Journal of Applied Horticulture, 28(3): 739-743, 2026
https://doi.org/10.37855/jah.2026.v28i03.113
Journal of Applied Horticulture
ISSN: 0972-1045

Effect of nitrogen and potassium fertilization on young tuberose cormel growth and corm production

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Abstract

Cormels of tuberose (*Polianthes tuberosa* L.) were planted in a lath house under 50% shade at the Department of Horticulture and Landscape Design, Tikrit University, Iraq, during the 2024/2025 growing season to investigate the effects of nitrogen and potassium fertilization on plant growth and corm production. The experiment included two factors: urea, applied at 0.5 and 1.0 g L^{-1} as a nitrogen source, and potassium sulphate, applied at 0.5 and 1.0 g L^{-1} as a potassium source, together with an untreated control and the corresponding treatment combinations. Vegetative growth traits, corm and cormel production, and lycorine alkaloid content were measured at the end of the experiment. The trial was conducted in a randomized complete block design (RCBD), comprising nine treatments with three replicates per treatment. Application of urea at 1.0 g L^{-1} significantly increased all the measured traits and produced the highest values for leaf length, number of leaves, leaf area, leaf greenness (SPAD index), mother-corm diameter, weight, volume and lycorine content (49.65 cm, 16.29 leaves $plant^{-1}$, 651.65 cm2 $plant^{-1}$, 38.11 SPAD units, 26.44 mm, 13.35 g, 12.43 cm^3 and 1.11 µg g^{-1}, respectively). Potassium sulphate at 1.0 g L^{-1} also produced high values for leaf length, leaf area, leaf greenness, mother-corm diameter, weight, volume and lycorine content (47.95 cm, 562.59 cm^2 $plant^{-1}$, 36.11 SPAD units, 23.77 mm, 11.42 g, 10.81 cm^3 and 0.98 µg g^{-1}, respectively). These results indicate that nitrogen and potassium fertilization can improve vegetative growth and corm development in tuberose plants.

Key words: Fertilization, lycorine, nitrogen, *Polianthes tuberosa*, potassium, tuberose.

Introduction

Tuberose (*Polianthes tuberosa* L.; syn. *Agave amica* Medik.) belongs to the Asparagaceae family and is native to Mexico (Thiede and Govaerts, 2017). Tuberose is one of the most important flowering cormous monocotyledons (Singh and Shankar, 2011). It grows very well in tropical and subtropical regions as a cut flower, and was introduced to China and India via Europe in the 16th century, where it is commercially produced (Zamin *et al*., 2020). Among other ornamental plants, tuberose possesses a distinctive and selective position because of its elegant shape, attractive, strongly fragrant flowers, cut flowers with long flowering white spikes and long vase life and for its florets which are regarded as a basic source for essential oil, so it is widely used for producing perfumes and cosmetics (Nisha *et al.*, 2025 and Rusdi *et al.*, 2021). Roots of tuberose are adventitious and fibrous, and although it could be propagated easily by corms (25-30 g in weight and 2-3 cm in diameter), it could be propagated also by cormels but this method needs up to 2-3 years to reach flowering age with high-quality flowers (Pranavi, 2026).

Lycorine is a crystalline alkaloid compound discovered in 1877 in the *Narcissus pseudonarcissus* plant. Interest in this alkaloid group and its compounds has been increasing because of their antitumor, antibacterial and antiviral activities (Jin and Yao, 2019). Lycorine ($C_{16}H_{17}NO_4$, MW: 287.31 g mol^{-1}) is a natural, medicinally active, widely used alkaloid and acts as an antipyretic, detoxifying, expectorant, fever-relieving and throat-inflammation-relieving agent (Saravani *et al.*, 2025). It also acts as an anti-inflammatory, anti-tumor and active medical substance inside medicinal herbs because it is not toxic to natural cells and lowers premature cellular aging resulting from stress and aging (Wang *et al.*, 2019b). It also helps in killing cancer cells especially in lungs and skin through its role in inducing programmed cell death and inhibiting its activity, and it works to strengthen the immune system (Singh *et al.*, 2020).

