, weight management, cardiovascular health, and blood sugar control. These benefits highlight the importance of carbohydrates in a balanced and nutritious diet. Thus, our research findings provide an opportunity to enhance not only the yields but also the functional value and end-use quality of the grain, potentially improving its nutritional benefits and overall contribution to human health.

The influence of polymers on disease development in grain crops: Fungal diseases threaten many of the world's most important crops. They can significantly impact crop yield and quality, leading to substantial economic losses and food insecurity [22; 40].

Investigating the impact of Aquasource and Van polymers on disease development in winter wheat and spring barley under natural infection in rain-fed conditions, we conclude that the remarkably dry climatic conditions in Spitak during the 2022 vegetation period led to the emergence of the following phytosanitary issues in the experimental fields of both spring barley and winter wheat: *Fusaruim* crown rot (FCR) and *Fusaruim* head blight (FHB) (*Fusarium graminearum* Schwabe); Covered smut (*Ustilago hordei* (Pers.) Lagerh.); Common bunt (*Tilletia caries* (DC.)Tul.); Stem rust (*Puccinia graminis* Pers. *f. sp. secalis* (Erikss. et Henn.)); Stripe rust (*Puccinia striiformis f. sp. tritici* (Pst)).

According to the assessment, the average infection of cereals with fungal diseases ranged from 2.5% to 5.7% (see Figure 2), notably low due to unfavorable weather conditions for their development. The highest disease incidence on barley (4.8%) was observed in the case of stem rust, while the lowest (2.8%) was noted in barley covered smut. For winter wheat, the highest disease incidence was observed with FHB (5.7%), while the lowest was recorded with common bunt (2.5%). It's worth mentioning that the data on the incidence and severity of fungal diseases in spring barley and winter wheat showed minimal variation across the different experimental variants.

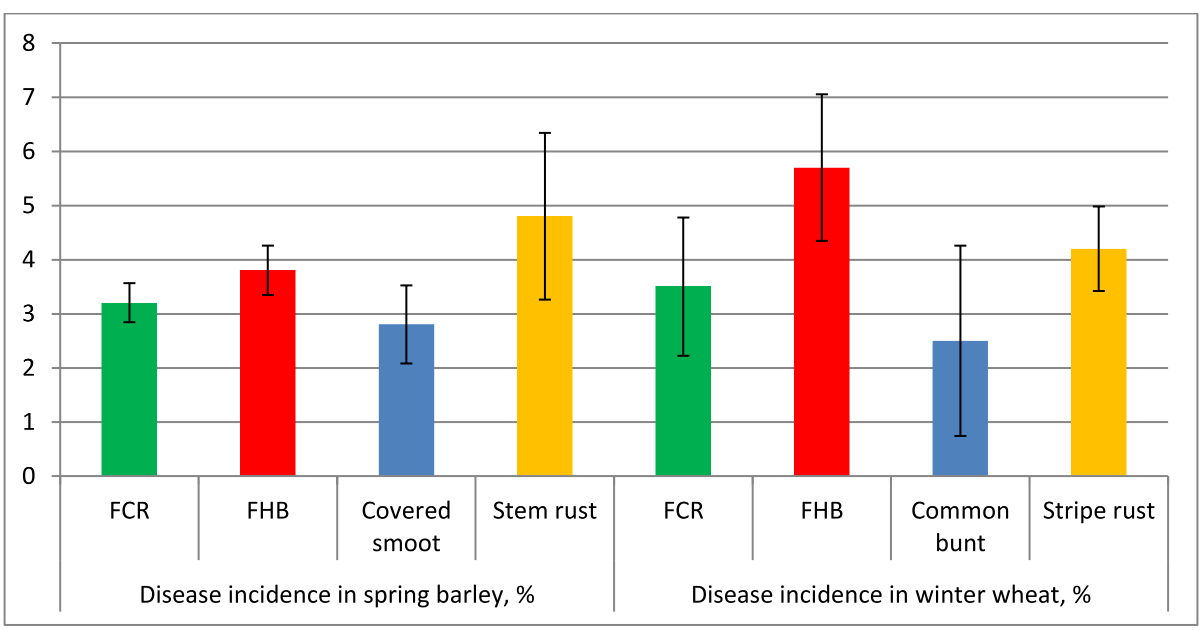


Figure 2. Disease incidence in spring barley and winter wheat, 2022: FCR - *Fusaruim* crown rot; FHB - *Fusaruim* head blight

