Research Article

Influence of Some Selected Superabsorbent Polymers on Vegetative Growth and Yield of Soft Wheat (*Triticum aestivum* L.) Genotypes in Thi-Qar Governorate, Iraq

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Abstract | This study investigated the effect of some environment-friendly green technologies comprising the administration of some superabsorbent polymers on the growth and yield characteristics of five exotic cultivars of soft wheat (*Triticum aestivum* L.). These wheat genotypes were introduced to Thi-Qar Governorate of Iraq from Syria, Iran, and Russia. The experimental design was factorial following randomized complete blocking (RCBD) with three replications for each treatment. The treatment factors included three types of green technologies (GT), *i.e.,* potassium polyacrylate (GT1), Akrotek polyketone (GT2), and local starch (GT3) and five wheat genotypes *i.e.,* T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Results showed that potassium polyacrylate (GT1) significantly enhanced the average plant height (104.87 cm), foliar contents of chlorophyll (0.771 SPADs), leaf area (50.66 cm^2), number of tillers (437.6 tillers m^{-2}), grain yield (7.162 ton ha^{-1}), and per spike number of grains (65.33 grains). Moreover, treatment of Akrotek polyketone (GT2) outperformed other treatments in 1000-grain weight (42.24 g). The genotype AC 113 (T1) exhibited the highest values for foliar chlorophyll content (0.763 SPADs), plant height (109.00 cm), leaf area (59.40 cm^2), grain yield (6.911 ton ha^{-1}), and 1000-grain weight (44.50 g). Conversely, genotype IR 01 (T4) showed superiority in the number of grains per spike (68.44 grains) and tillers (417.3 tillers m^{-2}). The interaction treatment GT1T1 exhibited the maximum average grain yield (7.847 ton ha^{-1}), not significantly different from the interaction treatments GT1T4, GT2T1, GT2T4, and GT1T3, which yielded 7.463, 7.357, 7.323, and 7.300 ton ha^{-1} grains, respectively. These findings underscore the importance of superabsorbent polymers (GT1 and GT2 green technologies) in enhancing the water and nutrient availability in the soil, which positively impacted the productivity of the introduced wheat genotypes.

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Introduction

Iraq is considered one of the major wheat-cultivating regions of the world, yet its productivity remains low and does not align with the population growth rate (Abduljabbar and Abd, 2025; Joudah Yasir, 2022). Therefore, scientific efforts must focus on developing new varieties suitable for regional conditions and with

high productivity potential (Abbas and Alkhamisi, 2025). The development, propagation, and distribution of new crop varieties, once their success and superiority are established, represent a primary goal of agricultural practice. The introduction of genotypes is considered one of the important methods in this field (Al-Falahi *et al.*, 2021; Sulayman and Alrijabo, 2022).

The correct and scientifically sound approach in all agriculturally advanced countries involves a continuous influx and retention of new crop genotypes with an aim to provide alternatives to local varieties that may degrade due to their continuous cultivation over several seasons within a particular set of environmental conditions (Duc *et al.*, 2015). Additionally, genotypes that do not excel in yield can be retained for their genetic reserves of other superior traits (Ahmed and Abdul-khader, 2017). Climate change currently stands as one of the most critical factors affecting wheat production and water availability worldwide, including in Iraq (Salman *et al.*, 2021; Al-Saidan, 2025a).

Water is fundamental to sustainable development and a common denominator for global challenges (Salem *et al.*, 2022). Water management is a key component of sustainable development, as developing countries, including Iraq, suffer from poor water management that could lead to the deterioration of agricultural processes (Ati *et al.*, 2019). Modern management involves controlling and optimizing water use to increase the nutrient availability within the rhizosphere. It involves utilizing natural and artificial resources to supply the crop with its water needs (Ati *et al.*, 2020; Al-Saidan, 2025b). Effective water management requires the use of certain methods that increase crop productivity and reduce the effects of loss, soil, and environmental pollution (Alharbi *et al.*, 2024). Among these methods is the application of green technologies such as superabsorbent polymers capable of absorbing water, saline solutions, and biological fluids 10 to 1000 times their own mass owing to their 3-dimensional hydrophilic polymer networking in their chemical structure (Qiouch, 2023; Damiri *et al.*, 2024).