Appropriate scientific means should be adopted to achieve good corm production. Nitrogen fertilization is considered one of these means because nitrogen is one of the most important essential nutrients for plant and crop production. Plants require high amounts of nitrogen and absorb it in the forms of ammonia and nitrate. Nitrogen is considered as the most important essential nutrient element because it is involved in protoplasm structure, amino acids, chlorophylls, co-enzymes, energy compounds, nucleic acids, and enhances vegetative growth and the root system of plants. Patel *et al.* (2006) found that fertilizing *Polianthes tuberosa* L. with nitrogen at 400 kg ha^{-1} improved vegetative growth and corm production. Sewedan *et al.* (2024) noted that fertilizing *Polianthes tuberosa* L. with nitrogen at 200 kg ha^{-1} increased vegetative growth and induced corm production. Mukhtar (2022) showed that fertilizing *Polianthes tuberosa* plant with nitrogen at 300 kg ha^{-1} and potassium at 300 kg ha^{-1} individually or in combination improved vegetative growth and flowering and resulted in the highest corm volume when compared with the control. Potassium also is an essential nutrient element for plants; it is present in plant tissues at 2-6% of dry matter weight in the forms of soluble organic salts or salts of organic acids and contributes to increasing photosynthetic compounds,

carbohydrates, translocation inside plants and stomatal movement (Sneha *et al*., 2025). Flower yield was found to be improved by the application of three different levels of Poultry manure along with the nitrogen and potassium fertigation in the tuberose 'Arka Prajwal' (Hasna *et al*., 2024). Bulbs and bulbet production of LA hybrid lilium, 'Masai' were enhanced through the use of farmyard manure along with inorganic NPK fertilizers (Saraswati *et al*., 2024). In fact, the integrated fertilisation and irrigation positively influenced the vegetative growth and early flowering of Iris tingitana 'Wedgewood' (Eissa *et al*., 2024). Adam (2021) revealed that fertilizing gladiolus (*Gladiolus grandiflorus* L.) with potassium sulphate (K_2SO_4, 48%) at 2 g/pot enhanced growth indications and increased leaf width, chlorophyll content and diameter, weight and volume of corms compared to the control.

Tuberose produces a lot of cormels which require 2-3 years to reach the flowering age. This study aimed to increase the size of cormels and reduce the time required for flowering besides improving their quality to be suitable for high quality cut flowers.

Materials and methods

The cormels used in the study were planted in the lath house under 50% shade affiliated with the Department of Horticulture and Landscape Design at Tikrit University, Iraq, during the 2024/2025 season to study the effect of fertilization with nitrogen and potassium on growth and corm formation of tuberose (*Polianthes tuberosa* L.) grown from cormels.

Corms of tuberose were obtained from Syria by a local nursery in Erbil, Iraq. Cormels (1.2-1.3 cm in diameter) were removed from the obtained corms and soaked in Rival© fungicide at 2 mL L^{-1} for 2 h and then planted on 15th March, 2024 in plastic pots 15 cm in diameter filled with soil medium + peat moss + perlite (1:1:1, by volume) at a depth of 5-8 cm under the medium surface.

This experiment consisted of two factors: the first was nitrogen fertilization, while the second was potassium fertilization. Urea at 0, 0.5 and 1.0 g L^{-1} was used as a source of nitrogen, while potassium sulphate at 0.0, 0.5 and 1.0 g L^{-1} was used as a source of potassium, in addition to their interactions. After the cultivated cormels had produced 4-6 true leaves, the first application of urea was made; then, after one week, the first potassium sulphate application was made. Fertilizer solutions were applied three times during the experimental period, twice during autumn. Each plant received 500 mL of the respective fertilizer solution at each application. Across all applications, plants received a total of 750 and 1500 mg urea under the 0.5 and 1.0 g L^{-1} treatments, respectively. Since potassium sulphate (K_2SO_4) contains 50% potassium, each plant received 375 and 750 mg potassium per plant under the 0.5 and 1.0 g L^{-1} treatments, respectively. Fertilizers were applied three times during the experimental period, with 500 mL of solution applied per plant at each application.

The total amount of fertilizer applied per plant was calculated based on a total application volume of 1.5 L of solution per plant (500 mL per application over three applications). Urea, containing 46% nitrogen (N), was applied at concentrations of 0.5 and 1.0 g L^{-1}. Accordingly, each plant received 0.75 and 1.50 g of urea, equivalent to 345 and 690 mg of N per plant, respectively. Similarly, potassium sulphate (K_2SO_4), containing 50% potassium oxide (K_2O), was applied at concentrations of 0.5 and 1.0 g L^{-1}. The lower concentration supplied 0.75 g of potassium sulphate per plant, equivalent to 0.375 g of K_2O or approximately 311 mg of elemental potassium. The higher concentration supplied 1.50 g of potassium sulphate per plant, equivalent to 0.750 g of K_2O or approximately 623 mg of elemental potassium per plant.