Comparing the infection rates of winter wheat and spring barley with *Fusaruim* crown rot across different experimental options, it was observed that during 2023, the highest infection rate (12.4% for winter wheat and 8.7% for spring barley) occurred in the variant utilizing Aquasource polymer at 150 kg ha^{-1} rate, while the lowest disease incidence of crown rot (5.9% and 4.3%, respectively) was observed in the option with Aquasource applied at 50 kg ha^{-1} (see Figure 3).

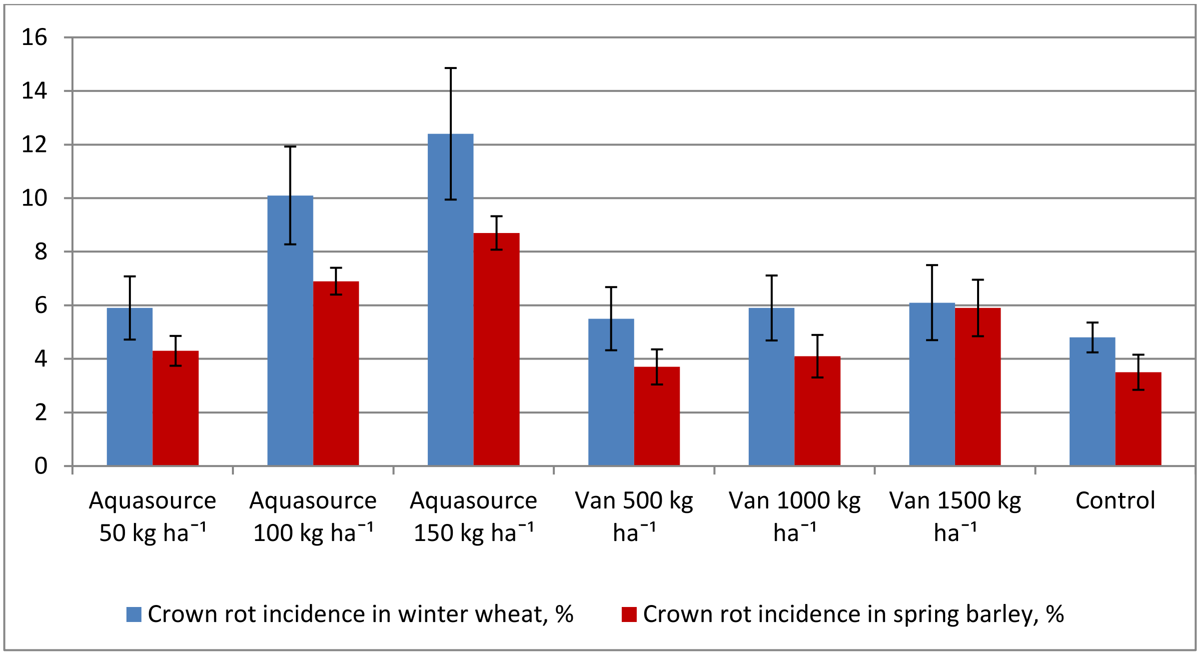


Figure 3. *FCR* incidences in winter wheat and spring barley, 2023.

