Research Article

Effect of Ethephon and Kinetin in Growth and Yield of Three Wheat Varieties

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Abstract | To determine the effects of ethephon and kinetin in some growth and yield traits of many of several wheat varieties, a field experiment was conducted in Al-Wardia area on the outskirts of Babil Governorate during the winter of 2022-2023. A complete randomized block design (RCBD) with -three replications was used in the factorial experiment. the treatment (0, 60, 120, mg L^{-1}) represented by symbols B_0, B_1 and B_2 were assigned to the sub-plots, while the cultivars (Buhuth 22, Abaa 99 and Sham 6) represented by A1, A2, and A3, occupied the main plots. The means were compared using the least significant difference (LSD) test at 5% probability level. Ethephon spray treatments (0, 0.550, and 0.850 kg ha^{-1}) were applied to sub-plots C0, C1, and C2. The results revealed that plants treated with the highest ethephon level (C2) showed superior performance in traits such as number of spikelets per meter, number of grains per spike, number of ears per meter, flag leaf area, chlorophyll content in the flag leaf, and total grain yield, indicating that higher ethephon concentration significantly enhanced both physiological and yield-related characteristics. The B2 level (120 mg L^{-1} kinetin) resulted in the highest values for flag leaf area and chlorophyll content, suggesting a positive role of kinetin at 120 mg L^{-1} in improving plant. In particular, improvements were observed in 1000-grain weight, spike number, number of grains per spike, chlorophyll content, and total grain yield. These effects reflect the positive interaction of growth regulators with physiological traits. Moreover, variety A2 was superior in total grain yield flag leaf area, flag leaf chlorophyll content and 1000 seed weight reflecting its better adaptability and potential under the tested conditions.

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Introduction

Wheat (*Triticum aestivum* L.) is one of the most important strategic crops in Iraq due to its high nutritional value and essential role in food security. It serves as a vital source of energy in the Middle East because of its high carbohydrate content, which contributes significantly to daily caloric intake. Despite Despite the availability of favorable environmental conditions for wheat cultivation, Iraq's wheat productivity remains relatively low. One possible explanation is the limited use of improved and high-yielding varieties (Wahid *et al*., 2017; Akol *et al*., 2024). along with continued reliance on traditional farming methods. Additionally, issues such as over-irrigation and poor agronomic practices have led to yield reductions. Both genetic factors (i.e., variety differences) and environmental conditions such as temperature, humidity, and photoperiod significantly affect growth traits and yield components (Al-Tamimi, 2019; Hassan *et al*., 2021).

Several studies have examined the performance of different wheat varieties under various environmental conditions. The results consistently show significant variation in growth and yield traits, including plant height, flag leaf area, number of tillers, spikes per plant, grains per spike, 1000-grain weight, and grain yield. Al-Rafaei *et al*. (2013) reported notable differences among cultivars, which translated into varying spike density and grain number per square meter, ultimately influencing yield (Al-Aboudi *et al*., 2019; Mohammed *et al*., 2019; Hassan *et al*., 2020). An analysis of *Triticum aestivum* L. varieties grown in three sites in Basra confirmed significant differences in all studied traits across two seasons.

Since few years there has been a world-wide interest in commercial utilization of plant growth regulators (PGRs) for enhanced germination and crop productivity. Cytokinins-particularly kinetin are included in these regulators, which have a direct influence on plant development via hormonal regulation. Kinetin treatments (as seed priming and/or foliar spray) could improve different physiological processes. Helman et al. (2011) also showed that kinetins regulate the activity of sugar transporter systems and nitrate reductase functioning, that favor abundarly growth in plants. Sohair *et al*. (2006) supported these findings, and more recently Hundi *et al*. (2025) reported that kinetin induces cell division, sustains chlorophyll content, and stimulates nutrient absorption from the soil to the photosynthetic tissues, ultimately increasing the longevity of the leaves and productivity.

