Research Article

Improving the Growth Yield Components and Quality Characteristics of Bread Wheat (*Triticum aestivum* L.) using Foliar Spraying with NPK Fertilizers

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Abstract | The experiment was carried out at the Center for Biotechnology and Environment / University of Fallujah, during 2023-2024 season to study the effect of balance NPK concentrations on growth, yield and quality of some wheat cultivars. A split block arrangement according to RCBD was used with three replications. The study included two factors, the first was three varieties (Latifiyah, Al-Rasheed and Iraq) as a main plots, and the second factor was balance NPK fertilizer (20,20,20) with two concentrations (50 and 100 mg/L) in addition to control treatment (water only) as a sub plots. The results showed significant differences between varieties in most studied characteristic. Al-Rasheed cultivar gave highest averages of plant height (80.76cm), flag leaf area (38.66cm^2), chlorophyll index (46.39 SPAD), spike length (12.90cm), spikes number (340.59m^2), number of grains spike^{-1} (32.95 grain spike^{-1}), 1000 grain weight (37.64g) and grain yield (4.127 t ha^{-1}). Wheat plants that sprayed with NPK concentration 100mg/L gave highest averages of plant height (77.86cm), flag leaf area (40.34cm^2), chlorophyll index (48.41 SPAD), spike length (12.50cm), spikes number (348.86m^2), number of grains spike^{-1} (33.44 grain spike^{-1}), 1000 grain weight (38.76g), grain yield (4.52 t ha^{-1}) and protein percentage (12.75%). The effect of interaction for both factor was significant in most studied traits.

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Introduction

Bread wheat (*Triticum aestivum* L.) is the most widely cultivated cereal globally, serving as a staple for over a third of the world population (Kaleri *et al*., 2023). Despite its significance, local production often fails to meet demand, necessitating strategies to boost yield and quality. Balanced fertilization, particularly with NPK, is crucial in improving wheat productivity (Abd El-Ghfar, 2022). Nitrogen is one of the major nutrients, plays a crucial role in all the metabolic processes of plants, formation of tissues, chlorophyll and amino acid (Ullah *et al*., 2018). So, Rate of photosynthesis, amount of RuBisCO protein, activity of Nitrate reductase, Invertase and protease (Alam *et al*., 2023) (Salesse-Smith *et al*., 2024).

Nitrogen deficiency affects biomass production and the plant's ability to utilize sunlight for growth and productivity (Xue *et al.*, 2022). Phosphorus is the second most essential nutrient after nitrogen and plays a crucial role in various metabolic processes that support plant growth and development. It is Participating in photosynthesis, the regulation of stomatal conductance, and the rate of transpiration, and carbon and nitrogen metabolism. Additionally, phosphorus contributes to the accumulation of soluble sugars and proteins and is a vital component of ATP, which facilitates energy transfer within the plant (Zhao *et al.*, 2021; Xu *et al.*, 2023). it stimulates early flowering, seed formation and stress resistance (Bourak *et al.*, 2023) (Luo *et al.*, 2024). Potassium is the third major nutrient, play a vital role in improving plant performance as a result of its positive impact on the activation of over 70 enzymes such as photosynthesis, energy use and respiration (Pandey and Mahiwal, 2020). It helps to strengthen the plants to resist disease and development its root system (Tewari *et al.*, 2022). Soil application is the most common method of supply the plant with essential nutrients (Rajesh and Paulpandi, 2013 However, the remaining 30% of these fertilizers in the soil contributes to contamination, as it releases protons through the nitrification process and binds with acidic cations, mainly aluminum and iron (Amoakwah *et al.*, 2024), ultimately leading to poor vegetative growth and reduced productivity. Conversely, excessive fertilization often results in excessive vegetative growth, increased susceptibility to pests and diseases, lower yields, and diminished crop quality (Rahman *et al.*, 2024). As a result, there is a growing global interest in improving plant nutrition and crop production through modern technologies. Foliar application is a simple yet effective technique that delivers nutrients directly to plant leaves in a uniform manner, enhancing nutrient efficiency, increasing crop yields, and reducing the need for chemical fertilizers compared to soil application (Ishfaq *et al.*, 2022). Therefore, this study aims to identify the optimal NPK concentration for foliar spraying to maximize growth, grain yield, and quality in three bread wheat cultivars.