In the options utilizing Van polymer, the highest incidence of crown rot (6.1% for winter wheat and 5.9% for spring barley) was recorded with a dose of 1500 kg ha^{-1}, while the lowest disease incidence (5.5% and 3.7%, respectively) was observed in the option with 500 kg ha^{-1}. Notably, crown rot incidence indicators in spring barley were lower compared to winter wheat. The increase in polymer dosage, observed in both Aquasource and Van variants, increased crown rot infection. Aquasource exhibited a notable increase, ranging from 5.9 to 12.4% for winter wheat and 4.3 to 8.7% for spring barley, compared to the Van options. Nevertheless, it's important to highlight that in the control version of the experiment, the lowest incidence of crown rot was observed (4.8% for winter wheat and 3.5% for spring barley). This suggests that the utilization of polymers substantially impacts the progression of crown rot.

Our findings are congruent with the investigations conducted by multiple researchers. Hydrogel polymers can have diverse effects on plant diseases, which may be beneficial or detrimental [41]. They enhance plant resilience to abiotic stress and can also create a conducive environment for certain soil-borne pathogens, influencing disease severity and plant-pathogen interactions. Hydrogels have been observed to promote fungal and bacterial growth, thereby creating a pathogen-friendly environment and contributing to plant diseases [42-43]. Additionally, soil abiotic properties also regulate plant disease, with higher available nitrogen potentially increasing disease susceptibility by favoring pathogen growth and reducing plant immunity [44-45]. Furthermore, research by Smiley and Machado [46] highlighted the significant influence of climatic conditions on *Fusarium* crown rot occurrence in winter wheat, which is closely associated with moisture and evaporative stress in dry semi-arid environments. According to Kolesnikow *et al*., pre-soaking wheat seeds in a new protein hydrolysate before sowing, combined with introducing acrylic hydrogel into the soil, significantly improved wheat yield. Simultaneously, the incidence of brown and yellow rusts decreased by up to 28.3%, and root rot by 5.6% [47].

Crown rot infection can significantly reduce yield and adversely affect several quality parameters of wheat grain. Specifically, grain infected with FCR exhibited a notable decrease in protein concentration, indicating that crown rot infection disrupts the extraction, translocation, and/or redistribution of nitrogen within the plant [48], thereby decreasing the functional value of the grain.

Analyzing the data presented in Figure 4 reveals that in the Aquasource polymer-utilizing variants, the infection rate of winter wheat spikes with FHB during the milk ripening stage in 2023 ranged from 21.5% to 25.7%. The average intensity of the disease was observed to be between 1.1 and 1.3 points, with the degree of development ranging from 6.5% to 7.9%. In contrast, with the Van polymer application, the incidence of FHB was higher, ranging between 28.8% and 30.2%. The average disease severity spanned from 1.7 to 1.9 points, while the degree of disease development varied between 12.3% and 13.7%.