The application of chemicals, which are known as growth retardants, has become more common lately. Ethephon is one such compound which is believed to minimize stem elongation and promote stem width by inhibiting cell division and elongation in the lower AMT. It further regulates crop emergence and crop growth via its reaction with crop components Concomitantly, application of growth regulators, such as ethephon is also becoming popular. Effect of ethephon Ethephon application has a fair effect to control the plant growth, because it inhibits apical meristematic regions via suppression of cell division, then results in sturdier plant to reduce risk of lodging. Additionally, ethephon has been found to be effective in improving crop architecture and yield, particularly in cereals (Song et al., 2017; Hamid, 2025b), such as wheat. According to Attiya *et al*. (2010), with a greater plant height (above 160 cm) having greater lodging susceptibility, which can be alleviated with ethephon application (Hamid, 2025a; Al-Hasnawi *et al*., 2020).

Accordingly, the objectives of the present study were to investigate the differential response of wheat genotypes on some selected morphological and productivity attributes. More specifically, the objectives were to determine how kinetin and ethephon applications to three wheat (*Triticum* spp.) cultivars (cv.) influence the physiological performance and grain yield potential of plants and to provide perspectives for improving the agronomic management of the crop for higher production.

Materials and Methods

To study the effects of ethephon and kinetin on the growth and yield of three wheat cultivars, a field experiment was conducted during the 2022-2023 growing season in Al-Wardia area on the outskirts of Babil province. Random samples of the trial soils were taken one month before sowing at a depth of 0-30 cm and tested in the Soil Department laboratory of Al-Musayyib Technical Institute.

Table 1: *The soil's physical and chemical characteristics.*

Quantity mg kg^{-1} soil					EC m.dS^{-1}	pH	Organic matter g kg^{-1} soil	Soil separators gm kg^{-1} soil			Soil texture
Fe	Zn	K	P	N				Sand	Clay	Loam	
3.8	0.40	177	10.4	64.2	3.96	7.5	11.11	160	280	560	Silty clay loam

The area was prepared by plowing, leveling and divided into main and sub-plots. Each sub-plot measured 3 × 3 m and contained 13 planting rows. The sub-plots were separated by 50 cm shoulders, and the main plots by 75 cm. A total of 81 experimental units were arranged using a factorial experiment in a Randomized Complete Block Design (RCBD) with three replications.

Experimental factors

- Main plot– wheat varieties (Factor A):
  - A1: Buhuth 22
  - A2: Abaa 99
  - A3: Sham 6
- Sub-plot– Kinetin concentrations (Factor B):
  - B0: 0 mg L^{-1} (control)
  - B1: 60 mg L^{-1}
  - B2: 120 mg L^{-1}
- Sub-sub plot–ethephon concentrations (Factor C):
  - C0: 0 kg ha^{-1} (control)
  - C1: 0.550 kg ha^{-1}
  - C2: 0.850 kg ha^{-1}

Kinetin and ethephon were applied as foliar sprays at the tillering stage (Zadoks growth stage ZGS 26), according to Zadoks *et al*. (1974). Ethephon used in this study was obtained from Sigma Chemical Co. (USA) in powder form, with the chemical name (2-Chloroethyl) Phosphonic acid, and a molecular weight of 144.5 g mol^{-1}. Spraying was performed using a 20-liter hand sprayer. Sub-plots were isolated using nylon strips to avoid spray drift.

Sowing was done manually on November 15, 2022, using a seeding rate of 120 kg ha^{-1}. Seeds were planted in rows 15 cm apart. Four split applications of urea fertilizer (46% N) were made: at sowing, at the three-leaf stage, at the appearance of the second internode, and at the booting stage. Additionally, triple superphosphate (TSP) fertilizer (45% P_2O_5) was applied before final land preparation to ensure nutrient availability. The wheat plants were harvested at full maturity on May 3, 2023.