Superabsorbent polymers are utilized to enhance water and nutrient use efficiency, as they can provide these resources to plants and release them slowly, in addition to their ability to improve soil physical and chemical properties (Oladosu *et al.*, 2022; Yasir, 2023). The use of these technologies will help find solutions for agricultural processes amidst current climate changes, water scarcity, and mismanagement. This approach allows for the cultivation and expansion of agricultural areas despite limited water availability, without threatening the environment or natural resources (Krasnopeeva *et al.*, 2022; Niu *et al.*, 2025). To identify the alternative varieties to the local ones, this study aimed to evaluate some soft wheat genotypes introduced from Syria, Iran, and Russia under the influence of environment-friendly green technologies (*i.e.,* some superabsorbent polymers) with high water absorbency on their productivity under the conditions of Thi-Qar Governorate of Iraq.

Materials and Methods

Study area and treatments

This study assessed under field conditions the effect of some superabsorbent polymers with high water absorption and retention potential on the growth and yield of five soft wheat genotypes. These genotypes were introduced to Thi-Qar Governorate of Iraq from Syria, Iran, and Russia. The experimental design was factorial following a randomized complete blocking (RCBD) with three replications for each treatment. The experiment was performed in the 2024-2025 wheat growing season. The first factor comprised three types of green technologies (GT) polymers, *i.e.,* potassium polyacrylate (GT1), Akrotek polyketone (GT2), and local starch (GT3). The second factor included five soft wheat genotypes, *i.e.,* T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype).

Experimental protocol

The experimental protocol consisted of the administration of polymer granules by mixing them with the soil at the time of seedbed preparation. The rate of application was according to the product guidelines for potassium polyacrylate and Akrotek @ 50 kg ha^{-1}. For starch, the same mixing ratio as the polymers was adopted. Ten seeds of each wheat genotype were sown per pot. Recommended N and P fertilizer applications were applied based on the advisory leaflets from the Ministry of Agriculture of Iraq. The following traits of wheat plants were assessed, *i.e.,* plant height (cm), leaf area (cm^2), foliar chlorophyll content (SPAD units), number of grains per spike, number of tillers, grain yield (tons ha^{-1}), and 1000-grain weight (g) (Manack *et al.*, 2014).

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Statistical analysis

Data regarding the above-mentioned plant growth and yield-related traits were statistically analyzed using Genstat 12 statistical software. Factorial analysis of variance was run to assess the impact of treatments on measured parameters, and treatment means were compared using the least significant difference (LSD) post-hoc test at a standard level of probability ($P \leq 0.05$).

Results and Discussion

Effect of treatments on average plant height

According to the results, the polymers (green technologies), wheat genotypes, and their interactions significantly affected the average plant height, as shown in Table 1. The highest average plant height (104.87 cm) was observed with potassium polyacrylate (GT1), while the lowest average height (96.07 cm) was recorded with starch (GT3). This superiority of potassium polyacrylate can likely be attributed to its greater capacity to retain water and nutrients compared to other green technologies, thereby enhancing their availability to the plant during growth stages. This finding is consistent with (Al-Amiri and Al-Baraka, 2023; Al-Saidan, 2025a). Genotypes differed in this trait. Genotype AC 113 (T1) exhibited the highest average height (109.00 cm), whereas genotype RU 10 (T5) showed the lowest (89.00 cm). Such observed variation in average plant height might be because of the genetic differences in node numbers and internode length, which are crucial traits distinguishing genotypes. Additionally, differences in their content of growth regulators, especially auxins and gibberellins responsible for cell elongation and expansion, could be a factor (Al-Saidan *et al*., 2019a; Mohammad *et al*., 2022). The GT1T1 treatment exhibited the highest average plant height (111.33 cm), with no significant difference from GT1T4, GT2T1, and GT1T2 (111.00, 110.33, 109.33 cm, respectively), while the GT3T5 treatment gave the lowest one (85.67 cm). These results demonstrate

Table 1: *Impact of some superabsorbent polymer hydrogels on the average plant height of different wheat genotypes under pot experiment.*

Green Technologies	Genotypes					Mean
	T1	T2	T3	T4	T5	
GT1	111.33	109.33	101.00	111.00	91.67	104.87a
GT2	110.33	104.67	97.00	105.67	89.67	101.47a
GT3	105.33	97.00	93.33	99.00	85.67	96.07b
Means	109.00	103.67	97.11	105.22	89.00	
$L.S.D_{0.05}$	Green Technologies	Genotypes	Interaction of Green Technologies and Genotypes			
	1.014	1.309	2.268			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at α = 0.05).

Table 2: *Impact of some superabsorbent polymer hydrogels on the average foliar chlorophyll content of different wheat genotypes under pot experiment.*

Green Technologies	Genotypes					Mean
	T1	T2	T3	T4	T5	
GT1	0.813	0.777	0.760	0.783	0.720	0.77a
GT2	0.777	0.720	0.720	0.743	0.670	0.73a
GT3	0.700	0.680	0.660	0.693	0.657	0.68b
Means	0.763	0.726	0.713	0.740	0.682	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of green technologies and genotypes			
	0.015	0.020	0.034			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at α = 0.05).

the differential response of wheat genotypes to GT1 and GT2 polymers' role in increasing the water and nutrient availability, which positively impacted this trait.