Materials and Methods

The experiment was carried out at the Center for Biotechnology and Environment / University of Fallujah, during the winter season of 2023-2024 to(In the center's field Its chemical and physical properties are showen in Table 1) study the response growth, grain yield and quality of wheat varieties to different spraying concentrations of balance NPK. The experiment followed a Randomized Complete Block Design (RCBD) with a split-block arrangement, incorporating two factors and three replications., the first factor was in the main plots and included three varieties of bread wheat (Latifiyah, Al-Rasheed and Iraq), The second factor fertilizer of balance NPK (20, 20, 20) with two concentrations (50 and 100 mg L) in addition to control treatment (water) which occupied the sub plots. All concentrations were added twice to the plants as foliar spray, first at tillering stage ZGS 20, second at booting stage ZGS 40. The net of sub plot area was $4m^2$, varieties grains were sown on 28th November at a rate 120 kg ha^{-1}. Before planting, the soil was examined for its physical and chemical characteristics.

Table 1: *Some physical and chemical of experiment soil*

Texture class			**Dissolved ions**		
pH		7.91	Na	mmol L^{-1}	55.21
EC		2.85 ds m^{-1}	Ca		13.20
Nitrogen availability		41.00mgkg^{-1}	Mg		14.83
Phosphorus availa-bility		35.00mgkg^{-1}	K		3.74
Potassium availa-bility		123.00mgkg^{-1}	Cl		35.20
Organic matter		0.73 %	So_4		34.00
Gypsum		55.00 g kg^{-1}	HCo_3		2.60
Lime		219.00gkg^{-1}			
Soil components					
Sand	249 g kg^{-1}	Silt	560 g kg^{-1}	Clay	191 g kg^{-1}
Soil texture			Silty loam		

Urea fertilizer containing 46% nitrogen was applied in four splits according to the treatment plan: the first at sowing, the second at ZGS:13, the third at ZGS:32, and the fourth at ZGS:40, following the Zadoks scale. Phosphorus, in the form of triple superphosphate, was incorporated at planting (Zadoks *et al.*, 1974) (Jaddoa and Salih, 2013). The crop was harvested on May 24th, and data were recorded and analyzed using the Genstat statistical software package. To compare treatment means, the least significant difference (L.S.D) test was conducted at a 0.05 probability level (Steel and Torri, 1980). Studied characters:'

- **Plant height (cm):** Ten plants were randomly chosen, their heights measured, and the mean height (cm) was determined.

- **Flag leaf area (cm^2):** Ten random plants were taken and their area was calculated according to the formulae of (Robertson and Giunta, 1994).

$$\text{length} \times \text{maximum width} \times 0.95$$

- **Chlorophyll Index (SPAD):** The chlorophyll content was measured using a SPAD-502-m device (Konica Minolta, Inc., Tokyo, Japan) on ten randomly selected flag leaves.
- **Spike Length (cm):** The spike length of ten randomly chosen plants was measured, and the average was recorded.
- **Number of Spikes (m^2):** The total count of spikes within a one-square-meter area was recorded.
- **Number of Grains per Spike:** Grains were counted from ten randomly selected spikes in each replicate.
- **1000-Grain Weight (g):** A sample of 1000 grains was collected from each plot and weighed using a digital balance with two decimal precision.
- **Grain Yield (t ha^{-1}):** Yield was estimated from a one-square-meter sample and adjusted to a 12% moisture level.
- **Protein and Carbohydrate Content in Grains (%):** Measured using the Kernelyzer-M device from Brabender (Germany) under the Agricultural Research Office, Ministry of Agriculture.

