Research Article

Optimizing Chickpea Production Through Strategic Management of *Asphodelus tenuifolius* Cav. in District Karak, Khyber Pakhtunkhwa

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Abstract | This study aimed to explore effective weed control methods for the troublesome weed *Asphodelus tenuifolius* Cav. (wild onion) in chickpea growing areas of district Karak, Khyber Pakhtunkhwa, Pakistan. A randomized complete block design with three replications was used to confirm the reliability and statistical accuracy of the experimental outcomes. Ten different treatment including three herbicides application (pendimethalin, dual gold, and fenoxaprop-p-ethyl), three mulching methods (black polythene, white polythene and available weed biomass), and extracts of three allelopathic weed namely *Asphodelus tenuifolius*, *Convolvulus arvensis* and *Lathyrus aphaca*, were compared to control. To evaluate the weeds and chickpea parameters including weed density (m^{-2}), dry weight (m^{-2}) of *A. tenuifolius*, chickpea plant height (cm), 500 seed weight (g), biological yield (kg ha^{-1}), grain yield (kg ha^{-1}) and cost benefit ratio. The data analysis exhibited that the pendimethalin resulted in the lowest *A. tenuifolius* density (5.10 m^{-2}), dry weight (0.65 kg m^{-2}), whereas the control treatments had the highest *A. tenuifolius* density (78.46 m^{-2}) and dry weight (19.92 kg m^{-2}). Similarly, regarding chickpea parameters, pendimethalin application exhibited the maximum plant height (47.3 cm), 500 seed weight (166 g), biological yield (4535 kg ha^{-1}), grains yield (1434 kg ha^{-1}), and cost benefit ratio (3.2). In contrast, all these parameters reached their minimum values in the control treatments. The research conclusions finally recognized pendimethalin as the most effective solution for *A. tenuifolius* management, resulting in substantial improvements in both chickpea yield and yield-related characteristics. Moreover, fenoxaprop-p-ethyl herbicide also confirmed notable positive effects on weed suppression and chickpea productivity. These results emphasized the crucial importance of implementing appropriate weed management approaches to improve chickpea productivity and to reduce competitive interference from weeds in chickpea production, ultimately contributing to developed agricultural sustainability and farmer productivity in the region.

Received | July 02, 2025; **Accepted** | December 08, 2025; **Published** | December 25, 2025
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Citation | Khan, I., Abdullah, M. Ibrahim, M.I. Khan, M. Saleem, S.A. Khan, I.A. Khan, H. Khan, Z. Hussain, M. Ilham, S. Afzal, B. Gul, N. Khan, M.A. Khan and M. Saeed. 2025. Optimizing chickpea production through strategic management of *Asphodelus Tenuifolius* Cav. in District Karak, Khyber Pakhtunkhwa. *Pakistan Journal of Weed Science Research,* 31(4): 258-265.
DOI | https://dx.doi.org/10.17582/journal.pjwsr/2025/31.4.258.265
Keywords | *A. tenuifolius*, Chickpea, Herbicides, Plant height, Weed density and yield

Introduction

Chickpea (*Cicer arietinum* L.) is a winter season crop from the family Fabaceae. It is self-pollinated, while nearly one percent is cross-pollinated (Kanatas and Gazoulis, 2022). In many parts of the world, chickpeas are mostly grown for eating. Because of its abundant dietary content and as a restorative crop, it increases soil fertility by fixing atmospheric nitrogen and dropping the need for chemical fertilizer. Chickpea seeds are a significant and economical source of highly edible components such as protein (15-22%), carbohydrates (50-58%), fats (3-10%), fiber (6-7%), moisture (7-8%), and minerals (Kakaei *et al*., 2024). According to Merga and Haji (2019), chickpeas rank third among pulses in terms of gross global production, with an average of 11.6 metric tonnes produced yearly. After India, Turkey, Russia, and Myanmar, Pakistan ranks fifth globally in terms of chickpea yield (Arriagada *et al*., 2022).