Table 3: *Impact of some superabsorbent polymer hydrogels on the average leaf area of different wheat genotypes under pot experiment.*

Green Technologies	Genotypes					Mean
	T1	T2	T3	T4	**T5**	
GT1	62.56	52.29	44.20	54.11	40.16	50.66a
GT2	60.80	50.12	38.12	52.60	35.12	47.35ab
GT3	54.85	46.42	34.18	50.10	30.14	43.14b
Means	59.40	49.61	38.83	52.27	35.14	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of green technologies and genotypes			
	2.556	3.299	5.714			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at $\alpha = 0.05$).

Effect of treatments on foliar chlorophyll content

Table 2 reveals that the highest average chlorophyll content (0.771 SPADs) was achieved with potassium polyacrylate (GT1), while the lowest average (0.678 SPADs) was observed with starch (GT3). Potassium polyacrylate likely maintained the higher moisture content, leading to increased root growth and subsequently enhanced vegetative growth and chlorophyll content in the plant (Singh *et al*., 2018; Yasir, 2021c). Genotype T1 showed the highest average (0.763 SPADs), whereas genotype T5 had the lowest average (0.682 SPADs). The genotype and variations in growth factors significantly contributed to the differences in this trait among the introduced genotypes. Physiological and phenotypic plant traits change with varying environmental factors. A genotype with a greater ability to adapt will optimally utilize elements of the new environment (Al-Saidan *et al*., 2019b; Khursheed and Zhala, 2023). The interaction treatment GT1T1 outperformed others, giving the maximum chlorophyll content (0.813 SPADs), while the treatment GT3T5 showed the minimum content (0.657 SPADs). The capability and adaptability of genotype T1, and its utilization of growth factors, were superior to those of the other genotypes.

Impact of treatments on average leaf area

Results as shown in Table 3 indicate the highest (50.66 cm^2) and lowest (43.14 cm^2) average leaf area by the application of potassium polyacrylate (GT1) and starch (GT3), respectively. Potassium polyacrylate likely served as a larger reservoir for water and essential nutrients for the plant throughout the vegetative growth period compared to other green technologies. This result is consistent with (Alabar, 2021; Negim *et al*., 2024). Table 3 also shows the superiority of genotype T1, yielding the maximum average leaf area (59.40 cm^2), while genotype T5 exhibited the minimum one (35.14 cm^2). Genotypes may differ in their response to temperature and photoperiod that ultimately impact the reproductive growth stages and vegetative growth duration of wheat plants. This is attributed to the variation among genotypes and their differential response to the study area's prevailing environmental situation. Genotypes with a longer vegetative growth period will have more time to produce a larger leaf area than those with shorter vegetative growth (Yasir, 2020; Mohammad *et al*., 2022). The treatments GT1T1 and GT3T5 yielded the highest and lowest average grain yield of 62.56 and 30.14 cm^2, respectively. This increase might be because of an increase in the plant dry matter resulting from the capacity and role of GT1 in enhancing water and nutrient availability, in addition to genotype T1's ability to optimally utilize environmental elements compared to other genotypes.

Table 4: *Impact of some superabsorbent polymer hydrogels on the average number of tillers of different wheat genotypes under pot experiment.*

Green technologies	Genotypes					Mean
	T1	T2	T3	T4	**T5**	
GT1	477.0	412.7	436.0	472.3	390.0	437.6a
GT2	390.7	355.0	375.0	435.0	345.0	380.1ab
GT3	341.0	311.3	320.0	344.7	287.3	320.9b
Means	402.9	359.7	377.0	417.3	340.8	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of green technologies and genotypes			
	15.67	20.23	35.03			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at $\alpha = 0.05$).