Studied traits

1. Flag leaf area (cm^2): Measured using the formula: *Flag leaf area = Leaf length × Leaf width × 0.95*, using the average of ten randomly selected flag leaves per unit.
2. Chlorophyll content (SPAD units): At 100% flowering, SPAD values were taken from top, middle, and bottom leaves using a Minolta Chlorophyll Meter (SPAD-502), and the average was calculated.
3. Number of Ears per m^2: Counted after harvest maturity by selecting a 1 m^2 area from the center of each sub-plot.
4. Number of Grains per Ear: Calculated by selecting 10 ears at random from each unit and determining the average grain number.
5. 1000-Grain Weight (g): Determined using a precision balance from a random sample of 1000 grains per unit.
6. Grain Yield (t ha^{-1}): Measured from three central rows covering 0.45 m^2 per unit and onverted to yield per hectare at 14% moisture content.

Statistical analysis

All collected data were analyzed using ANOVA (Analysis of Variance) under a split-plot arrangement using GenStat software (version 12.1). Treatment means were compared using the Least Significant Difference (LSD) test at a significance level of 0.05.

Results and Discussion

Flag leaf area (cm^2)

The results in Table 2 show that ethephon treatment (C2) significantly increased the flag leaf area compared to the control, with a maximum mean of 38.08 cm^2 and a minimum of 31.18 cm^2. This indicates a stimulatory effect of ethephon on leaf expansion, possibly due to its influence on cell elongation and division. Similarly, kinetin treatments also affected this trait. Plants treated with B2 recorded the highest mean value (35.08 cm^2), while those with B1 had a slightly lower mean (34.54 cm^2). The differences, although moderate, suggest that kinetin may enhance leaf area through its role in promoting chloroplast development and delaying senescence. Among the wheat varieties, A2 showed the largest flag leaf area (35.83 cm^2), while A1 exhibited the smallest (34.28 cm^2). This genetic variability indicates that varietal differences play a role in determining leaf morphology and size. Considering two-way interactions, the A2C2 combination showed the largest flag leaf area (39.86 cm^2), reflecting a synergistic effect of the A2 genotype and the ethephon application. While the interaction A2C0 was the lowest (30.98 cm^2) and the lack of ethephon caused an expressive decrease in leaf area in the variety. The cultivar x kinetin interaction was also significant. Regarding leaf area, the plants of the A2B0 treatment showed the highest (36.17 cm^2), and those under the A3B1 treatment the lowest (33.43 cm^2). This could be due to variations in cultivar response to cytokinin treatment. With respect to the interaction ethophon × kinetin, the plants, which gained C2B2 group, reached maximum average (39.00 cm^2), whereas the minimum one was verified with C0B2 (31.05 cm^2), evidence once again the significance combination of hormone in improving the leaf area. The three-way interaction (variety × kinetin × ethephon) was finally significant. A2B1C2 produced highest flag area (40.45 cm^2) representing combinative positive effect of genotype A2, kinetin B1 and ethephon C2. On the other hand, the lowest value (31.09 cm^2) was recorded in plants of A2B1C0 group affirming ethephon's importance in enhancing this trait.

Table 2: *Effects of kinetin and ethephon on the growth and yield of three types of wheat plants as measured by the flag leaf area (cm^2) trait.*

A	B	C			Mean B*A
		C_0	C_1	C_2	
A_1	B_0	31.27	33.52	35.95	33.58
	B_1	31.75	34.48	36.94	34.39
	B_2	31.14	35.00	38.52	34.89
A_2	B_0	31.15	37.73	39.63	36.17
	B_1	31.09	36.86	39.51	35.82
	B_2	30.69	35.37	40.45	35.50
A_3	B_0	31.53	34.92	37.57	34.67
	B_1	30.72	33.46	36.11	33.43
	B_2	31.30	35.21	38.02	34.84
LSD 0.05		1.972			1.139
A * C					Mean
A1		31.39	34.33	37.14	34.28
A_2		30.98	36.65	39.86	35.83
A3		31.18	34.53	37.23	34.31
LSD 0.05		1.139			0.658
B * C					Mean
B_0		31.31	35.39	37.72	34.81
B_1		31.18	34.93	37.52	34.54
B_2		31.05	35.19	39.00	35.08
LSD 0.05		1.139			0.658
Mean		31.18	35.17	38.08	
LSD 0.05		0.658			