After beans and peas, chickpeas rank as the third most significant legume crop in Pakistan. Chickpea is an important part of Pakistan's pulse production, making up 73% of all pulse-cultivated land and contributing 76% of total production (Ullah *et al*., 2020). In Pakistan, 883,000 hectares of chickpeas were grown during the growing season, resulting in a total production of 234,000 tonnes, and an average grain yield of 265 kg ha^{-1}. Chickpeas were grown on 29,010 hectares in Khyber Pakhtunkhwa province, yielding 18,660 tonnes with a significantly greater average yield of 643 kg ha^{-1} (Pakistan Economic Survey, 2023-2024). Production enhancement is interrelated with a number of factors, such as sowing time, plant density, access to water, the prevention of disease and insect pests, the availability of nutrients and weed management techniques (Dubey and Prakash, 2023). The average yield of chickpeas in Pakistan is still much lower than in the top producing nations, due to a number of problems. Weeds emergence in legume crops is one of the key and most significant causes of this yield inconsistency. When weeds germinate with chickpeas, they compete aggressively for sunlight, water, nutrients, space, and moisture. If they are not controlled rapidly and proficiently, this can adversely affect crop development (Reddy *et al*., 2022). Chickpea is greatly susceptible to weed competition because they cause up to 40-87% yield reduction (Singh *et al*., 2020). However, effective weed control can significantly advance chickpea yield by 17-100 percent. Weeds in Pakistan, reduced the productivity and quality of the grains by 24 to 63 percent (Abdullah *et al*., 2023). The first 49 days after chickpea crop sowing is considered the important period of weed-crop competition (Singh *et al*., 2020).

Chickpea weeds in Khyber Pakhtunkhwa include *A. tenuifolius* Cav., *Cenchrus longispinus* Hack. Fernald, *Cynodon dactylon* L. Pers., *Euphorbia dracunculoides* Lam., *Carthamus oxycantha* M. Bieb., *Cirsium arvense* L. Scop. and *Convolvulus arvensis* L. among them *A. tenuifolius* is a very challenging weed species in the chickpea that is predominant in sandy areas of Khyber Pakhtukhwa, Pakistan and endeavors beside the chickpea across the growing period. Annually it declined the average yield of chickpea up to 45%. In district Karak, *A. tenuifolius* was the utmost predominant weed species in chickpea (Abdullah *et al*., 2023). Application of various weed management approaches comprising herbicides, certain allelopathic weeds extract, and mulches can lead to enhancements in the production of chickpea (Khan *et al*., 2023). The goal of this current study is to determine which synthetic or bio herbicides are best suited for controlling weeds in chickpea. Transferring the technologies and useful knowledge acquired from field studies to end users.

Materials and Methods

Field experiment

The experiment was carried out during winter growing season 2023-2024 in farmer fields of District Karak, a major chickpea growing area in Khyber Pakhtunkhwa province, using randomized complete block design (RCBD), with three replications, each measuring 10m × 3m.

Weed extract preparation

The selected plants after proper collection were washed and dried in oven at 72 h and 65 °C trailed by the grinding of the products with the help of a grinder. The ground samples were kept in paper bag to be used further in the experiment. Preparation aqueous extracts of entire parts of the plants of *A. tenuifolius*, *C. arvensis* and *L. aphaca* to prepare powders. Subsequent the powder preparation of the plants, then individually at 100g per litter of each extracts concentration were prepare and put in distilled water 48 h at room temperature. The extracts were filtered using muslin cloth and finally using Whatman No. 1 filter paper. Then the different concentration of each species after 24 hours 100% of the entire extract of each plant was added with double distilled water. The aqueous extracts of each plant were then bottled and labeled to continue with the experimentation for testing herbicidal efficacy.

Application of treatments

Herbicides and allelopathic weed extracts were measured using a calculating cylinder and applied with a 12 L knapsack sprayer equipped with a flat nozzle, whereas mulch treatments were placed directly on the soil surface.

