

## Climate resilience of *makhana* cultivation in flood-prone and waterlogged region

***Makhana (Euryale ferox)*, a highly valued aquatic crop, has emerged as a climate-resilient farming option in flood-prone and waterlogged regions of India, particularly in Bihar, West Bengal, and parts of eastern Uttar Pradesh. Its unique adaptability to stagnant and shallow aquatic ecosystems makes it an ideal crop for areas frequently affected by excessive rainfall, prolonged submergence, and soil saturation conditions that hinder conventional agricultural production systems. The climatic resilience of *makhana* cultivation is attributed to its tolerance to waterlogging, efficient nutrient recycling, and compatibility with integrated farming systems such as fish–*makhana*–vegetable models. With minimal external input requirements and the ability to restore soil fertility through organic biomass accumulation, *makhana* offers a sustainable livelihood alternative for marginal farmers in vulnerable ecosystems. Enhancing agro-techniques, strengthening policy support, and improving socio-economic linkages can further expand *makhana* cultivation as a nature-based solution to climate risks.**

**Keywords:** Aquaculture, Cropping System, Integrated farming, *Mithila Makhana*, Nutraceuticals, Rural livelihoods, Superfood

**M**AKHANA (*Euryale ferox* Salisb.), also known as fox nut or gorgon nut, is a unique aquatic crop primarily cultivated in eastern region of India, especially in Bihar. Although the crop is grown in different parts of the world, India accounts for approximately 70–80% of the global production. Countries such as Japan, Korea, China, Bangladesh, and Russia also grow *makhana* in its wild form. It belongs to the family *Nymphaeaceae* and is valued for its nutritious seeds, which are consumed as a delicacy and used in traditional medicine.

With the increasing demand for healthy snacks and nutraceuticals, *makhana* is gaining prominence both nationally and globally. Despite its immense potential, *makhana* cultivation has long remained unorganized, with traditional techniques resulting in low yields and farmer dissatisfaction. However, recent advancements in agro-techniques offer new hope for transforming *makhana* into a high-value commercial crop.

*Makhana* cultivation in Bihar is a thriving agricultural sector with strong prospects for growth. Bihar is the largest producer of *makhana* in India, accounting for over 80% of the country's total production and contributing significantly to the global supply. The crop is primarily grown in the Mithila region and is a crucial part of the local economy, with an estimated annual turnover of ₹300 crores.

### Scope of *makhana* cultivation in India

**Agro-climatic suitability:** *Makhana* is well-suited to

climatic and ecological conditions of the Indo-Gangetic plains, especially in the states such as Bihar, West Bengal, Assam, Uttar Pradesh, and parts of Manipur and Odisha. Crop thrives in shallow water bodies, ponds, wetlands, and flood-prone lowlands, making it ideal for regions where conventional farming faces constraints.

**Economic importance:** *Makhana* is a cash crop with a growing market in India and abroad. Bihar alone contributes over 80% of national production, especially in districts like Darbhanga, Madhubani, Katihar, Araria, and Purnea. The *makhana* industry supports livelihood of more than 2.5 lakh farmers and labourers, particularly from marginalized communities. Rising demand in domestic and international markets is pushing prices upwards, making *makhana* cultivation highly lucrative.

**Nutritional and medicinal value:** *Makhana* seed is rich in protein, fiber, antioxidants, magnesium, potassium, and low in fat. It is recommended for diabetics, heart patients, and those looking for gluten-free and low-calorie diets. Ayurveda and traditional Chinese medicine also recognize its therapeutic value in treating ailments *viz.* insomnia, kidney disorders, and infertility.

**Government support and export potential:** *Mithila Makhana* was granted the Geographical Indication (GI) tag in 2022, creating new opportunities for branding and export. Government initiatives such as the Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) scheme and the 'One District One Product'

**Table 1.** Nutritional composition of *makhana* (per 100 g, dry/raw)

Nutrient	Amount
Energy	347–362 kcal
Carbohydrates	65–76 g
Sugars	<1 g
Dietary Fiber	7–14 g
Protein	9.7–14.5 g
Fat	0.1–0.5 g
Saturated Fat	<0.1 g
Calcium	60–160 mg
Phosphorus	180–300 mg
Iron	1.4–1.8 mg
Magnesium	100–120 mg
Potassium	350–450 mg
Sodium	4–7 mg
Zinc	1.1–1.5 mg
Antioxidants	Polyphenols, flavonoids
Glycemic Index (GI)	Low ( $\approx$ 45–50)
Gluten	None (Gluten-free)

(ODOP) program recognize *makhana* as a priority crop, providing support for value chain development, processing, packaging, and marketing.