Flag leaf chlorophyll content (SPAD)

Data presented in Table 3 indicate that ethephon significantly affected chlorophyll content in wheat flag leaves. The C2 treatment recorded the highest overall mean (43.91 SPAD), whereas the control (C0) had the lowest (36.12 SPAD). Regarding kinetin, B2 showed a slightly higher mean (40.05 SPAD) compared to B0 (39.52 SPAD), with minor variation. Among cultivars, A2 had the highest chlorophyll content (42.15 SPAD), while A3 exhibited the lowest (38.05 SPAD), suggesting genetic differences in pigment accumulation. The C2 × A2 interaction showed a notably high mean (46.96 SPAD), contrasting sharply with the lowest value in the C0 × A3 group (34.60 SPAD). This supports the positive influence of ethephon on chlorophyll retention in cultivar A2. Similarly, the A2 × B1 combination yielded the highest mean under kinetin treatment (42.46 SPAD), while the A3 × B1 interaction resulted in a lower chlorophyll level (37.78 SPAD). These variations imply differential cultivar responses to growth regulator types. A significant interaction was also noted between ethephon and kinetin, with the C2 × B2 combination producing 44.32 SPAD, compared to 35.87 SPAD in the C0 × B2 group. Furthermore, the three-way interaction A2 × B1 × C2 yielded the maximum chlorophyll content (46.99 SPAD), while A3 × B1 × C0 resulted in the lowest (33.81 SPAD). These patterns reflect both the additive and synergistic effects of cultivar traits and plant growth

Table 3: *Effects of kinetin and ethephon on the growth and yield of three wheat cultivars in connection to their flag leaf chlorophyll content (SPAD).*

A	B	C			Mean B*A
		C0	C1	C2	
A1	B0	36.33	37.50	43.49	39.11
	B1	37.18	39.20	42.62	39.67
	B2	37.46	37.39	42.56	39.13
A2	B0	36.84	42.09	46.01	41.64
	B1	36.84	43.22	46.99	42.35
	B2	36.62	42.89	47.87	42.46
A3	B0	34.46	36.93	42.05	37.81
	B1	35.52	36.73	41.08	37.78
	B2	33.81	39.32	42.52	38.55
LSD0.05	2.573				1.486
A * C					Mean
A1	36.99		38.03	42.89	39.30
A2	36.77		42.73	46.96	42.15
A3	34.60		37.66	41.89	38.05
LSD0.05	1.486				0.858
B * C					Mean
B0	35.87		38.84	43.85	39.52
B1	36.52		39.72	43.56	39.93
B2	35.96		39.86	44.32	40.05
LSD0.05	1.486				0.858
Mean	36.12		39.47	43.91	
LSD0.05	0.858				

Table 4: *Effects of ethephon and kinetin on the development and yield of three types of wheat plants as measured by spike count (m²).*

A	B	C			Mean B*A
		C0	**C1**	**C2**	
A1	B0	323.40	341.59	338.95	334.65
	B1	318.23	343.98	343.79	335.33
	B2	329.14	335.74	344.75	336.54
A2	B0	324.52	338.61	254.44	305.86
	B1	325.08	346.99	388.08	353.38
	B2	330.62	345.04	392.85	356.17
A3	B0	334.15	338.18	347.43	339.92
	B1	332.66	341.55	344.80	339.67
	B2	334.15	340.48	344.43	339.69
LSD0.05		69.921			40.369
A * C					Mean
A1		323.59	340.44	342.50	335.51
A2		326.74	343.55	345.12	338.47
A3		333.66	340.07	345.55	339.76
LSD0.05		40.369			23.307
B * C					Mean
B0		327.36	339.46	313.61	326.81
B1		325.32	344.17	358.89	342.80
B2		331.30	340.42	360.68	344.13
LSD0.05		40.369			23.307
Mean		328.00	341.35	344.39	
LSD0.05		23.307			