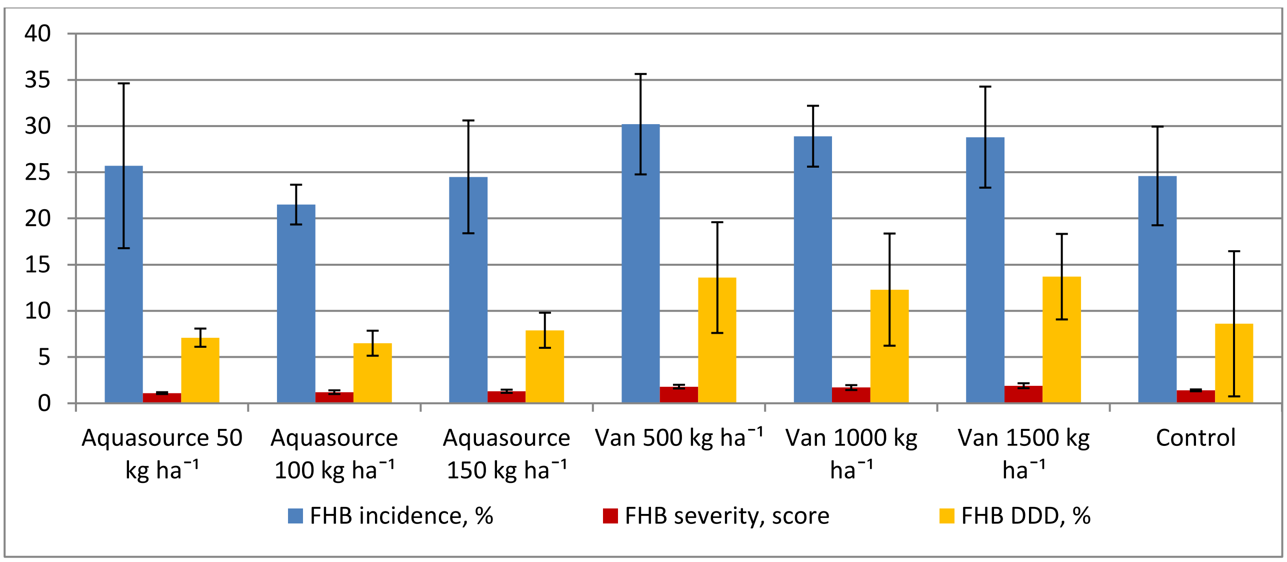


Figure 4. FHB development in winter wheat, 2023.

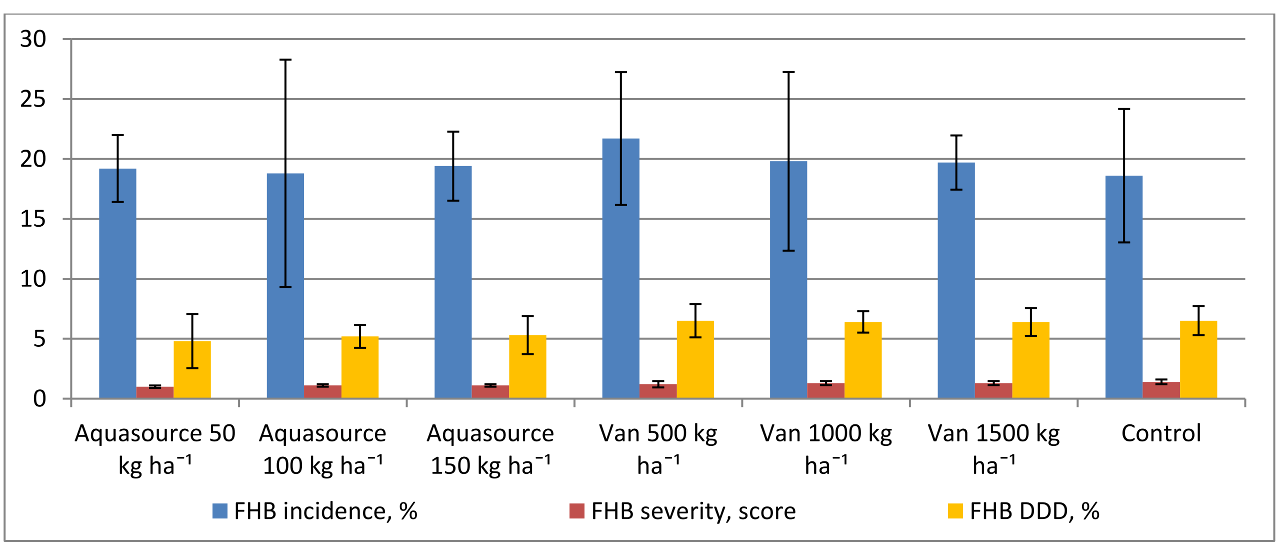


Figure 5. FHB development in spring barley, 2023.

Indeed, the incidence and severity of FHB were higher in the Van polymer application variants compared with the Aquasource options. However, the metrics from the control variants of the experiment (FHB incidence was 24.6%) did not show significant differences from the polymer-applied variants. This suggests that the utilization of polymers did not significantly impact the progression of FHB. It is important to note that climatic conditions greatly influence the incidence of Fusarium head blight.

A similar pattern is also observed in the case of spring barley (see Figure 5). Still, severity, intensity of FHB, and disease development degree indicators were relatively lower than those observed in winter wheat. However, the metrics from the control variants of the experiment (FHB incidence was 18.6%) did not show significant differences from the polymer-applied variants, where FHB incidence ranged from 18.38% to 21.7%.