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Treatments' effect on the average number of tillers

Potassium polyacrylate (GT1) continued to show superiority, yielding the highest average for this trait at 437.6 tillers m^{-2}. Conversely, starch (GT3) continued to lag, yielding the lowest average of 320.9 tillers m^{-2} (Table 4). The number of tillers is significantly influenced by water and nutrient availability, especially during the early stages of plant growth. Moreover, green technologies, particularly potassium polyacrylate, maintained water and nutrient availability in the soil for a relatively longer period and released them slowly according to the plant's needs and growth stage, which reflected positively on the increased number of tillers per plant (Yasir, 2021b; Krasnopeeva *et al.*, 2022). Table 4 indicates that the number of tillers varied among genotypes. Genotype T4 excelled by yielding the maximum average number of tillers (417.3 tillers m^{-2}), not significantly different from genotype T1 (402.9 tillers m^{-2}), while genotype T5 showed the lowest average of 340.8 tillers m^{-2}. Genotypes vary in their ability to produce tillers, which are critical yield components, as this trait is determined during early plant life stages. The differing nature of genotypes and their varying responses to new environmental conditions were likely the main reasons for the differences in the average of this trait. Genetic and environmental interactions may have contributed to the expression and superiority of certain traits that might not have been present in the genotype's original breeding environment (Al-Saidan, 2021). The treatment GT1T1 yielded the highest average of 477.0 tillers m^{-2}, not significantly different from GT1T4 (472.3 tillers m^{-2}), while GT3T5 showed the lowest average of 287.3 tillers m^{-2}. This result demonstrates the ability of genotypes T1 and T4 to utilize environmental elements, including green technologies, at the study site, which clearly reflected on the average of this trait compared to individual averages (Yasir, 2021a; Negim *et al.*, 2024).

Effect of treatments on the average number of grains per spike

Results indicate that the highest average of grain number per spike (65.33 grains) was achieved with GT1, while the lowest average (61.80 grains) was observed with GT3 (Table 5). The outperformance of GT1 can likely be attributed to its ability to increase water and nutrient availability more effectively than other green technologies, which positively impacted vegetative growth and reduced competition among plant organs during tiller and spike formation and development (Table 1, Table 4). Furthermore, GT1 enhanced photosynthetic efficiency and increased its products (Table 2, Table 3), leading to a reduction in floret abortion by minimizing inter-floret competition for assimilates, thereby increasing the per spike grain number (Alabar, 2021). Genotype T4 exhibited the highest average of grain number per spike (68.44 grains), with no significant difference from genotype T1 (67.33 grains), while genotype T5 exhibited the lowest number of grains per spike (55.00 grains) (Table 5). This can be attributed to the genetic differences among genotypes, particularly in the early stages of floral primordia formation, as the number of grains per spike is a quantitative trait largely linked to genetic factors (Mohammad *et al.*, 2022). The treatment GT1T4 yielded the highest average of 70.00 grains, not significantly different from GT1T1, GT3T4, GT3T1, GT2T1, GT1T3, and GT2T2 (69.00, 69.00, 67.00, 66.00, 65.00, 65.00 grains, respectively), while the interaction treatment GT2T5 gave the lowest number of grains per spike (50.00 grains). In addition to the genetic makeup and its capability to develop a greater number of floral primordia, other factors related to growth nature and its relationship with environmental elements also play a role. Genotypes with a greater ability to utilize and benefit from these elements will produce more grains per spike (Grabiński and Wyzińska, 2018).

Table 5: *Impact of some superabsorbent polymer hydrogels on the average number of grains per spike of different wheat genotypes under pot experiment.*

Green technologies	Genotypes					Mean
	T1	T2	T3	T4	**T5**	
GT1	69.00	62.67	65.00	70.00	60.00	65.33a
GT2	66.00	65.00	65.33	66.33	50.00	62.53b
GT3	67.00	58.00	60.00	69.00	55.00	61.80b
Means	67.33	61.89	63.44	68.44	55.00	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of green technologies and genotypes			
	2.791	3.604	6.242			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at $\alpha = 0.05$).

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Table 6: *Impact of some superabsorbent polymer hydrogels on the average 1000-grain weight of different wheat genotypes under pot experiment.*

Green technologies	Genotypes					Mean
	T1	T2	T3	T4	**T5**	
GT1	44.67	40.48	40.25	43.15	42.39	42.19a
GT2	49.74	38.44	35.33	45.66	42.03	42.24a
GT3	39.11	35.16	32.16	38.80	38.21	36.69b
Means	44.50	38.03	35.91	42.54	40.88	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of Green Technologies and Genotypes			
	1.581	2.042	3.536			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at α = 0.05).

Table 7: *Impact of some superabsorbent polymer hydrogels on the average grain yield of different wheat genotypes under pot experiment.*

Green technologies	Genotypes					Mean
	T1	T2	T3	T4	**T5**	
GT1	7.847	7.000	7.300	7.463	6.200	7.16a
GT2	7.357	6.900	7.033	7.323	5.700	6.86a
GT3	5.530	4.720	4.767	5.000	4.433	4.89b
Means	6.911	6.207	6.367	6.596	5.444	
$L.S.D_{0.05}$	Green technologies	Genotypes	Interaction of green technologies and genotypes			
	0.319	0.412	0.713			

GT1: potassium polyacrylate, GT2: akrotek polyketone, GT3: Local starch, Wheat genotype T1: AC 113, T2: AC 901, T3: AC 59 (Syrian genotype), T4: IR 01 (Iranian genotype), T5: RU 10 (Russian genotype). Small alphabets with mean values indicate statistically significant difference among treatments (factorial ANOVA; LSD at α = 0.05).