### Challenges in traditional *makhana* cultivation

Despite its potential, *makhana* cultivation faces several challenges:

- *Lack of standard agro-techniques:* Traditional methods are labour-intensive and result in low yields.
- *Limited mechanization:* Harvesting, seed processing, and puffing are mostly done manually.
- *Fragmented ponds and land tenure issues:* Most farmers lease ponds seasonally without long-term security.
- Post-harvest losses and inadequate processing infrastructure
- Weak market linkages and price fluctuations

To overcome these challenges, research institutions such as ICAR–RCER, the Research Centre for Makhana, Darbhanga (Bihar), and Bihar Agricultural University (BAU), Sabour, Bhagalpur (Bihar), have developed improved agro-techniques.

### Improved agro-techniques for *Makhana* cultivation

**Selection of suitable site:** For successful *makhana* cultivation, selecting an appropriate site is crucial. Ideal ponds should maintain a water depth of 1.2 to 1.5 m in pond conditions and 1 to 1.5 feet under field conditions throughout the cropping season, ensuring sufficient space for plant growth and seed development. The soil at the pond bottom should be clayey or loamy and rich in organic matter to support healthy root anchorage and nutrient availability. Additionally, the cropping site should receive ample sunlight, as *makhana* is a photosensitive

crop, and the water body must be free from industrial or sewage pollution.

### Land preparation

- Drain pond by March-end to expose soil
- Plough and puddle pond bottom for seed broadcasting
- Incorporate well-decomposed farmyard manure (FYM) at 5–10 tonnes/ha.

**Nursery raising and transplanting:** Traditionally, *makhana* is cultivated through direct seed broadcasting. However, nursery raising and transplanting has proven more effective. Unlike traditional method where seed are broadcasted directly into pond, this approach involves raising seedlings in controlled nursery before transplanting them into main pond. Nursery is usually prepared in December-January using shallow water beds or specially designed nursery ponds. Healthy and mature seeds are sown in nutrient-rich loamy soil and allowed to germinate for 30–45 days under proper care. Once seedlings reach a height of 3–5 inches with well-developed roots and leaves, they are transplanted at proper spacing (1.0 × 1.0 m) in main pond between February–March. It ensures uniform plant population with proper spacing, aeration, which promotes healthier growth, better utilization of nutrients and sunlight. Transplanted seedlings establish more quickly, resulting in early crop establishment and timely harvesting. This method also reduces seed requirement by ~50% compared to broadcasting, thereby lowering input costs. Since main pond can be weeded before crop transplanting, it allows for the efficient weed management. Most importantly, scientific trials have demonstrated 15–20% increase in yield, making this technique highly beneficial. Nursery-transplanting technique is gaining popularity among progressive farmers in Bihar and other *makhana*-growing regions due to its long-term economic and agronomic benefit.

**Integrated nutrient management:** *Makhana* responds well to organic and inorganic fertilizers. Biofertilizers like Azotobacter and PSB can enhance nutrient uptake and reduce chemical input dependency.

Nutrients	Doses (kg/ha)	Timing
N	40–60	Split dose (basal + top)
P <sub>2</sub> O <sub>5</sub>	20–30	Basal
K <sub>2</sub> O	20–30	Basal
FYM	5–10 t	Basal incorporation

**Water and weed management:** Effective water and weed management is essential for optimizing *makhana* growth and yield. Throughout the cropping period, the pond water level should be consistently maintained between 1.0 to 1.5 m in pond conditions and 1 to 1.5 feet in field conditions to support proper plant development and floating leaf expansion. Water stagnation or excessive fluctuations should be avoided to prevent stress on the crop.

