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SEED ACTIVATION EFFECT ON THE WHEAT GROWTH AND YIELD COMPONENTS

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SUMMARY

The applicable study assessed the impact of wheat (*Triticum aestivum* L.) cultivars and cytokinin (benzyl adenine) seed soaking on grain vitality, growth, and yield-related traits. The experiment materialized in the winter of 2022–2023 at the Al-Qasim Green University, Babylon, Iraq, laid out in a randomized complete block design with two factors. The first factor was cytokinin with three levels (100, 200, and 300 mg L^{-1}), while the second factor was the four wheat cultivars (IPA 99, Bohuth 22, Babylon 113, and Mawadah). The wheat cultivar IPA 99 excelled in grains per spike (57.50) and biological yield (17.95 t ha^{-1}), while the cultivar Mawadah stood out in spike m^2 (364.2), 1000-seed weight (46.87 mg) and grain yield (7.40 t ha^{-1}). The cytokinin activation treatments varied significantly, and 200 mg L^{-1} treatment led to spike count (359.7), grain yield (7.20 t ha^{-1}), and biological yield (18.06 t ha^{-1}). The cytokinin (300 mg L^{-1}) excelled in 1000-seed weight (47.20 mg). In their interaction, the cultivar Mawadah with cytokinin (200 mg L^{-1}) exhibited the highest 1000-grain weight (51.38 mg) and grain yield (8.80 t ha^{-1}). In conclusion, the study highlights the substantial influence of cytokinin treatments and wheat cultivars on key growth and yield parameters.

Keywords: Wheat (*Triticum aestivum* L.), cultivars, cytokinin, seed activation, growth and yield traits

Key findings: Wheat (*Triticum aestivum* L.) cultivar Mawadah, under the influence of cytokinins (200 mg L^{-1}), performed better and positively affected growth and yield-related traits.

INTRODUCTION

Wheat (*Triticum aestivum* L.) crop is of prominent economic importance and a mainly considered strategic crop worldwide. Wheat ranks first for cultivated area, reaching 265 million hectares globally (FAO, 2017). Grain revitalization techniques have emerged

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effective in several countries to improve crop performance, increase production per unit area, and reduce the time required for germination (Fuller and Hamza, 2013). This approach helped establish an efficient basis for grain emergence, improving its growth, flowering, and increasing yield (Al-Baldawi and Hamza, 2017).

Grain activation begins before planting, through grain soaking, to obtain the highest and homogeneous germination under varied environmental conditions, enhancing yield and its attributing traits (Basra *et al*., 2005; Farooq, 2005). Growth regulators can also stimulate grains, with plant growth controlled by hormones and the plant's interaction with its environment, achieving a positive balance, manifesting in the final grain yield (Attia *et al.,* 2010). Benzyl adenine (synthetic cytokinin) has become one of the best growth regulators, stimulating grains and increasing their vitality and strength, eventually influencing yield parameters positively (Nisler *et al.*, 2021). The reason could be due to the unique chemical structure that makes it more effective than other natural and synthetic cytokinins, where this process is not performed (Oshchepkov *et al.,* 2020).

However, the grain activation can overcome the losses, and the benzyl adenine treatment exhibited significant superiority in crop growth and yield-related traits, except for the 1000-seed weight, benzyl adenine treatment demonstrated remarkable superiority in the number of spikes per m^2, grains per spike, and grain yield (7.373 t ha^{-1}). Hussein (2015) found that cytokinin treatment significantly outperformed, yielding the highest average number of spikes, spikelets per spike, 1000-seed weight, grain yield, biological yield, and harvest index in wheat for the consecutive seasons.

Past studies demonstrated that the wheat cultivar Bohuth22 notably outperformed by achieving the highest average grains per spike, while additionally, the cultivar attained the maximum average 1000-seed weight (Abdul-Karim, 2017). Baqir (2018) indicated that the wheat cultivar Bohuth 22 exhibited significant superiority, yielding the highest average spike number, 1000-seed weight, grain, and biological yield. On the other hand, wheat cultivar IPA 99 achieved the ultimate average grains per spike, with no significant differences among the cultivars for the harvest index.

