



RESEARCH ARTICLE

First report on the successful cultivation of *Euryale ferox* Salisb. (Makhana) under sodic soil condition of Eastern Uttar Pradesh: A comparative study on direct sowing and transplantation method

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Abstract

The present study was done to observe the production potential of a high value crop *Euryale ferox* Salisb. under the sodic soil conditions of Eastern Uttar Pradesh. This study was done to find the differences between direct sowing method (experimental field-1) and transplantation of seedlings (experimental field-2) and their suitability under the climatic conditions of the experimental site. The average mean values of different climatic indices at the experimental site such as atmospheric temperature (high), atmospheric temperature (low), humidity and average rainfall were observed in the range of 19.35 ± 2.90 °C– 37.35 ± 2.00 °C, 7.40 ± 0.94 °C– 26.80 ± 0.97 °C, 52.12 ± 17.53 %– 73.55 ± 4.78 % and 0.00 ± 0.00 mm– 18.60 ± 22.60 mm, respectively during the study. The germination time of seed, size of leaves and number of leaves per plant were also recorded during the cultivation of *E. ferox*. Germination time of seed was recorded 35 days after the seed sowing. Comparison of the size of leaves of *E. ferox* between the fields showed that average diameter of leaves in experimental field-2 was greater than the experimental field-1. The mean value of number of leaves per plant in experimental field-1 was 6.27 ± 1.27 while in the experimental field-2, it was 6.36 ± 1.12 per plant after the 5th month of cultivation. The diameter of leaves in experimental field-1 and 2 was found to be 80.59 ± 2.84 cm and 89.73 ± 2.75 cm, respectively. The differences in diameter of leaves recorded significantly higher in experiment ($p < 0.05$). In experimental field-1 flowering started in the 1st week of May, 2025 whereas in experimental field-2, flowering started in the 3rd week of May, 2025. This study has indicated that climatic conditions of Eastern Uttar Pradesh are suitable for the *E. ferox* cultivation and it will be a valuable crop for this region to utilise waste water logged areas of the region.

Keywords: direct sowing; Eastern Uttar Pradesh; *Euryale ferox*; sodic soil; transplantation

Introduction

Euryale ferox Salisb. popularly known as prickly water lily, gorgon plant and fox nut, is an aquatic crop native to Asian continent and its distribution ranges from Northern India to Taiwan, China, Japan, Korea and Eastern part of Russia. This is a nutrient rich, non-cereal aquatic crop considered as super food. It grows in shallow and slow-flowing freshwater aquatic resources. In India, it is a valuable aquatic crop cultivated for its nutritious seeds known as makhana. Morphologically this plant has large prickly leaves which are purple in colour at below while upper surface of leaves is green coloured.

Fully grown leaves may get size more than 1 m in diameter. The stem and leaves are covered all over with prickles. Short, thick, erect rhizome provides strength to plant to stand and propagate. The flowers are with outer violet petals and inner white petals. The fruit of *E. ferox* have numerous seeds enclosed in a spiny capsule. The number of seeds in a fruit ranges from 75–125.

In India, *E. ferox* is distributed in Bihar, West Bengal, Manipur, Assam, Madhya Pradesh, Tripura and Uttar Pradesh. Presently its commercial production is limited up to the Bihar in Darbhanga, Samastipur, Saharsa, Supaul, Madhubani, Kishanganj, Katihar and

Purnia districts. These districts of Bihar cover 27000 ha land for the cultivation of *E. ferox*. Presently, Bihar accounts for 90 % of India's makhana cultivation and contribute significantly to global makhana production (1, 2). Cultivation of makhana is prevalent as a single crop but in some places, farmers are also adopts makhana cultivation with fish. This integration is popularised in districts where unrestricted water supply or perennial water bodies are available. The cultivation of *E. ferox* requires specific climatic conditions, including temperatures range from 20–35 °C, humidity levels of 50–90 % and annual rainfall of 100–250 cm (3).