Treatments

- T_1: Control
- T_2: Pendimethalin @ 2.0 L ha^{-1} (post application) at 25 DAS (days after sowing)
- T_3: Dual gold @ 2.0 L ha^{-1} (post application) at 25 DAS
- T_4: Fenoxaprop-e-ethyl @ 2.0 L ha^{-1} (post emergence) at 25 DAS
- T_5: Black polythene mulch at 25 DAS
- T_6: White polythene mulch at 25 DAS
- T_7: Available weed biomass mulch at 25 DAS
- T_8: *Asphodelus tenuifolius* weed extract at 25 DAS
- T_9: *Convolvulus arvensis* weed extract at 25 DAS
- T_{10}: *Lathyrus aphaca* weed extract at 25 DAS

Data recorded

Data were recorded on the following parameters; *A. tenuifolius* density (m^{-2}), *A. tenuifolius* dry weight (Kg m^{-2}), plant height (cm), 500 grain weight (g), biological yield (kg ha^{-1}), grains yield (kg ha^{-1}), cost benefit ratio (CBR).

Statistical analysis

Data were statistically analyzed by using Statistix 8.1 software, and treatments averages were compared using LSD test (Steel *et al*., 1997).

The data was statistically analysed, and the least significant difference (LSD) was determined using the approach developed by Steel *et al*. (1997). or several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds. For several reasons, the average yield of chickpea is low in Pakistan as compared to other chickpea producing countries worldwide but the most important reason is the presence of weeds.

Results and Discussion

A. tenuifolius density (m^{-2})

The data demonstrated that the weed density significantly influenced by the application of various weed control methods as presented in (Table 1). The data exhibited that the use of Pendimethalin as post emergence produced the lowest weed density (5.10 m^{-2}) of *A. tenuifolius*, which was trailed by Fenoxaprop-p-ethyl (6.03 m^{-2}), and Dual gold (7.13 m^{-2}), both were statistically comparable to each other. Current conclusions revealed that the efficacy of Pendimethalin and Fenoxaprop-p-ethyl as post emergence treatments inhibiting the development and propagation of *A. tenuifolius*. In contrast, control treatments had the maximum *A. tenuifolius* density (78.46 m^{-2}), showing significant weed production without interference. Singh *et al*. (2020) described that chickpea yield losses can reach 40-87% in fields with high *A. tenuifolius* population. Reddy *et al*. (2022) also reported a linear relationship between *A. tenuifolius* density and chickpea yield reduction, with each further *A. tenuifolius* plants m^{-2} reducing yield by 2.52%. Khan *et al*. (2023) confirmed that Pendimethalin and Fenoxaprop-p-ethyl application effectively control *A. tenuifolius* population in chickpea.

A. tenuifolius dry weight (kgm^{-2})

Data analysis showed that the use of various weed control approaches had a significant influenced on dryweight of *A. tenuifolius* as showed in (Table 2).

Table 1: *A. tenuifolius density (m^{-2}) as influenced by different weed control method in chickpea.*

S. No.	Treatments	*A. tenuifolius* density (m^{-2})
1	Control	78.46 a
2	Pendimethalin	5.10 h
3	Dual gold	7.13 h
4	Fenoxaprop p ethyl	6.03 h
5	Black polythene mulch	9.83 g
6	White polythene mulch	21.56 e
7	Available weed biomass mulch	27.40 d
8	*A. tenuifolius* weed extract	15.46 f
9	*Convolvulus arvensis* weed extract	29.53 c
10	*Lathyrus* aphaca weed extract	36.90 b
	LSD (0.05)	2.08

Mean values with dissimilar letters differ significantly at 0.05 probability level.

Table 2: *A. tenuifolius dry weight (kg m^{-2}) as influenced by different weed control method in chickpea.*

S. No.	Treatments	*A. tenuifolius* dry weight (kg m^{-2})
1	Control	19.92 a
2	Pendimethalin	0.65 h
3	Dual gold	1.34 h
4	Fenoxaprop p ethyl	0.98 h
5	Black polythene mulch	2.87 g
6	White polythene mulch	7.12 e
7	Available weed biomass mulch	14.34 d
8	*A. tenuifolius* weed extract	9.46 d
9	*Convolvulus arvensis* weed extract	10.57 c
10	*Lathyrus* aphaca weed extract	12.37 b
	LSD (0.05)	1.17

Mean values with dissimilar letters differ significantly at 0.05 probability level.