The viability and strength of grains during germination depended upon the nature of crop cultivars and their genetic differences, considered crucial indicators of the quality and type of grain, which affects the crop field establishment and the final yield. The study, based on wheat grain phenolics and the grain composition, bioactivity, and influencing factors, revealed that wheat cultivars were genetically distinct in multiple traits (Ma *et al.,* 2021). Therefore, based on the above discussion, the presented study sought to determine the effects of grain activation on the wheat's growth and yield-related traits and to know the extent of wheat cultivars' response to grain stimulation.

MATERIALS AND METHODS

The field experiment on wheat began in the winter of 2022–2023 in the research areas at Al-Qasim Green University, Babylon, Iraq. The experiment was in a randomized complete block design with two factors and three replications. The first factor was soaking the grains in cytokinin (Benzyl adenine) at three levels (100, 200, and 300 mg L^{-1}). The second factor was using four bread wheat cultivars (IPA 99, Bohuth 22, Babel 113, and Mawadah). The field soil's random sampling occurred from several locations at 0–30 cm depth before planting. Afterward, a process consisted of mixing the samples, then grinding and passing them through a 2-mm diameter sieve to analyze and determine their physical and chemical properties. The analysis transpired in the scientific laboratory in Diwaniyah Province, with the soil analysis results provided in Table 1**.**

The preparation of a standard solution of 1000 mg L^{-1} of synthetic cytokinin ($C_{12}H_{11}N_5$) proceeded by dissolving 1 g of it in 200 ml of distilled water, ensuring the complete dissolution of cytokinin in distilled water. Next, supplement the volume to one

Table 1. Physical and chemical characteristics of the field soil.

Properties	Values
pH	7.3
Electrical conductivity (ds m^{-1})	2.9
Available nitrogen (mg kg^{-1} soil)	46
Available phosphorus (mg kg^{-1} soil)	13
Available potassium (mg kg^{-1} soil)	134
Soil separators	
Soil (mg kg^{-1} soil)	254
Clay (mg kg^{-1} soil)	336
Silt (mg kg^{-1} soil)	410
Soil texture	Silty clay loam

liter with distilled water. Notably, the synthetic cytokinin used in this experiment was a product of HIMEDIA, from an Indian origin. The required parameters comprised diluting this standard solution to reach the concentrations needed in the different treatments of the experiment.

After the tamping process, the experimental land's plowing with moldboard plows ensued, followed by soil smoothing using disk harrows, then completed with the leveling process, engaging a leveling machine. Each replicate includes 16 experimental units; thus, the total number of experimental units was 48. The net dimensions of the experimental unit were 4 m^2 (2 m × 2 m), leaving a space of 50 cm among the experimental units and a one-meter space among the replications. The sowing proceeded in rows, and the distance between each row was 20 cm. Phosphate fertilizer (triple superphosphate P_2O_5) addition had an average of 80 kg ha^{-1} once (considering the number of elements found in the field soil) before planting, spread evenly over the experimental units during soil preparation.

Studied traits and analysis

The data recorded on the wheat crop include the traits, such as spikes per square meter (m^2) per experimental unit, grains per spike, and the 1000-grain weight (g) in each experimental unit, with each sample weighed using a sensitive balance. The biological yield (t ha^{-1}) measurement occurred after harvesting the plants using a sensitive balance after the plants completely dried, converting the weight to tons ha^{-1}. The total grain yield (t ha^{-1}) estimation also transpired after harvesting a square meter area randomly selected within the experimental unit, filtering the grain from the straw, and measuring the weight using a sensitive electric balance, with the obtained weight converted to tons per hectare. The harvest index (%) measurement employed the following equation.

$$Harvest\ index\ = \frac{Grain\ yield}{Biological\ yield} \times 100$$

The Genstat – 2019 program helped analyze all the data. Analysis of variance ensued as per the randomized complete block design (RCBD) with factorial arrangement. The mean differences' further comparison used the $LSD_{0.05}$ test.

RESULTS AND DISCUSSION

Spikes per m^2

For the number of spikes per square meter, the wheat cultivars (IPA 99, Bohuth22, Babylon113, and Mawadah) revealed significant differences (Table 2). Wheat cultivar Mawadah was significantly superior with the highest average (364.2 spike m^{-2}), and the cultivar Babylon 113 showed the lowest average for the said trait (327.8 spike m^{-2}), which also did not differ from the cultivar Bohuth22 that exhibited a relatively superior average (328.8 spike m^{-2}). The differences in the wheat cultivars may be due to their genetic makeup to produce spikes in wheat plants (Al-

Table 2. Effect of cultivars, cytokinin, and their interaction on the spikes per square meter in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (#)
	0	100	200	300	
IPA 99	296.7	301.3	401.3	356.3	338.9
Bohuth 22	331.0	320.7	349.3	314.3	328.8
Babylon 113	335.0	298.7	318.7	359.0	327.8
Mawadah	326.7	418.7	369.3	342.0	364.2
Means (#)	322.3	334.8	359.7	342.9	
$LSD_{0.05}$ Cultivars: 17.27, Motivation: 17.27, Interaction: 34.54.					