Results and Discussion

Plant height (cm)

Cultivars, NPK concentrations and their interaction significantly affected on plant height (Table 2). Cultivar Al-Rasheed gave the tallest plants (80.76cm) followed by Iraq (72.86cm), while the shortest plants were recorded by Latifiyah (70.13cm). Differences in plant height among cultivars may result from variations in their genetic composition. This result are in harmony with (Bunder, 2024). Regarding NPK concentrations, results in Table 2. Show that the highest values (77.86cm) were recorded at 100mg L Compared to the control, which resulted in a measurement of 70.69 cm. and this could be due to the nutrient balance has rapid cell production, increase in cell size and elongation a which resulted in taller plants. These results are consistent with the findings of (Abrol *et al*., 2020) and (Singh *et al*., 2023) (Laghari *et al*., 2024) who found an increase in plant height as a result of NPK spraying. As shown in Table 2. The interaction between cultivar Al-Rasheed and concentration of 100mg L recorded highest values (83.19cm) in comparison with Latifiyah at control which recorded lowest values (65.70cm).

Table 2: *Effect cultivars, NPK concentrations on plant height (cm)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	65.70	72.96	71.74	70.13
Al-Rasheed	78.48	80.60	83.19	80.76
Iraq	67.89	72.06	78.64	72.86
L.S.D	2.63			1.82
Mean	70.69	75.20	77.86	
L.S.D	1.81			

Table 3: *Effect cultivars, NPK concentrations on flag leaf area (cm^2)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	29.27	35.00	37.60	33.96
Al-Rasheed	34.60	36.83	44.53	38.66
Iraq	32.07	36.03	38.90	35.67
L.S.D	1.86			0.99
Mean	31.98	35.96	40.34	
L.S.D	1.79			

Flag leaf area (cm^2)

Table 3 clearly shows that the effect of cultivars on flag leaf area was significant. A comparison of mean flag leaf areas revealed that Al-Rasheed had the largest area (38.66cm^2), whereas the lowest area of flag leaf was obtained from Latifiyah (33.96cm^2). The differences among Al-Rasheed and the two other cultivars might be attributed to the differences in the genetic makeup. This result is in agreement with (Bunder, 2024). NPK concentrations showed significant differences among treatments for flag leaf area (Table 3). The highest area of flag leaf (40.34 cm^2) was recorded with concentration 100 mg L, while the lowest flag leaf area (31.98cm^2) was obtained with control. The reason for increasing flag leaf area when sprayed with balanced NPK might be due to the improves nutrient uptake efficiency, such as nitrogen use efficiency which increased cell division, enlargement and as result increase leaves area (Jha and Anjana, 2023) (Basir *et al*., 2024). These findings align with those reported by (Seadh *et al*., 2017) and

(Singh *et al*., 2023), who observed that NPK spraying led to an increase in wheat flag leaf area. As shown in Table 3, the interaction between cultivars and NPK concentrations significantly influenced flag leaf area. Overall, the highest flag leaf area was recorded in Al-Rasheed plants at 100 mg L (44.53 cm^2), while the lowest was observed in Latifiyah plants under the control treatment (29.27 cm^2).

Chlorophyll index (SPAD)

Results in Table 4. Clearly shwoed that varieties had a significant effect on chlorophyll index (SPAD). Al-Rasheed had the highest chlorophyll index (46.39 SPAD) followed by Iraq (42.80 SPAD), while the lowest chlorophyll index (40.75 SPAD) was produced with Latifiyah. These findings could be due to variations in the genetic composition of different cultivars. Plants sprayed with 100 mg L produced highest chlorophyll index (48.41 SPAD), while plants in the control treatment 0 mg L produced (38.37 SPAD) and this could be attributed to the nitrogen is integral to chlorophyll production, which is essential for photosynthesis, thereby enhancing leaf area and increasing the interception of Photosynthetically Active Radiation (Yadav, 2024). Increased nitrogen levels boost chlorophyll content, which is crucial for vigorous early growth and maintaining photosynthetic efficiency throughout the plant's life cycle (Kubar *et al*., 2022) and (Öner 2024). These results are in accordance with those obtained by (Seadh *et al*., 2017) and (Singh *et al*., 2023) who found that NPK application increase chlorophyll index. As for the interaction, the highest means (53.44 SPAD) were recorded with the Al-Rasheed cultivar and concentration of 100mg L.