According to our observations, total precipitation in 2023 (370.1 mm) significantly surpassed the region's multi-annual average (298 mm). Peak precipitation in 2023 coincided with the heading and ripening stages of cereal grains, which are the most critical stages for FHB infection. As noted by Avagyan and Martirosyan [49], this favored more intense disease development.

Climatic conditions have a profound impact on pathogens, the diseases they cause, and their interactions [50]. Optimal temperatures may shorten the incubation period, potentially increasing the number of polycyclic pathogen generations per growth period [51]. Additionally, environmental conditions can affect disease resistance [52]. An extended flowering stage, induced by low temperatures and prolonged rainy periods, elevates the susceptibility to FHB epidemics, with the severity being predominantly influenced by air temperature and relative humidity [53].

It should be noted that FHB not only reduces grain yield but also grain quality [54]. Moreover, kernels infected with FHB are the primary source of deoxynivalenol (DON) [55], a mycotoxin that can have severe adverse effects on human health. DON contamination in grains can lead to various health issues, including nausea, vomiting, diarrhea, abdominal pain, headaches, and acute exposure symptoms [56]. Chronic exposure to DON, even at low levels, can impair immune function, affect nutrient absorption, and potentially lead to long-term health problems [57]. Therefore, the presence of FHB in grain crops not only impacts agricultural yield and quality but also poses significant risks to food safety and public health.

In conclusion, FHB infection diminishes wheat quality by negatively impacting protein and gluten content. The severity of *Fusarium* infection correlates inversely with the value of wheat quality parameters [58].

CONCLUSION

The application of Aquasource and Van polymers at different rates significantly improved the morphological features and yield of both spring barley and winter wheat. Specifically, Aquasource at 100 kg ha^{-1} and Van at 1000 kg ha^{-1} were identified as optimal doses, enhancing spike length, spikelet number, grain count, and overall grain weight. Notably, under rain-fed conditions, these polymers mitigated water stress and enhanced soil moisture retention, supporting better plant growth and boosting grain crop productivity.

This study is novel in its dual focus on agronomic and nutritional benefits. The polymers not only improved crop morphology and yield but also increased the concentrations of carbohydrates, proteins, and gluten as revealed by chemical analysis. This enhancement in nutritional value and end-use quality of the grains positions them as superior functional foods. This research provides a significant advancement in agricultural productivity and food science, offering practical solutions for farmers and valuable insights for developing nutritionally enriched grains.

The utilization of polymers has a substantial impact on the progression of FCR. Specifically, Aquasource application led to higher crown rot incidence compared to Van options, with increased polymer dosage correlating with elevated FCR incidence. FCR infection can significantly reduce yield and adversely affect wheat grain quality by decreasing protein concentration and reducing the grain's functional value.

In contrast, the utilization of polymers did not substantially impact the progression of FHB, which is greatly influenced by climatic conditions. Wheat kernels infected with FHB are the primary source of deoxynivalenol (DON). Therefore, the presence of FHB in grain crops impacts agricultural yield and quality and poses significant risks to food safety and public health, thereby reducing the grain's functional value.

Overall, this dataset serves as a fundamental basis for advancing research in polymer applications aimed at enhancing agricultural crop productivity, particularly within irrigated environments in RA.

Abbreviations: RA: Republic of Armenia, AQS: Aquasource, FCR: *Fusarium* crown rot.), FHB: *Fusarium* head blight, DON: deoxynivalenol.

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Authors' contributions: GA conceptualization, methodology, validation, resources, data curation, writing-original draft preparation, writing-review, and editing; SD and AE - resources, writing-review, and editing; AA - statistical analysis, writing-review, and editing; SS conceptualization, resources, writing-review, and editing; HM - conceptualization, validation, data curation, writing-original draft preparation, writing-review, editing, and supervision. All authors read and approved the final version of the manuscript.

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