In Uttar Pradesh, cultivation of *E. ferox* is still not been taken up on a large scale due to lack of dissemination of a scientific approach to popularise this crop among the farmers. *Euryale ferox* has an immense potential in Eastern Uttar Pradesh due to the availability of substantial waterlogged area and huge aquatic resources. The waterlogged fields have limited scope to practice any other agricultural practices in this region. As per the Uttar Pradesh Government, approximately 83.93 lakh ha of the state's landmass is under waterlogged though the value slightly decreases after the post monsoon season up to 79.63 lakh ha (4). Nearly 1.37 million ha land is salt affected in Uttar Pradesh which is a major concern to address and directly or indirectly affecting agriculture production in Eastern Uttar Pradesh (4). Salt affected areas also have limitations for farmers to adopt diversified agriculture activities. *Euryale ferox* is found to be highly suitable for the salt affected and waterlogged area of the Eastern Uttar Pradesh. Climatic conditions of Eastern Uttar Pradesh are similar to Bihar where cultivation of *E. ferox* is successfully practiced. Hence, cultivation of *E. ferox* has the potential and offers a promising option to strengthen the socio-economic conditions of farmers through the optimum utilisation of waterlogged resources of Eastern Uttar Pradesh.

Nutritionally, *E. ferox* is a good source of protein, carbohydrate and minerals and it is emerging as a luxurious food globally (5–7). Price of makhana is increasing due to limitation in its production. The major constraints in production enhancement of *E. ferox* are the less availability of water, requirement of skilled labour, intensive and rigorous management during the early phase of crop. The other issues which need more attention during cultivation are infestation of aphid, snail, root borer, microbial diseases, filamentous algae and rooted aquatic weeds.

To draw the attention of farmers of Eastern Uttar Pradesh towards this crop, experimental trials of *E. ferox* cultivation were conducted at instructional fish farm, College of Fisheries, Acharya Narendra Deva University of Agriculture and Technology, Kumarganj, Ayodhya, Uttar Pradesh, India. Cultivation of makhana through direct sowing is a common practice in ponds while transplantation method is suitable in field method. Present study was done to do a comparative study of direct sowing and transplantation method under climatic zones of Eastern Uttar Pradesh.

Materials and Methods

Selection of site and land preparation

The present study shows the first report of successful cultivation of *E. ferox* (makhana) in Eastern Uttar Pradesh under sodic soil condition. The soil characteristics of the selected site was recorded during a previous study, the values of pH and exchangeable sodium percentage (ESP) were recorded 9.16 ± 0.05 and 46.46 ± 0.24

respectively (8). To conduct the present study, a total experimental water area of 3950 m² was selected. The selected area was waterlogged and it was modified through earthen work to convert it into two experimental ponds. The water area of the *E. ferox* experimental field-1 and 2 was 1350 m² and 2600 m², respectively. During preparation, the depth of the pond was maintained to 75 cm up to the berm of ponds to keep in mind the requirement of water level for the cultivation of *E. ferox*. The overall depth of pond was kept 1.50 m to prevent experimental field from flooded condition. Prior to the seed sowing, ploughing was done through plough to maintain a 30 cm fine muddy layer. Further one more ploughing was done through cultivator to facilitate easy spreading of rhizome both vertically and horizontally. After each ploughing, a land leveller was used to create an even surface to ensure uniform water level through the experimental fields. After the ploughing, ponds were filled with water up to 30 cm height (9).

Selection of variety

Selection of variety was done in view of the subtropical climatic condition of the area. Accordingly, “*Swarna vaidehi*” a variety of *E. ferox* was selected for cropping. This variety was introduced in 2013 by the ICAR-Research Complex for Eastern Region, Patna, Bihar. Important characteristics of this variety are, it produces 12–16 numbers of fruits and have only 8–9 numbers of leaves per plant. The production potential is approximately 2.8 to 3.00 t/ha. Shallow water depth upto 30 cm is suitable for this variety. These seeds are also good source of calcium and minerals (8, 10).

Manuring

Euryale ferox has large leaves and it require more nutrients compared to other agricultural crops. In *E. ferox*, only basal dose of manure is recommended. During the experimental trial, the application of organic manure in the form of farmyard manure (FYM) was applied at the rate of 20 t/ha in both experimental fields. A ploughing was also done after the application of FYM for thorough mixing of the manure into the soil to ensure even distribution of manure and availability of nutrients to the plants. The application of FYM in agriculture field is a common practice to reduce sodicity and to reduce other adverse effects of salt affected areas. High content of organic matter is able to replace sodium ion from the soil exchange complex; it also reduces the dispersal of soil particles in sodic soil through the binding of soil particles together. Erosion of soil particles through water and air is a common character of sodic soil. The high requirement of FYM for *E. ferox* crop is also helpful for the soil reclamation in salt affected areas.