Number of ears per square meter (m^2)

Data in Table 4 reveal that ethephon treatments significantly influenced the number of ears per square meter. Plants treated with the highest ethephon level (C2) showed a greater mean number of ears (344.39 m^2) compared to the control (C0), which had the lowest mean (328.00 m^2). Similarly, kinetin treatments affected this trait, with B2 exhibiting a higher mean (344.13 m^2) than B0 (326.81 m^2). Among the cultivars, A3 had the highest mean number of ears per m^2 (339.76), while A1 had the lowest (335.51), reflecting inherent genetic differences in spike production.

The ethephon ×cultivar interaction was significant. The greatest mean value for number of ears (345.55 m^2) was observed for the A3C2 combination and the smallest for the A1C0 interaction (323.59 m^2). The cultivar x kinetin interaction was also significant, with A2B2 showing the highest average (356.17 m^2), a fact for contrast to A2B0, which gave the lowest (305.80 m^2) mean. In addition, the interaction ethephon × kinetin was significant for the spike density. The C2B2 treatment had the greatest mean (360.68 m^2), while C0B2 had the lowest (331.30 m^2). Moreover, the three-way interaction (cultivar × kinetin × ethephon) was statistically significant. A2B2C2 group had the highest number of ears m^2 (392.85 m^2), with the lowest mean found for the A2B2C0 treatment (318.23 m^2). These findings indicate combined and amulative effects of genotype and growth regulators on spike formation.

Table 5: *Effects of ethephon and kinetin on the growth and yield of three types of wheat plants in terms of the number of grains per spike (spike^{-1} grain).*

A	B	C			Mean B*A
		C0	**C1**	**C2**	
A1	B0	46.40	50.84	56.86	51.37
	B1	43.68	50.77	55.78	50.08
	B2	44.71	52.53	54.68	50.64
A2	B0	43.68	46.95	54.43	48.36
	B1	43.46	49.48	55.21	49.38
	B2	45.95	50.21	59.75	51.97
A3	B0	44.53	50.99	52.24	49.25
	B1	44.40	51.59	53.77	49.92
	B2	45.15	48.54	53.29	49.00
LSD0.05		2.204			1.273
A * C					Mean
A1		44.93	51.38	55.77	50.70
A2		44.36	48.88	56.47	49.90
A3		44.69	50.37	53.10	49.39
LSD0.05		1.273			0.735
B * C					Mean
B0		44.87	49.60	54.51	49.66
B1		43.85	50.61	54.92	49.79
B2		45.27	50.43	55.91	50.54
LSD0.05		1.273			0.735
Mean		44.66	50.21	55.11	
LSD0.05		0.735			

Number of grains per spike (spike^{-1})

Table 5 shows that ethephon treatments significantly influenced the number of grains per spike. The C2 treatment yielded the highest mean (55.11 grains spike^{-1}), while the control (C0) recorded the lowest (44.66 grains spike^{-1}). Kinetin treatments also affected this trait, as B2 resulted in a higher mean (50.54 grains spike^{-1}) compared to B0 (49.66 grains spike^{-1}).

Among the cultivars, A1 had the greatest grain number per spike (50.70), while A3 showed the lowest (49.39), indicating genetic variation in reproductive potential.

Significant interaction was observed between cultivar and ethephon. The A2C2 combination resulted in the highest grain number (56.47 grains spike^{-1}), while A2C0 recorded the lowest (44.36 grains spike^{-1}), emphasizing the combined effect of genotype and ethephon on fertility traits.