The experiment was conducted using a factorial randomized complete block design (RCBD) consisting of nitrogen and potassium treatments with nine treatment groups, three replications, and six plants per experimental unit. The total number of plants in the experiment was 162. Data were analysed using SAS software, and treatment means were compared using Duncan's multiple range test at a 5% significance level.

In July 2024, the following data were recorded: leaf length (cm), leaf width (cm), number of leaves (leaves $plant^{-1}$), leaf area (cm^2 $plant^{-1}$) according to the method described by Kesgin *et al*. (2025) and chlorophyll (SPAD index). On the other hand, at the end of this experiment the plants were left inside their bags until 15/1/2025 to permit the growth of corms and cormels. Fifteen days before corm and cormel harvesting, irrigation was withheld, then corms and cormels were removed from the pots, dried and prepared for measurement and thoroughly cleaned of attached soil and the following data were recorded: mother corm diameter (mm), weight (g), and volume (cm^3), number of cormels less than 1.3 cm in diameter (cormels /corm), cormel diameter (mm), weight (g) and volume (cm^3).

Lycorine alkaloid contents in corms (µg g^{-1}): Processing of plant material: Following complete vegetative decline, the corms were randomly selected for each treatment after being cleaned from the pots. They were then sliced into thin slices and dehydrated in a drying oven at a controlled temperature of 40-45 °C to preserve the thermolabile alkaloidal compound and thereafter milled into a powder.

The extraction technique: The extraction was performed as previously described. Approximately 3 g of powdered plant material was steeped in 5 mL of 3% hydrochloric acid for 4 hours in an ultrasonic bath at 35 °C. The extract was then made alkaline using 1 mL of 20% NH_4OH, and the volume was adjusted to 10 mL with distilled water in a volumetric flask. The alkaline solution was centrifuged at 4500 rpm for 10 min to remove the precipitated material, and the supernatant was retained. Alkaloids were then extracted in a separatory funnel using chloroform (2 × 3 ml) for 10 min. The organic solvent was evaporated under vacuum to obtain the alkaloid extract, which was then dissolved in 1 mL of 0.2 % trifluoroacetic acid (TFA). A 30 µl aliquot was injected for HPLC analysis.

To develop the lycorine calibration curve, 1 mg of the alkaloid was dissolved in 3 mL of 0.1% TFA and filtered using a filter (100 × 15 mm, 0.55 µm). The stock solution was diluted to prepare five lycorine concentrations ranging from 1.0 to 150 µg ml^{-1} (Emir and Somer, 2018).

Preparation of standard solutions: A total of 5 mg of lycorine was dissolved in 10 mL of 0.5% TFA and filtered using a filter (150 × 15 mm, 0.60 µm). A 30 µl aliquot was then injected into the C_{18} column. The calibration curve regression equation was Y (peak area) = 14.6312012 ×x (concentration of Lycorine) − 1.228507, with $R^2 = 0.9987$.

Separation conditions using HPLC: The analysis was carried out using a liquid chromatography system (HPLC) type Shimadzu, LC-2010 AHT, with a with a C18 column (250 mm length × 4.6 mm internal diameter). A 30 µL sample aliquot was

injected for analysis.. The mobile phase of trifluoroacetic acid : water : acetonitrile (0.01 : 80 : 20 v/v/v) was applied at a flow rate of 1.5 mL min^{-1}, UV detection was performed at a wavelength of 285 nm, detector type U-PAD2 (pulsed Amperometric Detection) and a column temperature of 25°C (Unver Somer *et al*, 2013).

Results

Table 1 shows that the traits Leaf length (cm), Leaf width (cm), No. of leaves (leaves $plant^{-1}$), Total chlorophylls (SPAD), Mother corm diameter (mm), Mother corm weight (g) and Lycorine (µg g^{-1}) demonstrated a highly significant main effect ($P \leq 0.01$) for both nitrogen and potassium factors. Additionally, the N×K interaction for SPAD index was also highly significant ($P \leq 0.01$), indicating that the plants' adaptation to N levels depended directly and significantly on the applied amount of K. For the traits Mother corm weight (g), Mother corm diameter (m) and cormel diameter (mm), the direct effect of N and K as well as their interaction were significant ($P \leq 0.01$). In summary, the levels of N and K factors caused highly significant differences throughout nearly all measured characteristics.