Euryale ferox develops a strong rhizome which penetrate under soil upto the depth of 0.2–0.5 m and horizontally spread upto 4–5 m.

Use of fertilisers

In *E. ferox*, the use of fertiliser is not common, but due to sodic soil condition and low microbial activity in soil, the application of fertilisers to balance proportion of nitrogen, phosphorus and potassium (NPK) before the sowing was done. Urea, diammonium phosphate and potash were used at the rate of 160 kg/ha, 130 kg/ha and 60 kg/ha respectively as a basal dose in nursery (experimental field-1). The application of inorganic fertiliser during the crop is not recommended for *E. ferox* because inorganic fertiliser increases the growth of filamentous algae in the field which further lead to deterioration of foliage of *E. ferox* plants.

Seed sowing

Cultivation of *E. ferox* is common through direct sowing method in pond system and transplantation of seedlings from the nursery in field system. Recommended seed density for the direct sowing is 60–75 kg/ha while in transplantation method, plants are first raised in nursery field for 3 months and later they are transplanted into the main field (1, 7, 8, 10). Plants raised by sowing 30 kg/500 m² nursery field is sufficient for transplanting in 1 ha main field (10). In the present study, direct sowing was done in experimental field-1 (area 1350 m²) during the month of January 2025. Aquatic weed infestation was a major issue to address in *E. ferox* cultivation in its early stages. To overcome this problem, turbid fish pond water of nearby instructional fish farm was used. A total quantity of 24 kg seeds of *E. ferox* was sown in experimental field-1 to fulfil the requirements of both experimental fields.

Nursery management

Germination started after 35 days of seed sowing with the appearance of purple leaves at the surface of water in the experimental field-1 (Fig. 1). During the seed germination period, water level was kept in the range of 30–40 cm. At early stage of crop, the shoots were very vulnerable against the aphid infestation. To prevent this, neem (*Azadirachta indica* A. Juss.) oil emulsion was applied at the rate of 3 mL/L water through the sprayer machine on the surface of leaves of *E. ferox*. During the nursery phase of cultivation, application of neem oil emulsion was done once in a week to prevent insect infestation. Early seedlings of *E. ferox* were also found vulnerable against the filamentous algae; to minimise the infestation, the filamentous algae were frequently removed manually by using screens. During the slow wind condition, filamentous algae tend to get attached with leaves and stem of seedlings which leads in drowning of the plants into the water and resulting in the deterioration of plants. Infestation of filamentous algae also allows the invasion of other microbial organism in the ecosystem. Faster wind conditions increase the propensity of accumulation of filamentous algae at the corner of the field which is found to be more harmful for the plants of that area and needed to be eradicated as early as possible. Preventive application of copper oxychloride was also helpful to minimise infestation of some groups of filamentous algae and microbes.

Transplantation and management

Transplantation of seedlings in the experimental field-2 and thinning of plants in the experimental field-1 was done simultaneously. Transplantation of seedlings is recommended after 3 months of seed sowing. Prior to transplantation, application of basal dose of manure and fertilisers was done after a thorough ploughing. One more ploughing was done just after manuring. Later, water was filled up to the 30 cm mark. The seedlings of the *E. ferox* were uprooted carefully from the experimental field-1 without any damage and transplanted into the experimental field-2 in the 3rd week of April, 2025. During the transplantation it was ensured that leaves of plants remained on the water surface. Submergence of plants was avoided during the transplantation and planting, distance between plant to plant and line to line was 100 cm. After transplantation, schedule of application of neem oil emulsion at the rate of 3 mL/L were maintained weekly once and water level was kept maximum up to the height of 45 cm up to the flowering stage.



Fig. 1. Nursery with initial stage of plants.