Table 3. Effect of cultivars, cytokinin, and their interaction on the grains per spike in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (#)
	0	100	200	300	
IPA 99	60.00	57.00	59.00	54.00	57.50
Bohuth 22	54.67	52.00	56.33	50.67	53.42
Babylon 113	50.33	44.67	52.33	48.67	49.00
Mawadah	43.00	54.00	51.33	49.00	49.33
Means (#)	52.00	51.92	54.57	50.58	
$LSD_{0.05}$ Cultivars: 3.36, Motivation: 3.36, Interaction: N.S.					

Fatlawi *et al*., 2022). The presented results were consistent with previous studies in wheat genotypes (Muhammad *et al.*, 2017; Baqir, 2018).

The cytokinin treatments displayed substantial differences in the number of spike m^2 (Table 2). The cytokinin treatment of 200 mg L^{-1} remarkably excelled with an average of 359.7 spike m^2 compared with the control treatment that gave the lowest average (322.3 spike m^{-2}). However, it did not differ significantly from the cytokinin treatment of 300 mg L^{-1} (342.9 spike m^{-2}). Cytokinins can considerably stimulate the growth of spikes, affecting the processes of cell division and proliferation that lead to spike formation. A report also stated that cytokinins are prominent in regulating genetic interactions related to spike growth, where hormones and genes interact to determine the wheat's number and size of spikes (Muhammad *et al.,* 2017).

The effects of the interaction between the two study factors were also notable for the number of spikes (Table 2). The cultivar Mawadah with cytokinin concentration (100 mg L^{-1}) achieved the highest average (418.7 spike m^{-2}) compared with the rest of the interaction treatments. However, the above interaction had a nonsignificant difference from the interaction of cultivar IPA 99 and cytokinin concentration 200 mg L^{-1} with an average of 401.3 spikes m^{-2}. The wheat cultivar IPA 99 with cytokinin concentration (0 mg L^{-1}) achieved the lowest average for the trait (296.7 spike m^{-2}).

Grains per spike

For grains per spike, the wheat cultivars exhibited significant differences (Table 3). Cultivar IPA 99 superbly excelled, resulting in the highest number of grains per spike (57.50 grains $spike^{-1}$), and the cultivar Babylon113 showed the lowest grains per spike (49.00 grains $spike^{-1}$). However, the genotype had a nonsignificant difference from the cultivar Mawadah (49.33 grains $spike^{-1}$). The number of grains depends on pollination efficiency and fertilization of the maximum number of florets in the spikes, which varies among wheat cultivars (Al-Taher and Al-Hamdani, 2016). The relevant results were also consistent with past findings in wheat crops (Abdul-Karim, 2017; Baqir, 2018).

The cytokinin levels also showed substantial differences in the number of grains per spike (Table 3). The cytokinin treatments (200 and 100 mg L^{-1}) and control treatment achieved the highest averages for grains per spike (54.57, 51.92, and 52.00 grain $spike^{-1}$, respectively) compared with the cytokinin

treatment (300 mg L^{-1}), which provided the lowest grains per spike (50.58 grain $spike^{-1}$). The seed soaking in cytokinins may enhance the plant's ability to interact more effectively with environmental conditions, such as fertilization and irrigation. These positive interactions can have a beneficial impact on the number of seeds in wheat spike. Cytokinin has become a flowering-promoting hormone, and successful flowering leads to the development of more flowers that may mature into grains and seeds in wheat genotypes (Farhood *et al*., 2020).

1000-grain weight

The wheat cultivars considerably differed in the 1000-grain weight (Table 4). Cultivar Mawadah was superior by showing the highest 1000-grain weight (46.87 g) compared with the cultivar IPA99, which gave the minimum average for the said trait (40.96 g). The explanation for this may be due to the compensatory property between the yield components. Cultivar IPA 99 excelled in the number of grains per spike (Table 3); therefore, the grain weight must be low, and the opposite is true. The other yield components, i.e., the number of spikes m^2, grain per spike, and the seed weight, cannot all rise in wheat (Mohammed *et al*., 2021). These results were also analogous to past findings in wheat genotypes (Abdul-Karim, 2017).