Data recorded in Table 2 show significant superiority of urea at 1.0 g L^{-1} when compared with other nitrogen concentrations for leaf length and width, number of leaves, leaf area and SPAD index of leaves with recorded values of 49.65 cm, 1.63 cm, 16.29 leaves/plant, 651.65 cm^2 $plant^{-1}$, 38.11 SPAD, respectively. Regarding the effect of potassium sulphate concentration, 1.0 g L^{-1} was more effective when compared with other concentrations with recorded values of 47.95 cm, 1.57 cm, 15.25 leaves/plant, 562.59 cm^2 $plant^{-1}$ and 36.11 SPAD, respectively.

Regarding the combined treatments, these results indicate that nitrogen and potassium fertilization improved growth and corm development. Nitrogen 1.0 g L^{-1} + potassium sulphate at 1.0 g L^{-1} recorded the highest values in terms of leaf length and width, leaf area and SPAD index in leaves (51.65 cm, 1.68 cm, 690.67 cm^2 $plant^{-1}$ and 39.56 SPAD, respectively).

Data in Table 3 showed that fertilizing with urea at 1.0 g L^{-1} resulted in significantly the highest values in terms of mother corm diameter, weight and volume, cormel number, diameter, weight and volume and lycorine alkaloid contents in corms (26.44 mm, 13.35 g, 12.43 cm^3, 12.47 cormels /corm, 14.51 mm , 1.57 g, 1.74 cm^3 and 1.11 µg g^{-1}, respectively).

Treating tuberose with potassium sulphate at 1.0 g L^{-1} resulted in the highest values in most cases, i.e., mother corm diameter, weight and volume, cormel diameter, weight, volume and their lycorine alkaloid content with recorded values of 23.77 mm, 11.42 g, 10.81 cm^3, 13.70 mm, 1.55 g, 1.53 cm^3 and 0.98 µg g^{-1}, respectively.

In the same manner, superiority was observed for the combined treatment including urea at 1.0 g L^{-1} + potassium sulphate at 1.0 g L^{-1} which resulted in the highest values in terms of mother corm diameter (28.05 mm), weight (14.87 g) and volume (14.12 cm^3), cormel diameter (14.83

Table 2. Effect of different concentrations of nitrogen and potassium fertilizers and their interaction on some vegetative growth characters and SPAD index of *Polianthes tuberosa* L. during the 2024/2025 season

Treatments	Concentrations (g L^{-1})		Leaf length (cm)	Leaf width (cm)	Number of leaves $plant^{-1}$	Leaf area (cm^2 $plant^{-1}$)	SPAD index
Nitrogen fertilization (urea)	0.0		42.20 c	1.43 c	13.47 c	346.49 c	30.41 c
	0.5		46.97 b	1.54 b	14.96 b	532.32 b	34.90 b
	1.0		49.65 a	1.63 a	16.29 a	651.65 a	38.11 a
Potassium fertilization (K_2SO_4)	0.0		44.43 c	1.50 c	14.47 b	473.34 c	32.45 c
	0.5		46.44 b	1.53 b	14.99 a	494.52 b	34.87 b
	1.0		47.95 a	1.57 a	15.25 a	562.59 a	36.11 a
Interaction	Urea	K_2SO_4					
	0.0	0.0	40.84 f	1.40 h	13.21 f	285.53 i	28.44 e
		0.5	42.65 e	1.43 g	13.44 ef	315.88 h	30.38 d
		1.0	43.11 e	1.46 f	13.77 e	438.06 g	32.43 c
	0.5	0.0	44.97 d	1.51 e	14.44 d	512.43 f	33.13 c
		0.5	46.86 c	1.54 d	15.22 c	525.49 e	35.25 b
		1.0	47.48 c	1.57 c	15.22 c	559.05 d	36.33 b
	1.0	0.0	49.08 b	1.59 c	15.77 b	622.07 c	35.78 b
		0.5	49.81 b	1.62 b	16.33 a	642.21 b	39.00 a
		1.0	51.65 a	1.68 a	16.77 a	690.67 a	39.56 a

Values with the same letters for each individual factor and for the interaction do not significantly differ according to Duncan's Multiple Range Test at the 5% level of probability.