For cultivar × kinetin interaction, A2B2 had the highest mean (51.97 grains spike^{-1}), while A2B0 produced the lowest (48.36 grains spike^{-1}). The interaction between ethephon and kinetin further supported this pattern; C2B2 plants recorded 55.91 grains spike^{-1}, while C0B1 had the lowest (43.85 grains spike^{-1}).

The three-way interaction was significant. Plants in the A2B2C2 treatment showed the highest number of grains per spike (59.75), whereas A2B1C0 plants had the lowest (43.46). These results highlight the combined influence of genetic and hormonal factors on spike fertility.

Table 6: *Effects of ethephon and kinetin on the growth and yield of three wheat cultivars in the 1000-grain weight (g) characteristic.*

A	B	C			Mean
		C_0	C_1	C_2	B*A
A_1	B0	32.56	34.58	36.60	34.58
	B1	32.28	33.39	36.47	34.05
	B2	31.57	32.79	36.66	33.67
A_2	B0	33.07	33.13	37.56	34.59
	B1	32.71	33.47	37.08	34.42
	B2	34.69	36.04	38.54	36.42
A_3	B0	31.97	34.13	36.14	34.08
	B1	31.61	35.19	36.33	34.38
	B2	31.99	35.89	35.21	34.36
LSD 0.05		2.444			1.411
A * C					Mean
A1		32.14	33.59	36.58	34.10
A2		33.49	34.21	37.73	35.14
A3		31.86	35.07	35.89	34.27
LSD 0.05		1.411			0.815
B * C					Mean
B0		32.53	33.95	36.76	34.41
B1		32.20	34.01	36.63	34.28
B2		32.75	34.91	36.80	34.82
LSD 0.05		1.411			0.815
Mean		32.50	34.29	36.73	
LSD 0.05		0.815			

Grain weight (g)

Table 6 reveals a significant effect of ethephon on 1000-grain weight. Plants treated with C2 recorded the highest mean (36.80 g), while the control (C0) showed the lowest (32.71 g), indicating the positive influence of ethephon in enhancing grain filling. Among cultivars, A2 produced the highest grain weight (35.14 g), whereas A1 had the lowest (34.10 g), reflecting genetic variability in seed development. The cultivar × ethephon interaction was notable. A2C2 plants achieved a mean of 37.73 g, while A3C0 plants had the lowest weight (31.86 g), highlighting the combined influence of variety and ethephon on grain mass. For the cultivar × kinetin interaction, A2B2 recorded the greatest mean (36.42 g), while A1B2 had the lowest (33.67 g), indicating that response to kinetin varied by genotype. The ethephon × kinetin interaction also had a significant effect. C2B2 produced the highest 1000-grain weight (36.80 g), compared to C0B1 with the lowest (32.20 g). Finally, the three-way interaction showed strong synergy. A2B2C2 achieved the maximum grain weight (38.54 g), while A1B2C0 recorded the minimum (31.67 g). These findings emphasize the combined effect of genotype and growth regulators on grain development and weight accumulation.

Grain yield (tonne ha^{-1})

Table 7 demonstrates that grain yield was significantly affected by ethephon treatments. Plants treated with the highest level (C2) recorded the maximum yield (3.92 tonnes ha^{-1}), whereas the control (C0) produced the lowest yield (3.38 tonnes ha^{-1}), highlighting the positive role of ethephon in enhancing productivity.

Kinetin treatments also influenced yield. B2-treated plants produced the highest mean yield (3.73 tonnes ha^{-1}), while B1 had the lowest (3.55 tonnes ha^{-1}), indicating moderate variation in response to kinetin concentration.

Among cultivars, A2 had superior performance, yielding 3.77 tonnes ha^{-1}, while A1 and A3 recorded lower and similar yields (3.54 tonnes ha^{-1}), suggesting genetic variability in yield potential.