Results

The observation of water quality parameters and the general health and growth of seedlings were done throughout the study period. The climatic conditions of the experimental site are reflected in Table 1. Variable climatic indices during the trial period from January 2025 to June 2025 were observed. The average mean values of different climatic indices such as atmospheric temperature (high), atmospheric temperature (low), humidity and average rainfall were found $19.35 \pm 2.90^\circ\text{C}$ – $37.35 \pm 2.00^\circ\text{C}$, $7.40 \pm 0.94^\circ\text{C}$ – $26.80 \pm 0.97^\circ\text{C}$, $52.12 \pm 17.53\%$ – $73.55 \pm 4.78\%$ and $0.00 \pm 0.00\text{ mm}$ – $18.60 \pm 22.60\text{ mm}$, respectively. Observations of the water quality and plant's indices of both experimental fields are shown in Tables 2–4. During the study period, size of leaves and leaves per plant were observed (Fig. 2). The mean value of the number of leaves per plant in experimental field-1 was 6.27 ± 1.27 while it was observed that 6.36 ± 1.12 per plant in experimental field-2. A comparison on the size of leaves of *E. ferox* between the fields showed that the average diameter of leaves in experimental field-2 was greater than experimental field-1. Cultivation in experimental field-2 was done through transplantation method and it might be that the plants got a fresh nutrient rich environment to grow fast. The value of leaves diameter was also recorded in both the experimental fields in the mid of the month of June 2025, and the leaves diameter was found more in experimental field-2 compared to that of experimental field-1 and values of leaves are found to be $89.73 \pm 2.75\text{ cm}$ and $80.59 \pm 2.84\text{ cm}$, respectively with significant difference ($p < 0.05$). Time of flowering was also observed, in experimental field-1 flowering started in the 1st week of May 2025 whereas in experimental field-2, flowering started in the 3rd week of May 2025 (Fig. 3).

Observation of disease and insect infestation during the cultivation

Plant protection during the cultivation is a key factor which ultimately decides yield and profitability. Earlier, *E. ferox* was considered as a hardy crop but in recent times the numbers of risk factors are found to have increased in *E. ferox* cultivation. In the present study, the following risk factors were observed during the cultivation.

Insect pests

Aphid (*Rhopalosiphum nymphaeae*)

Aphid (*Rhopalosiphum nymphaeae*) also called as water lily aphid, is a major insect cause of infestation during the early days of *E. ferox*

Table 1. Climatic parameters of the area of cultivation during the study period

Sl. No	Parameters	Unit	January 2025	February 2025	March 2025	April 2025	May 2025	June 2025
1.	Atmospheric temperature (average high)	°C	19.35 ± 2.90	25.7 ± 1.50	32.38 ± 3.80	37.17 ± 1.90	37.20 ± 1.40	37.35 ± 2.00
2.	Atmospheric temperature (average low)	°C	7.40 ± 0.94	8.80 ± 1.50	13.76 ± 1.40	20.30 ± 2.20	24.90 ± 0.40	26.80 ± 0.97
3.	Average relative humidity	%	73.55 ± 4.78	57.96 ± 4.90	63.82 ± 3.02	52.12 ± 17.53	66.40 ± 1.15	68.60 ± 3.32
4.	Average rainfall	mm	0.50 ± 1.00	0.00 ± 0.00	0.00 ± 0.00	7.65 ± 13.25	18.50 ± 23.45	18.60 ± 22.60
5.	Sunshine	hr	4.27 ± 2.78	9.20 ± 0.70	9.22 ± 0.37	9.02 ± 0.74	8.10 ± 0.86	6.90 ± 2.15