Table 1. Analysis of variance (ANOVA) for the effects of nitrogen and potassium fertilization treatments on vegetative, reproductive, and biochemical characteristics

S. O. V.	d.f.	M.S.										
		Leaf length (cm)	Leaf width (cm)	No. of leaves (leaf/plant)	Leaf area(cm^2/ plant)	SPAD index	Mother corm diameter (mm)	Mother corm weight (g)	Mother corm volume (cm^3)	cormels diameter (mm)	Cormels weight (g)	Cormels number	Cormels volume (cm^3)	Lycorine (µg g^{-1})
Block	2	1.375	0.000337	0.274	343.907	0.398	0.232	0.041	0.028	0.04	0.012	0.15	0.03	0.001
N	2	128.082 **	0.0902 **	17.854 **	212846.3 **	134.627 **	94.641 **	79.449 *	40.58 **	29.789 **	15.24**	12.8**	8.45**	0.112 **
K	2	28.021 **	0.0104 **	1.416 **	19570.84 **	34.197 **	16.461 **	16.2 *	3.227 **	0.883 **	1.12**	2.05**	0.94**	0.083 **
N*K	4	1.051	0.00035	0.09	2725.976 **	1.582 **	1.071 **	1.687 *	0.053	1.469 **	0.21*	0.44*	0.18**	0.018 **
Error	16	0.452	0.000225	0.072	42.549	0.218	0.1	0.072	0.205	0.042	0.015	0.11	0.025	0.001
Total	26													

Table 3. Effect of different concentrations of nitrogen and potassium fertilizers and their interaction on corms and cormels characters and lycorine alkaloid contents of *Polianthes tuberosa* L. during the 2024/2025 season

Treatment	Concentrations (g L^{-1})		Mother corm diameter (mm)	Mother corm weight (g)	Mother corm volume (cm^3)	No. cormels / corm	Cormels diameter (mm)	Cormels weight (g)	Cormels volume (cm^3)	Lycorine (µg g^{-1})
Nitrogen fertilization (urea)	0.0		19.91 c	6.89 c	6.49 c	8.40 c	10.92 c	1.35 c	1.18 c	0.74 c
	0.5		21.51 b	9.69 b	9.44 b	11.47 b	13.24 b	1.49 b	1.41 b	0.88 b
	1.0		26.44 a	13.35 a	12.43 a	12.47 a	14.51 a	1.57 a	1.74 a	1.11 a
Potassium fertilization (K_2SO_4)	0.0		21.55 c	8.73 c	8.13 c	10.14 b	12.25 c	1.36 c	1.35 c	0.83 c
	0.5		22.54 b	9.79 b	9.41 b	10.88 a	12.71 b	1.49 b	1.44 b	0.91 b
	1.0		23.77 a	11.42 a	10.81 a	11.32 a	13.70 a	1.55 a	1.53 a	0.98 a
Interaction	Urea	K_2SO_4								
	0.0	0.0	19.33 g	5.73 g	5.21 h	7.88 f	10.07 e	1.33 e	1.17 f	0.64 g
		0.5	19.85fg	6.22 g	6.02 g	8.55 ef	10.12 e	1.35 de	1.17 f	0.73 f
		1.0	20.55ef	8.71 f	8.23 f	8.77 e	12.57 d	1.35 de	1.19 f	0.84 e
	0.5	0.0	20.85 e	8.93 f	8.84 e	10.77 d	12.45 d	1.37 de	1.32 e	0.86 e
		0.5	20.98 e	9.49 e	9.38 d	11.55 cd	13.58 c	1.50 c	1.38 d	0.87 e
		1.0	22.71 d	10.66 d	10.09 c	12.10 bc	13.68 c	1.59 b	1.53 c	0.93 d
	1.0	0.0	24.46 c	11.53 c	10.34 c	11.77 bc	14.25 b	1.39 d	1.55 c	1.00 c
		0.5	26.81 b	13.66 b	12.83 b	12.55 ab	14.44 b	1.60 b	1.77 b	1.14 b
		1.0	28.05 a	14.87 a	14.12 a	13.10 a	14.83 a	1.71 a	1.89 a	1.19 a

Values with the same letters for each individual factor and for the interaction do not significantly differ according to Duncan's Multiple Range Test at the 5% level of probability.

mm), weight (1.71 g) and volume (1.89 cm^3) and lycorine alkaloid contents in corms (1.19 µg g^{-1}).