Table 4: *Effect cultivars, NPK concentrations on chlorophyll index (SPAD)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	35.12	42.00	45.12	40.75
Al-Rasheed	41.52	44.20	53.44	46.39
Iraq	38.48	43.24	46.68	42.80
L.S.D	2.24			1.19
Mean	38.37	43.15	48.41	
L.S.D	2.15			

Spike length (cm)

Cultivar type, NPK concentrations, and their interaction had a significant impact on spike length (Table 5). The Al-Rasheed cultivar produced the longest spikes (12.90 cm), followed by the Iraq cultivar (11.80 cm), while the shortest spikes were observed in the Latifiyah cultivar (10.87 cm). The obtained result is consistent with (Bunder, 2024) who confirmed that genotypes differed in the spike length. The concentration 100mg L gave the highest values of spike length (12.50cm) did not differ significantly from the 50mg L (12.00cm) In contrast, the control treatment resulted in the lowest values, measuring 11.08 cm. This could be due to the enhanced nutrient absorption by the plant, which stimulated increased cell division. This result is in agreement with those obtained by (Seadh *et al*., 2017) and (Abrol *et al*., 2020) who found an increase in the spike length as a result of NPK spraying. As shown in Table 5. the interaction between Al-Rasheed cultivar and the concentration 100mg L recorded tallest spikes (13.67cm) in comparison with Latifiyah cultivar at water which recorded lowest means (9.91cm).

Table 5: *Effect cultivars, NPK concentrations on spike length (cm)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	9.91	10.87	11.84	10.87
Al-Rasheed	12.10	12.91	13.67	12.90
Iraq	11.23	12.20	11.98	11.80
L.S.D	1.08			0.92
Mean	11.08	12.00	12.50	
L.S.D	0.82			

Number of spikes (m^{-2})

In this study, the number of spikes was significantly influenced by cultivars, NPK concentrations, and their interaction (Table 6). The Al-Rasheed cultivar produced the highest number of spikes (340.59 m^{-2}), followed by the Iraq cultivar than Latifiyah which gave the lowest mean for this trait (306.05m^{-2}). These differences may be due to the ability Al-Rasheed variety to branch. The obtained result is consistent with (Jaddoa and Kadom, 2016), (Bunder 2023) who confirmed that genotypes differed in the number of spikes. The concentration 100 mg L gave the highest acquire of number of spikes (348.86m^{-2}) Compared to the control treatment, which yielded the lowest values. (291.64m^{-2}). This increase might be due to the role of balance NPK in regulating the act of plant hormones which led to increased cell division in addition to the supply appropriate and continues of nutrients increased the accumulation of dry matter to improved vegetative growth (Coskun *et al*., 2019). These result are similar to those (Seadh *et al*., 2017) and (Kumar *et al*., 2025) who found an excess in the number of tillers due to NPK application. The highest values of number spikes (367.83m^2) were obtained by the interaction of Al-Rasheed cultivar with NPK concentration at 100mg L in comparison Latifiyah cultivar with water which recorded lowest value (271.44m^2).

Table 6: *Effect cultivars, NPK concentrations on number of spikes (m^2)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	271.44	317.84	328.87	306.05
Al-Rasheed	310.94	343.00	367.83	340.59
Iraq	292.54	336.88	349.89	326.44
L.S.D	7.65			5.18
Mean	291.64	332.58	348.86	
L.S.D	6.57			

Table 7: *Effect cultivars, NPK concentrations on number of grain spike^{-1}*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	27.09	30.48	31.32	29.63
Al-Rasheed	30.28	33.29	35.27	32.95
Iraq	29.22	28.45	33.72	30.46
L.S.D	1.89			1.52
Mean	28.86	30.74	33.44	
L.S.D	1.13			