Significant interaction was observed between cultivar and ethephon. A2C2 plants yielded the highest (4.59 tonnes ha^{-1}), whereas A3C0 plants had the lowest (3.32 tonnes ha^{-1}). Similarly, the cultivar × kinetin interaction showed that A2B2 resulted in the highest yield (4.00 tonnes ha-1), while A1B0 yielded the least (3.50 tonnes ha-1).

Table 7: *Effects of ethephon and kinetin on the growth and yield of three types of wheat plants as measured by the total yield characteristic (tonne h-1).*

A	B	C			Mean B*A
		C_0	C_1	C_2	
A_1	B0	3.41	3.32	3.77	3.50
	B1	3.52	3.34	3.66	3.51
	B2	3.63	3.33	3.84	3.60
A_2	B0	3.43	3.65	4.09	3.72
	B1	3.31	3.61	3.87	3.60
	B2	3.22	3.88	4.90	4.00
A_3	B0	3.38	3.45	3.65	3.49
	B1	3.39	3.57	3.64	3.53
	B2	3.18	3.76	3.81	3.58
LSD 0.05		0.492			0.285
A * C					Mean
A1		3.52	3.33	3.76	3.54
A2		3.32	3.71	4.29	3.77
A3		3.32	3.59	3.70	3.54
LSD 0.05		0.285			0.164
B * C					Mean
B0		3.41	3.47	3.84	3.57
B1		3.40	3.51	3.72	3.55
B2		3.34	3.66	4.19	3.73
LSD0.05		0.285			0.164
Mean		3.38	3.55	3.92	
LSD 0.05		0.164			

The ethephon × kinetin interaction significantly impacted grain yield. C2B2 treatment produced the highest yield (4.19 tonnes ha-1), while C0B0 yielded the lowest (3.34 tonnes ha-1).

The three-way interaction further enhanced yield differences. A2B2C2 recorded the maximum yield (4.90 tonnes ha-1), indicating a strong synergistic effect of growth regulators and cultivar. In contrast, A2B2C0 had the lowest yield (3.22 tonnes ha-1), underlining the importance of treatment combinations for optimizing wheat productivity.

Discussion

Statistical analysis in the present work reflected that A2 cultivar had superiority over the other varieties in most of the parameters of vegetative growth and yield. In particular, A2 genotype showed the higher flag leaf area, the higher flag leaf chlorophyll content, the higher 1000-grain weight and the higher total grain yield measured (Tables 2, 3, 6 and 7). These discrepancies are primarily genetic in nature among the cultivars, as previously shown (Saad and Malah, 2018; Al-Sultani and Latheeth, 2019), wherein genetic nature has a significant effect on stem diameter and flag leaf size.

A larger flag leaf area improved photosynthetic capacity, which may be an important contributing factor to increase of grain yield. Comparable findings were reported by Faleh (2015), who reported that differences among varieties for flag leaf characteristics significantly influenced plant productivity. These observations are consistent with the studies of Baqer and Naqeeb (2018), Al-Tubi (2019) and Alaamer *et al.* (2023) who emphasized the genetic control of chlorophyll content and its impact on crop performance.