The statistical analysis revealed that the various control methods successfully reduced the dry weed biomass, indicating that the treatments effectively inhibited weed development and dry biomass accumulation. Results revealed that application of Pendimethalin (post-emergence) documented the minimum dry weight (0.65 kg m^{-2}) of *A. tenuifolius*, that was followed by Fenoxaprop-p-ethyl (0.98 kg m^{-2}) and Dual gold (1.34 kg m^{-2}), these were statistically similar to each other. Current outcomes suggested that these herbicides such as Pendimethalin, Fenoxaprop-p-ethyl and Dual gold, were mostly successful in decreasing the development of dry biomass of *A. tenuifolius*. Conversely, the un-treated treatments, where no methods of weed control were applied, had the highest dry weight (19.92 kg m^{-2}) of *A. tenuifolius*. Data showed that without interference, *A. tenuifolius* proficient abandoned growth and biomass accumulation, ensuing in higher dry biomass. These findings are constant with Khan *et al.* (2023) who stated that application of Pendimethalin considerably declined the dry biomass of different weeds. Furthermore, our outcomes are maintained by the effort of Kanatas and Gazoulis (2022), indicated that herbicides application led to the lowermost dry weed biomass and the uppermost production of grains.

Table 3: *Plant height (cm) as influenced by different weed control method in chickpea.*

S. No.	Treatments	Plant height (cm)
1	Control	25.4 g
2	Pendimethalin	47.3 a
3	Dual gold	44.8 ab
4	Fenoxaprop p ethyl	42.3 b
5	Black polythene mulch	35.4 d
6	White polythene mulch	29.6 g
7	Available weed biomass mulch	34.1 e
8	*A. tenuifolius* weed extract	40.4 c
9	*Convolvulus arvensis* weed extract	32.8 e
10	*Lathyrus* aphaca weed extract	31.5 f
	LSD (0.05)	1.3

Mean values with dissimilar letters differ significantly at 0.05 probability level.

Plant height (cm)

Statistical analysis revealed that different weed control method significantly affected the plant height of chickpea as displayed in (Table 3). The choice of weed control practices considerably impact the development of chickpea plants, thereby inducing their yield and production. The results exhibited that application of Pendimethalin (post-emergence) noted the tallest plant height (47.3 cm), that was trailed by Fenoxaprop-p-ethyl (42.3 cm). This showed that Pendimethalin and Fenoxaprop-p-ethyl were successful in stimulating higher growing in chickpea plants. Conversely, the un-treated (control) treatments, where no treatments were applied, had the smallest plant height (25.4 cm). This revealed that without involvement, weed opposition undesirably affected the development of chickpea plant heights. These conclusions indicated that improving plant height through successful weed control tactics is critical for attaining superior yield and production of chickpea. Our outcomes align with previous studies by Khan *et al.* (2023), who suggested the careful use of Pendimethalin for weed inhibition and stimulating chickpea plant height. Similarly, Abdullah *et al.* (2023) established that herbicides like Pendimethalin provide effective weed control, whereas also enhancing chickpea plant height.

500 grain weight (g)

The analyzed data revealed that 500-grain weight were significantly affected by the application of different weed control method as presented in (Table 4). Results showed that the maximum 500-grain weight was observed in Pendimethalin (166 g) and Fenoxaprop-p-ethyl (165 g) as post-emergence application, that was followed application of Dual gold (155 g), these are statistically different to each other. In contrast, the control treatments revealed the smallest 500-grain weight (123 g). Un-weeded plots, keeping the utmost weed density, documented the lowermost grain weight, as weeds not only strive with the crop for nutrient resources, but also inhibit its growing, decreasing total yield potential. Current results highlighted that treatments with severe weed density demonstrated lower 500-grain weight. Pendimethalin and Fenoxaprop-p-ethyl were effectively controlled weeds and exhibited higher 500-grain weight. These conclusions underlined the significance of weed control techniques in maximizing crop efficiency. Effectively controlling weeds over the use of herbicides can raise an environment beneficial to crop improvement, leading to greater seed weight, and enhanced productivity (Khan *et al.*, 2023). Comparable outcomes were described by Singh *et al.* (2020), who reported a lessening in the grain weight, and a decline in total grain yield with increasing density of *A. tenuifolius* plants. Likewise, Reddy *et al.* (2022) defined that various methods of weed control substantially improved grain weight.