For 1000-grain weight, cytokinin levels revealed significant differences (Table 4). The cytokinin treatment of 300 mg L^{-1} achieved superiority by giving the highest average for 1000-grain weight (47.20 g) compared with the control treatment, which was average (44.75 g). Meanwhile, cytokinin concentrations (100 and 200 mg L^{-1}) showed 42.14 and 42.87 g averages, respectively. These differences were due to the effect of cytokinins on the accumulation and storage of nutrients inside the grains, increasing the grain weight. Cytokinins can also stimulate the growth of cells and tissues in grains, boosting the total size of grains. Cytokinins affect grain size by stimulating cell growth and tissue development, which can form bigger grains, providing a higher grain yield (Al-Assadi and Al-Khikani, 2019).

The interaction between the two studied factors was also prominent for the 1000-grain weight (Table 4). Cultivar Mawadah and cytokinin concentrations (200 and 300 mg L^{-1}) achieved the highest and same average for the said trait (51.38 g). However, these interactions did not differ from those of cultivar Bohuth 22, with a cytokinin concentration of 300 mg L^{-1}, and cultivar Mawadah, with a cytokinin concentration of 100 mg L^{-1}). Both showed the lowest value for the 1000-grain weight (38.36 g).

Grain yield

The wheat cultivars differed substantially in total grain yield (Table 5). Cultivar Mawadah was significantly superior by providing the maximum grain yield (7.40 t ha^{-1}) compared with the three other cultivars, viz., IPA 99, Bohuth 22, and Babylon 113 (6.83, 5.89, and 5.79 t ha^{-1}, respectively). The number of spikes has become an influential factor in determining crop productivity, and the cultivar Mawadah, as a high yielder, also has more spikes per square meter (Jabbar *et al*., 2023). It might be its leading position in the number of spikes (Table 2) and 1000-grain weight (Table 4). A positive relationship usually

Table 4. Effect of cultivars, cytokinin, and their interaction on the 1000-grain weight in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (g)
	0	100	200	300	
IPA 99	42.69	41.39	38.70	41.06	40.96
Bohuth 22	43.74	41.42	41.71	50.06	44.23
Babylon 113	46.20	47.41	39.71	46.31	44.91
Mawadah	46.38	38.36	51.38	51.38	46.87
Means (g)	44.75	42.14	42.87	47.20	

$LSD_{0.05}$ Cultivars: 2.45, Motivation: 2.45, Interaction: 4.90.

Table 5. Effect of cultivars, cytokinin, and their interaction on the grain yield in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (t ha^{-1})
	0	100	200	300	
IPA 99	7.06	5.18	8.20	6.89	6.83
Bohuth 22	5.66	5.47	6.02	6.40	5.89
Babylon 113	6.23	4.79	5.80	6.35	5.79
Mawadah	4.96	8.32	8.80	7.53	7.40
Means (t ha^{-1})	5.98	5.94	7.20	6.79	
$LSD_{0.05}$ Cultivars: 0.41, Motivation: 0.41, Interaction: 0.83.					

Table 6. Effect of cultivars, cytokinin, and their interaction on the biological yield in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (t ha^{-1})
	0	100	200	300	
IPA 99	17.67	18.17	18.47	17.50	17.95
Bohuth 22	16.10	15.93	16.07	14.30	15.60
Babylon 113	16.60	17.90	18.73	16.33	17.39
Mawadah	18.13	18.17	18.97	16.27	17.88
Means (t ha^{-1})	17.12	17.54	18.06	16.10	
$LSD_{0.05}$ Cultivars: 1.53, Motivation: 1.53, Interaction: N.S.					

appears between the number of spikes and grain yield, as spikes carry the number of grains; therefore, increased spikes can contribute to raising production (Al-Taher and Al-Hamdani, 2016). These results were also consistent with past findings in wheat genotypes (Baqir, 2018; Muhammad, 2018).