Kernel yield per plant was also highest in A2 as a result of high 1000-grain weight (Table 6). This agrees with Abdullah et al. (2024) who stressed the role of genotype in yield potential. Spike number per m^2 (Table 4) is an additional stage that the A3 cultivar proved to be a good performer, and probably due to its tillering capacity, a stage genetically determined one. An increase in the cultivar potential to do so is related to the capacity of photosynthesis, as reported by Eskandari and Kazemi (2010), Abdul Razzaq (2016), and Al-Hassan (2017), because the cultivar to produce and use photosynthetic materials is determinant to convert tillers in fertile spikes. On the other hand, A1 variety presented the highest number of grain/spike. Given that grain number is a major determinant of yield, this finding emphasizes the importance of genetic constitution of the variety on yield traits. Consistent results were presented by Mohammed *et al.* (2018) who reported that grain number per spike differed among cultivars when treated with the growth regulator kinetin. The use of kinetin gave a significant increase in growth and yield characters, mainly at level B2. It also improved characteristics as spikelets number, grains number by spike and chlorophyll content, which can be owed to the fact that kinetin may enhance chlorophyll system and nutrient absorption in addition to carbon metabolism. These effects contribute in high photosynthetic efficiency, which results in better grain filling. This is in line with the findings of Abu Zaid (2000), Ali *et al*. (2021), and Sadak *et al*. (2013) who emphasized that the kinetin had favorable influences on photosynthesis and nutrient remobilization to developing grains. All of the measured traits (flag leaf area, chlorophyll content, number of spikes, number of grains per spike, 1000-grain weight, and total yield) were significantly higher in the ethephon treatment (C2 level) (Tables 2–7). The efficacy of ethephon is due to the suppression of excessive stem growth, induction of carbohydrate accumulation, and improvement of partitioning of photosynthates to the grains. These findings are similar to those of Hashim (2006), Dogara *et al*. (2024), and Al-Myali *et al*. (2020) reported that higher ethephon concentration made a tremendous benefit on wheat grain yield. The beneficial effect of ethephon is in part explained by its positive effects on source–sink relations. Ethephon increases flag leaf area and chlorophyll content and, therefore, improves the plant's ability to produce and translocate assimilates effectively, which results in a higher degree of grain weight and yield of wheat. This also helps to explain why an increase in the number of spikes per plant following ethephon application could have a greater effect on GY than other GY components. Reductions in the number of spikes cannot be offset by the increase in grain weight or grain number per spike only (Hashim, 2006; Dogara *et al*., 2024; Hamid *et al*., 2025). In conclusion, kinetin and ethephon either alone or interactively improved wheat yield and growth, and the performance of A2 was the best in all traits treated with C2B2. These results suggest the need for careful choice of cultivars and growth regulators for stepped-up wheat productivity in the study area.

Conclusions

The results of this study demonstrated that cultivar A2 (Abaa 99) exhibited superior performance compared to the other cultivars, producing the highest values in most vegetative growth traits and achieving a total grain yield of 3.77 tons ha^{-1}. Application of kinetin at 120 mg L^{-1} (B2) significantly enhanced plant growth and yield components, resulting in a grain yield of 3.73 tons ha^{-1}. Similarly, the application of ethephon at 0.85 kg ha^{-1} (C2) led to the highest mean values across most growth and yield parameters, with a total grain yield of 3.92 tons ha^{-1}. These findings suggest that ethephon at 0.85 kg ha^{-1} and kinetin at 120 mg L^{-1} can be effectively used to enhance the growth and productivity of Abaa 99 wheat cultivar under the tested conditions. However, this study was conducted under specific agro-climatic conditions and soil types, which may limit the generalizability of the findings. Future research should focus on evaluating these treatments across different soil textures, environmental conditions, and wheat genotypes to validate their broader applicability. Additionally, studies on the economic feasibility and long-term effects of repeated ethephon and kinetin use on soil health and crop sustainability are recommended.

Novelty Statement

This study identifies a high-performing package—foliar ethephon at 0.85 kg ha^{-1} with kinetin at 120 mg L^{-1}—that significantly enhances flag leaf physiology and yield components in wheat under central Iraqi conditions, with Abaa 99 showing the strongest response. These field-validated results provide a practical, cultivar-specific regulator strategy to boost wheat productivity in similar agro-environments.

Author's Contribution

Ali S. Hassoon: Supervision; Experimental design; Formal analysis (ANOVA/LSD); Interpretation; Writing – review & editing; Project administration; Correspondence.
Rasha A. AlBakri: Investigation; Measurements; Validation; Visualization; Resources; References and formatting.

Generative AI and AI-assisted technology statement
No generative AI or AI assisted tools were used for study design, data collection, statistical analysis, or drafting of scientific content. Language polishing and reference formatting were performed manually by the authors, who take full responsibility for the content.

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

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