Discussion

Results illustrated in Tables 2 and 3 refer to the positive role of nitrogen fertilization in improving growth characteristics. In this regard, increasing length and width of leaves by nitrogen fertilization led to an increase in total leaf area per plant which was maximized with an increasing number of leaves per plant. This may be due to the critical role of nitrogen in forming plant pigments by synthesizing amino acids and essential proteins for building chloroplasts. This response may be attributed to the important role of nitrogen in amino acid and protein synthesis, chlorophyll formation and the development of photosynthetically active tissues. Adequate nitrogen availability can therefore promote leaf development and enhance photosynthetic capacity, contributing to improved vegetative growth. In this respect, the availability of nitrogen to be absorbed by plant roots and its accumulation in plant tissues was reflected in increasing its concentration in leaves and in turn increasing photosynthetic products. On the other hand, nitrogen increased growth of underground parts as a result of increased carbohydrates produced by photosynthesis, so the compounds that plants need to build amino acids, co-enzymes and chlorophyll were increased (Wang *et al.*, 2019a) and this was reflected in increased plant growth and corm and cormel growth, including corm diameter, weight and volume. Increasing lycorine alkaloid contents of corms by nitrogen fertilization may be due to the role of nitrogen in building IAA and enhancing meristem activity, cell division, new cell production, increasing photosynthesis and protoplasm building (Xu *et al.*, 2020). Because auxins and gibberellins are involved in cell division and enlargement and nitrogen is essential in the production of such growth regulators, leaf length and width were increased by nitrogen fertilization. Potassium, on the other hand, increases root efficiency in taking up nitrogen essential for chlorophyll production. Potassium plays an essential role in increasing leaf length, width and chlorophyll contents. As a result, increasing number of leaves led to an increase in potassium solutes, osmotic pressure, cell enlargement, protein formation and photosynthetic enzymes (Singh *et al*, 2020). This suggests potential improvements in nutrient uptake, photosynthesis and application (Al-Hashemi *et al*., 2026a). Potassium is also important as a counterion (maintaining electrical balance) for NO_3^- transport from roots to foliage in the xylem. Applying potassium, on the other hand, positively influenced the photosynthetic process, transpiration, photophosphorylation, translocation, formation of ATP and nutrient activities (Rawat *et al*., 2022). Nitrogen and potassium promote plant growth through complementary physiological and biochemical mechanisms. Potassium contributes to membrane potential regulation, stomatal movement, photosynthesis and assimilate translocation, while supporting efficient nutrient uptake and plant metabolism. This enhances nitrogen, phosphorus and potassium absorption and stimulates hormone-like signaling pathways that regulate plant growth, thereby improving water and nutrient uptake efficiency, as well as cell division and elongation (Al-Hashemi *et al*., 2026a). In particular, it stimulates cell division, stem growth, chlorophyll synthesis, flower differentiation and nutrient redistribution (Abdalijabar *et al*., 2026). Several other experimental results are consistent with our findings and confirm the results of this study (Al-Hashemi and Meftahizade, 2026, Al-Hashemi *et al*., 2026b).

The results suggest that appropriate nitrogen and potassium fertilization can promote vegetative growth, improve corm and cormel development, and increase lycorine content in tuberose under the experimental conditions. Among the evaluated treatments, the combined application of urea at 1.0 g L^{-1} and potassium sulphate at 1.0 g L^{-1} produced the highest values for several measured growth and corm-production characteristics. Among the treatments evaluated, the combined application of urea at 1.0 g L^{-1} and potassium sulphate at 1.0 g L^{-1} was the most effective and is therefore recommended under the conditions of this study.

Ethics approval and consent to participate: This study is not a clinical trial and no human participants were involved in this research.

Consent for publication: The authors declare their consent to the publication of this article.

Data availability: All data generated during this study are included in this article.

Competing interests: The authors declared no potential conflicts of interest regarding the research, authorship and publication of this article.

Funding: There is no financial support.

Authors' contributions: The authors conducted the experiments in collaboration and wrote the manuscript.

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Received: May, 2026; Revised: June, 2026; Accepted: July, 2026