Number of grains spike^{-1}

Results from Table 7. Show significant differences in the number of grains spikes^{-1} due to different Varieties, NPK concentricity and the interaction between the study factors. The highest cultivar in number of grains spike^{-1} was Al-Rasheed (32.95 grain spike^{-1}) followed by Iraq (30.46 grain spike^{-1}) did not differ significantly from the plants of Latifiyah which gave (29.63 grain spike^{-1}). The difference between the varieties in this characteristic was due to the difference in genotype. The obtained result was in agreement with finding of (Jaddoa and Kadom, 2016) and (Bunder 2023) who confirmed that the varieties differ in number of grains spikes^{-1}. The concentration 100mg L gave highest values of grains spike^{-1} (33.44 grain spike^{-1}) Compared to the control treatment, which resulted in the lowest value (28.86 grains per spike).The superiority of 100mg L treatment in this trait can be attributed to the superiority in the number of spikes per unit area (Table 6). This result is in agreement with those obtained by (Seadh *et al*., 2017) and (Kumar *et al*., 2025) who found an increase in the number of grains spike^{-1} as a result of NPK spraying. As shown in Table 7. The interaction between Al-Rasheed cultivar and concentration of 100 mg L recorded highest values (35.27 grain spike^{-1}) in comparison with control at Latifiyah cultivar which recorded lowest values (27.09 grain spike^{-1}).

Table 8: *Effect cultivars, NPK concentrations on 1000 grain weight (g)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	31.82	35.08	37.25	34.71
Al-Rasheed	34.95	37.23	40.74	37.64
Iraq	33.92	36.05	38.29	36.09
L.S.D	1.05			0.88
Mean	33.56	36.12	38.76	
L.S.D	0.50			

1000-grain weight (g)

The results presented in Table 8 clearly indicate that cultivars, NPK concentrations, and their interaction had a significant impact on 1000-grain weight. Among the cultivars, Al-Rasheed exhibited the highest 1000-grain weight at 37.64g, while Latifiyah recorded the lowest at 34.71g. This variation in grain weight may be attributed to differences in growth parameters such as flag leaf area (Table 3) and chlorophyll index (Table 4), which influenced photosynthetic activity and the efficient translocation of assimilates to the grains, ultimately extending the grain-filling period. The obtained result was consistent with (Jaddoa and Kadom, 2016) and (Bunder, 2023), who confirmed that there was a significant difference between the wheat varieties in grain weight. The highest 1000-grain weight was recorded with 100 mg L (38.76g), while the lowest value was noticed with control treatment (33.56g). This might be attributed to the role of major nutrients as nitrogen, phosphorus and potassium which significantly enhances the growth parameters due to the optimized nutrients availability that supports Multiple interconnected physiological and biochemical pathways necessary for plant development and biomass production which led to gave the large amount of dry matter transfer towards the sinks (Safar-Noori *et al*., 2018) and

(Abbas *et al*., 2022). This results in agreement with (Abrol *et al*., 2020). Regarding the interaction, Al-Rasheed plants produced heaviest 1000 grain weight (40.74g) when sprayed with 100mg L, whereas Latifiyah cultivar produced the lightest 1000 grain (31.82g) when sprayed with water only.

Table 9: *Effect cultivars, NPK concentrations on grain yield (t ha^{-1})*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	2.50	3.42	3.84	3.25
Al-Rasheed	3.23	4.02	5.14	4.13
Iraq	3.02	3.49	4.59	3.70
L.S.D	0.16			0.11
Mean	2.92	3.64	4.52	
L.S.D	0.11			

Grain yield (t ha^{-1})

The data presented in Table 9 demonstrates that the effects of cultivars, NPK concentrations, and their interactions on this trait were significant. Among the cultivars, Al-Rasheed recorded the highest yield at 4.13 t ha^{-1}, followed by Iraq (3.70 t ha^{-1}) than Latifiyah (3.25 t ha^{-1}), and this could be attributed to differences in the components of the yield such as number of spikes (Table 6), number of grains spike^{-1} (Table 7) and 1000 grain weight (Table 8). These results are in agreement with those obtained by (Jaddoa and Kadom. 2016) and (Bunder. 2023) who confirmed that the wheat varieties differ in grain yield due to different genotypes. Plants sprayed with 100mg L produced highest grain yield (4.52 t ha^{-1}), while plants in the control treatment produced (2.918 t ha^{-1}). This increase with 100mg L might be due to the significant influence of NPK on physiological and biochemical processes in the plant, and reflected in improving the growth parameters associated with the components of the yield, as a result increased in the grain yield (Singh *et al*, 2023). These results are in accordance with (Singh *et al*., 2023) who found an increase in the grain yield as a result of NPK spraying. Regarding the interaction, Al-Rasheed generated the highest grain yield (5.14 t ha^{-1}) when sprayed with 100mg L NPK, whereas Latifiyah cultivar gave lowest yield (2.50 t ha^{-1}) when sprayed with water only.