Impact of treatments on the average 1000-grain weight

Akrotek polyketone (GT2) yielded the highest average of 1000-grain weight (42.24 g), with no significant difference from potassium polyacrylate (GT1), which yielded 42.19 g, while starch (GT3) showed the lowest average 1000-grain weight (36.69 g) (Table 6). This might be attributed to less competition in GT2 treatment, especially since this treatment resulted in a lower grain number per spike as compared to GT1 (Table 5). These findings corroborate the results of Al-Jobouri and Amjad (2020). Genotype T1 outperformed others by yielding the highest average of 44.50 g, with no significant difference from genotype T4 (42.54 g), while genotype T3 exhibited the lowest 1000-grain weight (35.91 g). This is due to the genotype's ability to utilize growth factors and achieve a balance in grain competition within a single spike. As a result of the lower grain count for genotype T1 and its ability to utilize growth factors, the amount of assimilates and deposition in individual grains increased, leading to higher grain weight, which compensated for the grain number per spike (Table 5). This result is in line with the findings of Grabiński and Wyzińska (2018) and Mohammed *et al.* (2021). The treatment GT2T1 excelled by yielding the highest average of 49.74 g, while the treatment GT3T3 exhibited the lowest 1000-grain weight of 32.16 g. This result likely indicates the role of green technologies in increasing plant dry matter production, especially during the grain-filling stage, and increasing final grain weight.

Effect of treatments on average grain yield

Regarding average grain yield, the treatment GT1 exhibited the highest average of 7.162 ton ha^{-1}, not significantly different from the treatment GT2 (6.863 ton ha^{-1}), while treatment GT3 exhibited the minimum grain yield of 4.890 ton ha^{-1} (Table 7). Polymer treatments showed enhanced growth traits (Table 1, Table 2, Table 3) as well as the yield components (Table 4, Table 5, Table 6), consequently leading to an increased total grain yield. This finding aligns with the results of Alabar (2021). Genotype T1 showed the highest average of 6.911 ton ha^{-1}, not significantly different from the genotype T4 with 6.596 ton ha^{-1} grain yield, while genotype T5 showed the lowest average of 5.444 ton ha^{-1}. The results obtained by genotypes T1 and T4 in vegetative growth (Table 1, Table 2, Table 3) had the greatest impact on yield components (Table 4, Table 5, Table 6), which aligns with (Al-Saidan, 2021). The treatment GT1T1 outperformed others by yielding the highest average of 7.847 ton ha^{-1}, not significantly different from GT1T4, GT2T1, GT2T4, and GT1T3 (7.463, 7.357, 7.323, 7.300 ton ha^{-1}, respectively), while the treatment GT3T5 showed the lowest average of 4.433 ton ha^{-1}. These results highlight the ability of genotypes T1, T4, and T3 to adapt and utilize environmental factors in the study area, and concurrently, the capacity of polymers GT1 and GT2 to increase water and nutrient availability in the soil, thereby leading to greater dry matter production by the aforementioned genotypes, which reflected on

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their increased growth and overall grain yield.

Conclusions and Recommendations

Based on overall study results, it is concluded that the cultivation of wheat genotypes AC 113 and IR 01 would be promising alternatives to local wheat genotypes and are recommended for maintaining high wheat productivity in the area. Furthermore, the reliance on highly absorbent polymers, particularly potassium polyacrylate and Akrotek polyketone, as green agricultural inputs is crucial for the sustained wheat production. These polymers possess the ability to sustain water and nutrients for the longest possible duration during the plant growth stages and reduce soil moisture loss. This is specifically vital as the countries of Middle-East including Iraq, face pressing issues of climate change and water scarcity that directly impact crop productivity and water availability.

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Novelty Statement

This study aimed to evaluate some soft wheat genotypes introduced from Syria, Iran, and Russia (to identify the alternative varieties to the local ones) under the influence of environment-friendly green technologies (i.e., some superabsorbent polymers) with high water absorbency on their productivity under the conditions of Thi-Qar, Governorate of Iraq.

Generative AI and AI-assisted technology statement
The authors declare that no generative AI and AI assisted technology was used in the creation of this manuscript.

Conflict of interest
The authors have declared no conflict of interest.

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