Table 2. Water quality parameters during the cultivation in experimental field-1

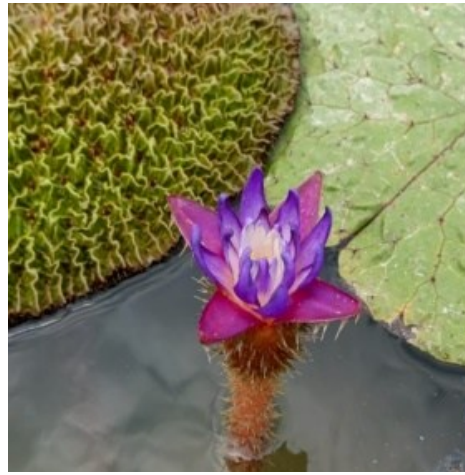
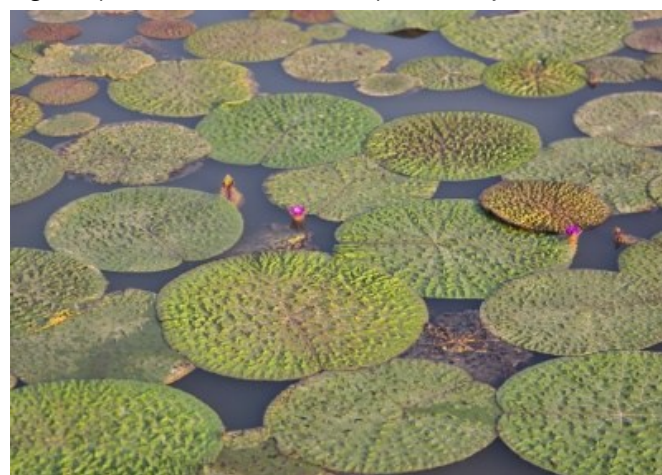
Sl. No	Parameters	Unit	January 2025	February 2025	March 2025	April 2025	May 2025	June 2025
1.	Water temperature	°C	17.05 ± 0.24	19.59 ± 2.16	24.42 ± 0.33	26.29 ± 0.36	27.28 ± 0.65	30.82 ± 0.25
2.	pH		8.25 ± 0.07	8.40 ± 0.02	8.38 ± 0.02	8.36 ± 0.02	8.35 ± 0.04	8.31 ± 0.05

Table 3. Water quality parameters during the cultivation in experimental field-2

Sl. No	Parameters	Unit	April 2025	May 2025	June 2025
1.	Water temperature	°C	26.81 ± 0.43	27.35 ± 0.56	30.75 ± 0.39
2.	pH		8.21 ± 0.06	8.25 ± 0.08	8.29 ± 0.07

Table 4. Plant growth indices during the period of study

Sl. No	Parameters	Number of samples	Experimental field-1 (direct sowing method) June 2025	Experimental field-2 (transplantation method) June 2025
1.	Number of leaves per plant	50	6.27 ± 1.27	6.36 ± 1.12
2.	Maximum diameter of complete green leaves	50	80.59 ± 2.84 cm	89.73 ± 2.75 cm
3.	Flowering time		1 st week of May 2025	3 rd week of May 2025

**Fig. 2.** Experimental field-1 and 2 with plants of *Euryale ferox*.**Fig. 3.** Plants of *Euryale ferox* at flowering stage.

cultivation. This insect colonises in many aquatic plants including species of the family Nymphaeaceae (9, 11). The infestation of this insect in *E. ferox* crop for the first time was observed in a previous study (11). The peak activity of aphid insect was observed in February to April during the cultivation in present study, especially in the initial purple-coloured leaves in the experimental field-1. This insect attack on the upper side of *E. ferox* leaves and sucks its sap. Infestation leads to the decaying of leaves and leaves turned into yellow/rust red in colour. As natural colour of leaves turned out into the green, the activity of this insect gets reduced during cultivation. Infestation of aphid was controlled by the application of neem oil emulsion at the rate of 3 mL/L through sprayer machine weekly once during the first 3 months of cultivation later it was applied as per the symptoms on leaves.

Root borers

Presence of root borers especially *Donacia* spp was observed in both experimental fields during the mid-period of cultivation (Fig. 4). Root borers can weaken the plants and its rhizome; the rhizome become soft and spongy in texture and starts decaying. The leaves become deteriorated with blackish and yellowish in colour. Eradication of root borers from both the experimental fields were done by the application of emamectin benzoate at the rate of 0.50 g/L. The application was done 3 times during the cultivation, at an interval of 10 days to eradicate it completely from both the experimental fields.

Gastropods

Gastropods (snails) were observed in both the experimental fields during the month of April and May (Fig. 5). The snails eat decaying leaves of *E. ferox*. They lay eggs on leaves and the larvae start boring



Fig. 5. Infestation of gastropods in *Euryale ferox*.



Fig. 6. Infestation of fungal disease in *Euryale ferox*.



Fig. 4. Infestation of root borer in *Euryale ferox*.

into fresh leaves (9, 11). To eradicate snails from the experimental fields, copper oxychloride was used at the rate of 3 g/L of water. The treatment of copper oxychloride was done at an interval of 10 days, particularly in the month of April, May and in mid-June.

Fungal disease

Appearance of yellowish colour at the margins of leaves and tan to brown colour spots at the inner surfaces is found as symptoms of fungal disease (Fig. 6). The fungal disease was observed in the month of April in experimental field-1. Copper oxychloride at the rate of 3 g/L of water was applied to overcome this disease.