Protein content in grain (%)

Table 10 indicates that the impact of cultivars on protein percentage was not significant, whereas the effects of NPK concentrations and their interaction with cultivars were significant. Wheat plants treated with 100 mg L exhibited a notable increase in protein percentage (12.75%), while the control treatment recorded the lowest value (11.17%), which was not significantly different from the 50 mg Lconcentration (11.80%). The reason for increasing protein percentage when plants sprayed with NPK might be due to the role of nitrogen in its union with carbohydrates and the formation of basic amino acids of proteins (Toppo *et al*., 2024) and role of Phosphorus in building amino acids (Sepat and Rai. 2013). Also Potassium acts as an enzymatic activator in nitrate assimilation, which is crucial for protein synthesis.

It also aids in the translocation and storage of plant assimilates, supporting the overall growth and development of wheat, which can lead to increased protein content (Bonfim-Silva *et al*., 2018). These findings align with those reported by (Seadh *et al*., 2017) (Sultonov *et al*., 2025) who found an increase in NPK caused a increase in protein content. As shown in Table 10. the interaction between 100mg L and the Al-Rasheed cultivar recorded highest value (13.26%) in comparison with control at Latifiyah which recorded lowest value (10.17%).

Table 10: *Effect cultivars, NPK concentrations on protein content (%)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	10.17	11.95	12.26	11.46
Al-Rasheed	10.94	11.99	13.26	12.07
Iraq	12.41	11.45	12.73	12.20
L.S.D	0.93			NS
Mean	11.17	11.80	12.75	
L.S.D	0.69			

Carbohydrate content in grain (%)

Results in Table 11. clearly show that the effect of cultivars, NPK concentrations and their interaction had non significant effect on carbohydrate content in grain. The necessity of transferring the results of agricultural research to farmers through extension centers and their affiliated farms, and transferring what can be applied in terms of knowledge and skills that can be applied by farmers, to increase their productivity and income (Saleh *et al*., 2023: The necessity of educating the agricultural extension service about the latest agricultural technologies and information, based on the results of agricultural studies and research, and transferring them to farmers for their benefit. (Khamis *et al*., 2023, 2025).

Table 11: *Effect cultivars, NPK concentrations on carbohydrates content (%)*

Cultivars	NPK Concentrations (mg L)			Means
	0	50	100	
Latifiyah	55.38	53.58	53.86	54.27
Al-Rasheed	56.20	57.51	53.72	55.81
Iraq	57.04	58.71	54.50	56.75
L.S.D	NS			NS
Mean	56.21	56.60	54.03	
L.S.D	NS			

Conclusions and Recommendations

Considering all the results presented above, it can be concluded that superiority of the plants Al-Rasheed cultivar which sprayed with balance NPK concentration 100mg L.

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Novelty Statement

This study provides a comprehensive evaluation of balanced NPK foliar fertilization across different bread wheat cultivars under local agro-environmental conditions. While previous studies have reported the general benefits of foliar nutrition, limited information is available regarding the optimum concentration of balanced NPK fertilizer and its interaction with cultivar performance. The novelty of this work lies in the simultaneous assessment of growth traits, chlorophyll status, yield components, grain yield, and quality characteristics in response to different NPK concentrations.

Author's Contribution

Ehab Jabbar Aldabbagh: Wrote the first draft, Conceived the idea, prepared research protocol and supervised the research work, Conducted experiments, recorded data, and Analyzed.

Ali Razzaq Aljanabi: Conducted experiments and recorded data, analyzed.

Dheeaa Salih Alrawi: Provided the technical support and revised the manuscript technically.

Jasim Saleh: Check the manuscript with Journal format with updating the paper.

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. personal efforts, and the research was carried out with personal efforts.

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