Biological grain weight (kg ha^{-1})

Data revealed significant differences in the biological yield by different weed control method as presented in (Table 5). The results exhibited that the highest biological yield (4535 kg ha^{-1}) was found in Pendimethalin as post-emergence application, that was trailed by Fenoxaprop-p-ethyl (4166 kg ha^{-1}) as post-emergence, both statistically different to each other. Application of herbicides successfully managed weed development, permitting the chickpea to flourish and attain greater biological yields. In contrast, the un-treated treatments showed the smallest biological yield (3124 kg ha^{-1}), demonstrating that the dense weed infestation in these plots had a harmful effect on chickpea, ultimately leading to lesser biological yield. These conclusions are constant with previous research by Khan *et al.* (2019). Based on these consequences, it is prudent to employ weed control approaches like application of herbicides such as Pendimethalin and Fenoxaprop-p-ethyl, along with the execution of mulches. These methods can effectively diminish weed opposition, foster healthy crop development, and finally improvement the biological yield. These outcomes are in alignment with previous studies by Khan *et al.* (2023). Growers should consider adopting these control methods to increase their crop efficiency, and ensure a greater biological yield for forage purposes, as highlighted by Kanatas and Gazoulis (2022).

Table 4: *500 grain weight (g) as influenced by different weed control method in chickpea.*

S.	Treatments	500 grain weight (g)
1	Control	123 h
2	Pendimethalin	166 a
3	Dual gold	155 b
4	Fenoxaprop p ethyl	165 a
5	Black polythene mulch	153 b
6	White polythene mulch	147 d
7	Available weed biomass mulch	143 e
8	*A. tenuifolius* weed extract	151 c
9	*Convolvulus arvensis* weed extract	138 f
10	*Lathyrus* aphaca weed extract	132 g
	LSD (0.05)	2.5

Mean values with dissimilar letters differ significantly at 0.05 probability level.

Grain yield (kg ha^{-1})

The grain yield stands as a fundamental factor of crop achievement. The data revealed that the grain yield of chickpea influenced by various weed control method as presented in (Table 6). The results exhibited that the maximum grain yield (1434 kg ha^{-1}) was achieved by post-emergence application of Pendimethalin. Similarly, followed by post-emergence application of Fenoxaprop-p-ethyl (1357 kg ha^{-1}) both were statistically different to each other. In contrast, due to unsuccessful weed management and the growing of weeds in the field, the control treatments showed the least grain yield (1023 kg ha^{-1}). Our results underlined the important yield losses in the grain yield, when weeds are left uninhibited until the critical period of weed opposition. These conclusions support with the earlier research conducted by Reddy *et al*. (2022). Weeds pose as challenging oppositions, competing with crops for resources, thereby lessening grain yield. Effective control of weeds as attained with the use of Pendimethalin and Fenoxaprop-p-ethyl herbicides, leads to improved grain yield, as corroborated by Khan *et al*. (2018, 2023). Plots with lesser weed populations tend to evident greater grain yield, underscoring the essential role of weed management in enhancing crop efficiency, as emphasized by Khan *et al*. (2019).

Table 5: *Biological yield (kg ha^{-1}) as influenced by different weed control method in chickpea.*

S. No.	Treatments	Biological yield (kg ha^{-1})
1	Control	3124 j
2	Pendimethalin	4535 a
3	Dual gold	3963 c
4	Fenoxaprop p ethyl	4166 b
5	Black polythene mulch	3823 d
6	White polythene mulch	3637 f
7	Available weed biomass mulch	3556 g
8	*A. tenuifolius* weed extract	3732 e
9	*Convolvulus arvensis* weed extract	3445 h
10	*Lathyrus* aphaca weed extract	3356 i
	LSD (0.05)	63

Mean values with dissimilar letters differ significantly at 0.05 probability level.