For grain yield, the cytokinin levels also indicated significant differences (Table 5). The cytokinin treatment of 200 mg L^{-1} achieved the optimum average for grain yield (7.20 t ha^{-1}). Likewise, the treatment of 200 mg L^{-1} positively affected the number of spikes (Table 2) and the grain per spike (Table 3), which notably manifested in grain yield. However, the cytokinin treatment of 100 mg L^{-1} showed the lowest grain yield (5.98 t ha^{-1}). The indicative results were also highly analogous to past findings in wheat (Muhammad *et al.*, 2017; Hussein, 2015).

The interactions between cultivars and cytokinin levels meaningfully influenced the grain yield (Table 5). Cultivar Mawadah with a cytokinin concentration of 200 mg L^{-1} achieved the highest average grain yield (8.80 t ha^{-1}), and the same interaction excelled for 1000-grain weight (Table 4). Cultivar Mawadah with cytokinin concentration of 0 mg L^{-1} provided the minimum average grain yield (4.96 t ha^{-1}).

Biological yield

For biological yield, the wheat cultivars (IPA 99, Bohuth22, Babylon 113, and Mawadah) differed significantly (Table 6). Cultivar IPA 99 significantly led by showing the utmost biological yield (17.95 t ha^{-1}). However, the said promising genotype had nonsignificant differences from two wheat cultivars, Mawadah and Babylon 113, for biological yield (17.88 and 17.39 t ha^{-1}). Cultivar Bohuth22 displayed the lowest average for the said trait (15.60 t ha^{-1}). Selecting wheat cultivars with improved and locally suitable genetic makeup can lead to higher biological yields. Wheat cultivars possessing high productivity may contribute to achieving immense biological yield (Muhammad, 2018; Ali *et al*., 2024).

The results further revealed that cytokinin levels also indicated marked differences in biological yield (Table 6). The cytokinin treatments (200 and 100 mg L^{-1}) and the control treatment achieved significant superiority by giving the highest average values for the biological yield (18.06, 17.54, and 17.12 t ha^{-1}, respectively). However, the cytokinin treatment of 300 mg L^{-1} supplied the lowest average for the said trait (16.10 t ha^{-1}). Seed soaking with cytokinins can improve seed

Table 7. Effect of cultivars, cytokinin, and their Interaction on harvest index in wheat.

Cultivars	Cytokinin concentrations (mg L^{-1})				Means (%)
	0	100	200	300	
IPA 99	39.99	28.52	18.47	39.39	31.59
Bohuth 22	35.15	34.36	37.50	44.76	37.94
Babylon 113	37.54	26.79	30.98	38.90	33.55
Mawadah	27.39	45.81	46.39	46.29	41.47
Means (%)	35.02	33.87	33.34	42.34	
$LSD_{0.05}$ Cultivars: 4.47, Motivation: 4.47, Interaction: 8.95.					

quality, resulting in the production of robust and more productive plants and, in turn, raising biological yield (Zheng *et al.* 2016). Soaking with cytokinins can also enhance the plant's ability to adapt to harsh environmental conditions, including nutrients and water availability.

Harvest index

The wheat cultivars notably differed in the harvest index (Table 7). Cultivar Mawadah exhibited the highest average harvest index (41.47%) and excelled the cultivar Babylon 113 (33.55%). These results align with past findings in wheat genotypes (Al-Taher and Al-Hamdani, 2016; Baqir, 2018). However, the cultivar IPA 99 yielded the lowest average harvest index (31.59%), which might be due to its highest biological yield (Table 6). The cytokinin treatments also demonstrated significant differences in the harvest index. The cytokinin treatment of 300 mg L^{-1} achieved the maximum average harvest index (42.34%), which could refer to the cytokinin treatment's superiority in 1000-seed weight, indirectly affecting the harvest index by influencing the biological and grain yield (Hussein, 2015).

The interactions between the wheat cultivars and cytokinin levels also remarkably influenced the harvest index (Table 7). Cultivar Mawadah with cytokinin concentration of 200 mg L^{-1} achieved the optimum average harvest index (46.39%), which logically reflects the treatment's superiority in grain yield (Table 6) and affects the harvest index. In contrast, the wheat cultivar IPA 99, with a cytokinin concentration of 200 mg L^{-1}, yielded the minimum average harvest index (18.47%).

CONCLUSIONS

The differences in wheat cultivars have an apparent effect on grains' strength and vitality, which is an essential factor in the performance of the cultivars. Environmental factors, typically, can also reduce their impact on the grain. Cytokinin positively influenced significantly the wheat's grain yield and its components.

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