Filamentous algae/rooted submerged aquatic weeds

Filamentous algae and rooted aquatic weeds are harmful for *E. ferox*. Occurrence of filamentous algae was common in both experimental fields and frequent removal of filamentous algae was done manually. Infestation of rooted submerged aquatic weeds such as *Potamogeton* (eel grass) and *Chara* (multicellular fresh water green algae) were found more in experimental field-1. It has been observed

that in direct sowing method, rooted aquatic weeds were a major concern to address. Once the weeds start growing, removal of rooted aquatic weed became very labourious. The growth of rooted aquatic weeds suppressed the growth of *E. ferox* plants which in turn lead to decaying of plants in initial days of cultivation.

Discussion

Eastern Uttar Pradesh and Northern Bihar are adjoining state and climatic conditions of both the region are almost similar. *Euryale ferox* is a photo sensitive crop and successful cultivation of *E. ferox* is reported in the atmospheric temperature range of 5–43 °C in wetland ecosystem of Northern Bihar and it was reported that temperature had no adverse impact on the crop (12). The mean atmospheric temperatures during different months of the present study ranged from 7.40 ± 0.94 °C to 37.35 ± 2.00 °C, and these values were within the reported range and comparable to previous studies conducted in North Bihar (12). According to the previous studies during the 2007–2016, it is reported that, climate change in reference to raising temperature, decreasing relative humidity and rainfall, nut size of *E. ferox* were relatively smaller as well as kernel percentage was reduced (63.15–61.74 %). Similarly, the leaf size was significantly decreased (110.48–106.57) due to high temperature and reduced humidity (12). Observation of the previous study in the northern region of Bihar suggested that *E. ferox* achieves 125.83 cm diameter and maximum leaf size of 132–137 cm in the month of August and September (12). In the present study the diameter of leaves in experimental field-1 and 2 was to be found 80.59 ± 2.84 cm and 89.73 ± 2.75 cm respectively in the month of June. It may be due to the change in climatic and sodic soil conditions. Low microbiological

activities and dispersal of soil particles are adverse characters of sodic soil that leads to low productivity which limited the availability of nutrients to the plants. The mean value of number of leaves per plant in experimental field-1 was 6.27 ± 1.27 while it observed that 6.36 ± 1.12 per plant in experimental field-2 which is found less in number compare to the previous studies in Bihar. Previous studies reported 10.44 numbers of leaves per plant (12, 13). The difference may be overcome by the soil reclamation through the application of increased quantity of FYM and continuous cropping of *E. ferox* in the same fields. *Euryale ferox* produce huge amount of organic matter due to its larger size of leaves during its growing phase. The cultivation of *E. ferox* in the Eastern Uttar Pradesh under sodic soil condition is being reported here for the first time. Observation related to the germination of seed, flowering of plants and growing stage suggested that seed sowing in month of November to January is suitable to grow *E. ferox* in the study area. The validation of climatic, soil suitability and economic feasibility of crop in reference to overall production require further more study.

Conclusion

The present study demonstrated the first successful cultivation of *Euryale ferox* Salisb. in Eastern Uttar Pradesh where soil sodicity is a major concern. Sodic soils are known to be less productive because, excessive sodium negatively impacts soil structure, water infiltration, aeration and nutrient availability; hindering plant growth. Insect pests and diseases may cause pose challenges, especially at the early stages of shoot growth, which have to be carefully and systematically addressed. We tried both direct sowing and transplantation methods of cultivation and we suggest transplantation as the better method for better results in terms of foliage growth. Moreover, diseases, insect infestation and algal growth were very less in transplantation method when compared to direct sowing. Our continuing experiments on the fruiting and harvest may give further essential information on the successful farming of this valuable crop.

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Authors' contributions

The development of experimental site was done by SKV. Practice of cultivation, collection of data, practical execution and composition of this study was conducted by SKV, AKY, SK, PKM and SS. The study design was executed by RKV, CPS, SK, SD, AS, JS, PP, RK and correspondence was done by PKM. All authors read and approved the final manuscript.

Compliance with ethical standards

Conflict of interest: Authors do not have any conflict of interests to declare.

Ethical issues: None

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