Regular monitoring and manual removal of aquatic weeds such as azolla, lemna, and hydrilla is necessary, as these compete with *makhana* for nutrients, light, and

space, thereby reducing productivity. Using bamboo rafts or floating platforms facilitates safe and efficient weeding operations without damaging the crop.

**Pest and disease management:** Although *makhana* is relatively hardy, it is susceptible to certain pests and diseases that can affect yield and quality. One common disease is leaf spot, caused by cercospora species, which appears as small brown to black circular spots on leaves, leading to leaf drying and reduced photosynthesis. This can be effectively managed by spraying mancozeb at 2 g per liter of water.

Among pests, leaf-eating caterpillars are occasionally observed feeding on tender leaves, creating holes and damaging leaf surfaces. Their infestation is usually sporadic but should be controlled either through manual collection or by spraying neem-based biopesticides.

**Harvesting and post-harvest operations:** *Makhana* harvesting typically begins in July–August, once fruits mature and naturally sink to the bottom of the pond. Skilled laborers, referred to as divers, manually collect these sunken fruits from the pond bed using bamboo rafts or small boats. Each fruit contains approximately 20 to 40 seeds.

Since the crop is aquatic and fruits mature at different intervals, harvesting is carried out in multiple rounds over several weeks. Timely harvesting is essential because prolonged submergence can lead to seed spoilage or germination within the fruit, reducing quality and market value.

After collection, fruits are sun-dried to reduce moisture content and then cracked manually or mechanically to extract the seeds. Seeds are cleaned, sorted, and graded based on size and weight, which directly influence their market price.

The most critical step is puffing, which involves roasting dried seeds in hot sand and then popping them using iron pans. This traditional method requires skill to ensure uniform popping without burning. The final puffed *makhana* is then cooled, cleaned, and packed for storage or sale.

**Intercropping and crop rotation:** During the *rabi* season, after harvesting *makhana* (August–September), farmers can cultivate crops like mustard, lentil, wheat, or green gram on pond bunds or drained pond beds, depending on moisture retention. Additionally, intercropping *makhana* with aquatic crops such as water chestnut (*singhara*) or integrating fish farming in the same pond can be highly beneficial.

This integrated approach not only diversifies production but also enhances the ecological balance of the pond ecosystem. Crop rotation with legumes in the off-season helps replenish soil nitrogen and breaks the cycle of pests and diseases associated with continuous *makhana* cultivation. Furthermore, adoption of *makhana*–fish–vegetable or *makhana*–*singhara*–mustard systems has been shown to significantly increase overall farm productivity and profitability.

**Effect of *makhana* cropping system and soil fertility:** Studies have shown that *makhana* cultivation significantly contributes to soil nutrient status by adding approximately 8.0 t/ha/year (dry weight basis) of biomass, which greatly

supports sustainable soil management.

The plant itself contains about 0.31% N, 0.48% P, 0.40% K, 2200 mg/kg Fe, 1000 mg/kg Mn, 8.0 mg/kg Cu, and 105 mg/kg Zn, while the seeds contain 1.67% N, 0.40% P, 0.12% K, 960 mg/kg Fe, 40 mg/kg Mn, 12 mg/kg Cu, and 125 mg/kg Zn.

On average, the *makhana* cropping system contributes approximately 34.35 kg/ha N, 56.04 kg/ha P, 53.07 kg/ha K, 27.26 kg/ha Fe, and 12.31 kg/ha Mn to the soil. These values clearly indicate that *makhana* cultivation improves the soil nutrient profile, making it a highly sustainable and beneficial cropping system.

**Organic *makhana* farming:** Growing awareness around chemical-free produce has led to increased adoption of organic *makhana* farming using bio-inputs. Certification and branding play an important role in fetching premium prices.

Organic *makhana* farming relies on natural resources such as farmyard manure (FYM), compost, biofertilizers (Azotobacter, phosphate-solubilizing bacteria), and botanical pesticides like neem extract to maintain soil fertility and manage pests and diseases. The rising demand for organic and chemical-free food products in both domestic and international markets has opened new avenues for certified organic *makhana*.

Although initial adoption may require additional effort and knowledge, long-term benefits include premium pricing, improved soil and water quality, reduced input costs, and enhanced farm sustainability. Organic *makhana* farming also supports biodiversity conservation and aligns well with climate-resilient agriculture, offering promising opportunities for small and marginal farmers, especially in Mithilanchal (Darbhanga, Madhubani, and Purnea districts), where *makhana* is a traditional crop.