Table 6: *Grains yield (kg ha^{-1}) as influenced by different weed control method in chickpea.*

S. No.	Treatments	Grains yield (kg ha^{-1})
1	Control	1023 h
2	Pendimethalin	1434 a
3	Dual gold	1302 c
4	Fenoxaprop p ethyl	1357 b
5	Black polythene mulch	1224 d
6	White polythene mulch	1165 e
7	Available weed biomass mulch	1154 f
8	*A. tenuifolius* weed extract	1204 e
9	*Convolvulus arvensis* weed extract	1124 fg
10	*Lathyrus* aphaca weed extract	1113 g
	LSD (0.05)	21

Mean values with dissimilar letters differ significantly at 0.05 probability level.

Cost benefit ratio (CBR)

The cost-benefit ratio is a crucial cost-effective indicator that enables the calculation of the productivity of various control strategies. Through the calculation of the cost-benefit ratio for each method, comprising herbicides, mulches, allelopathic weed extracts, it becomes achievable to determine the optimum chickpea grain. A higher cost-benefit ratio denotes greater economic viability of the treatment. In the data analyzed, noticeable differences in the cost-benefit ratios were perceived across different weed management methods, showed in (Table 7). Results revealed that application of Pendimethalin as post-emergence recorded the maximum cost-benefit ratio of (3.2), trailed closely by Fenoxaprop-p-ethyl at (2.9) as post-emergence. In contrast, the control treatments yielded the minimum cost-benefit ratio (1.9). Both herbicides efficiently inhibited weed development, resulting in improved economic returns and indicating greater return on investment compared to other management practices. Based on our conclusions, application of Pendimethalin and Fenoxaprop-p-ethyl herbicides emerged as successful weed control method, yielding greater cost-benefit ratio, and improved economic outputs from crop cultivation. These conclusions align with prior research by Iqbal *et al*. (2021). By studying the cost-benefit ratio, agriculturalists can gauge the economic feasibility of various weed control practices, and make educated decisions concerning the utmost cost-effective approach for chickpea production, as highlighted by Khan *et al*. (2023).

Table 7: *Cost benefit ratio as influenced by different weed control method in chickpea.*

S. No.	Treatments	CBR
1	Control	1:1.9
2	Pendimethalin	1:3.2
3	Dual gold	1:2.8
4	Fenoxaprop p ethyl	1:2.9
5	Black polythene mulch	1:2.6
6	White polythene mulch	1:2.4
7	Available weed biomass mulch	1:2.3
8	*A. tenuifolius* weed extract	1:2.6
9	*Convolvulus arvensis* weed extract	1:2.4
10	*Lathyrus* aphaca weed extract	1:2.3

Conclusions

The following conclusions are resulting from studies on *A. tenuifolius* and related weeds in

Links Researchers

chickpea: Pendimethalin and Fenoxaprop-p-ethyl as post-emergence application, revealed to be an effective, achievable, and economical tactic for weed management. Pendimethalin and Fenoxaprop-p-ethyl, significantly reduced *A. tenuifolius* density and other weeds. Highest benefit-cost ratio is attained through the use of Pendimethalin and Fenoxaprop-p-ethyl herbicides, due to their economical nature and requirement of fewer labor.

Acknowledgement

Pakistan Science Foundation (PSF) is highly acknowledged for the financial support of this study under the research project entitled "Management studies of noxious weed (*Asphodelus tenuifolius* cav.) in chickpea growing areas of District Karak, Khyber Pakhtunkhwa, Pakistan". The University of Agriculture Peshawar and Department of Weed Science and Botany is also acknowledged for providing research related facilities for conducting this research.

Novelty Statement

Based on our conclusions, application of Pendimethalin and Fenoxaprop-p-ethyl herbicides emerged as successful weed control method, yielding greater cost-benefit ratio, and improved economic outputs from chickpea cultivation at District Karak, Khyber Pakhtunkhwa, Pakistan.

Author's Contribution

Imtiaz Khan: Developed the research concept, set the study's goals, and supervised all aspects of its completion.
Abdullah: Performed data analysis, writing, table development and interpretation.
Muhammad Ishfaq Khan: The manuscript was critically evaluated and modified.
All authors participated in collecting data, conducted experiments, and collected results from experiments.

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

Conflict of interest
The authors declare no competing interests.

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