**Socio-economic impact:** *Makhana* cultivation has emerged as a significant driver of socio-economic development, especially in the Mithilanchal region of Bihar. It provides seasonal employment and livelihood opportunities to thousands of small and marginal farmers, pond owners, and labourers involved in sowing, weeding, harvesting, puffing, and marketing.

Being labor-intensive, *makhana* farming also creates employment for women and rural youth, promoting gender inclusiveness and reducing rural–urban migration. Rising demand in health-conscious and urban markets has transformed *makhana* from a subsistence crop into a commercially viable enterprise, significantly increasing household incomes.

Initiatives such as the GI tag for '*Mithila makhana*', government subsidies, and training programs have strengthened farmer cooperatives and Self-Help Groups (SHGs). Overall, *makhana* cultivation has become a powerful tool for poverty alleviation, rural empowerment, and sustainable agricultural development.

**Policy support and recommendations:** *Makhana* cultivation has received growing attention from policymakers in recent years, especially after the granting of GI status to *Mithila makhana*, which has supported branding, quality assurance, and market recognition.

Under the Pradhan Mantri Formalization of Micro Food Processing Enterprises (PMFME) Scheme, support is

extended to farmer-producer organizations, cooperatives, and individual entrepreneurs engaged in *makhana* processing. Moreover, the National Horticulture Mission and various Bihar State Government schemes provide financial assistance for pond renovation, seed distribution, training, and establishment of *makhana* processing units, helping boost production and post-harvest value addition.

To further strengthen the *makhana* sector, several policy recommendations are essential:

- **Recognize *makhana* as a priority aquatic crop** under national agricultural policies to ensure structured support for research, infrastructure, and marketing.
- **Invest in rural infrastructure** such as cold storage, packaging units, and transportation networks to reduce post-harvest losses.
- **Promote formation of cooperatives and FPOs** to ensure collective bargaining and better price realization.
- **Develop customized crop insurance and credit facilities** tailored for *makhana* farmers.
- **Increase investment in research and extension services**, especially by



Weeds incidence in makhana field



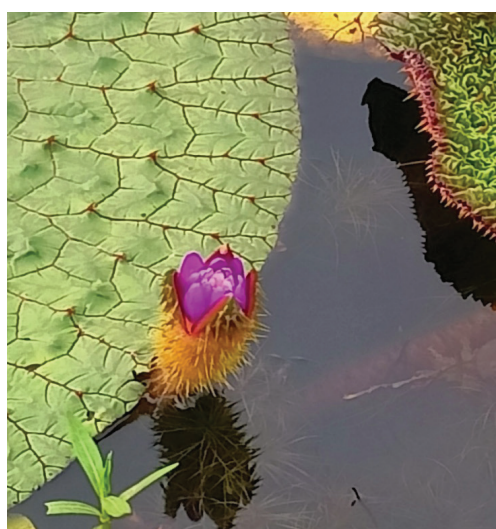
Makhana leaf



Field View of makhana



Makhana flower



Mature makhana seed



Makhana seed after fruit burst

ICAR and State Agricultural Universities, to develop high-yielding varieties, mechanization solutions, and climate-resilient technologies.

### SUMMARY

*Makhana* cultivation, once considered a marginal and labor-intensive enterprise, is now emerging as a high-potential agribusiness in eastern India. Integration of improved agro-techniques such as nursery-based transplanting, INM, mechanization can transform productivity and profitability of *makhana* farming. With the robust support from research institutions, policy frameworks, and market interventions, India is well poised to become a global leader in *makhana* production,

processing, and export. The journey from pond to plate offers a promising path not only for agricultural diversification but also for rural prosperity, employment, and sustainable development.

For further information, please write to:

<sup>1</sup>Bihar Agricultural University, Sabour, Bhagalpur, Bihar 813 210; <sup>2</sup>ICAR Research Complex For Eastern Region, ICAR Patna Rd, near BIT, adjacent to Airport Police Station, Patna, Bihar 800 014; \*Corresponding email: bk151219@gmail.com