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Agronomic Practices and Cultivation of Makhana (*Euryale ferox* Salisb)

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Euryale ferox Salisb. or Makhana, or Fox Nut, is an expensive aquatic cash crop that has been famous in terms of its superior nutritive composition and therapeutic effects. The crop is traditionally grown in perennial wetlands and natural depressions in the lower Gangetic plains especially in Bihar, India but now the crop is experiencing an important shift in its agronomy. It outlines the exact ecological needs, both soil and climatic parameters, as well as the key agronomic interventions such as nursery management, Integrated Nutrient Management (INM), and uniform spacing geometries with the high-yielding varieties, such as Swarna Vaidehi and Sabour Makhana-1. In addition, the biologically sensitive pest and weed management guidelines necessary in the ecology of wetlands. A critical look at the process of harvesting (labour-intensive) and the post-harvest processing (popping, thermo-mechanical) is provided and highlights the bottlenecks in existing supply chains. Makhana can be regarded as a very profitable crop with enormous potential in functioning markets of functional food products worldwide.

Keywords: Fox Nut, Integrated Nutrient Management, Popping, Sabour Makhana-1

Introduction

Makhana, scientifically referred to as *Euryale ferox* Salisb., is one of the most notable aquatic cash crops, which is part of the family Nymphaeaceae. Known commonly as Fox Nut or Gorgon Nut, the genus is monotypic with its native area being South-East Asia and China and at the present, India leads the world in production. It is in the state of Bihar, in the lower Gangetic plains of India, that is done in the very great majority. *Euryale ferox* is a perennial herb with erect, short and thick rhizomatous stem. It grows huge, floating, grossly corrugated leaves with prickly surfaces. It is an autogamous crop (self-pollinating), and fertilization is very early, hermetically closed and under the water surface. It is a spongy, large, berry with 20-25 tiny black seeds, a hard outer coating, which eventually produces a nutritious increased endosperm (the makhana "pop"). Makhana is scientifically known as a high-value functional food. It has a large essential amino acid index (89-93 %), which means that its protein structure is comparable to those of the fish and is even superior to most plant-based diets. It has low fat content, high-complex carbohydrate, and high-antioxidant forming the active ingredients, thioredoxin-1 (Trx-1) that makes this compound most useful in treating cardiovascular diseases and rheumatic diseases in traditional medicine.

Soil and Climatic Requirement

The growth of makhana is also very sensitive to different environmental factors as it only grows in tropical and subtropical wetland habitats.

Climate

- **Temperature:** Seed germination needs lower temperatures between 12ºC to 15ºC. The ambient temperature must be 25ºC- 30ºC in order to achieve maximum vegetative growth and reproduction.
- **Rainfall / Humidity:** It grows well in areas that experience a rainfall of 100-250 cm/ year with the higher humidity level promoting its broad leaf transpiration rate.

Soil

- **Texture and Composition:** Excessively water-retentive clayey or clay-loam soils are needed by the crop. The essentials are a muddy bottom which is soft and allows establishment of rhizomes and uptake of nutrients.
- **Chemical Properties**: The soil is supposed to have a lot of organic matter. The optimal pH is neutral to slightly alkaline (7.0-7.8).
- **Carbon sequestration:** Ongoing agronomic research suggests that long-term makhana farming in wetlands can be a good niche to store soil carbon to provide greater lability index and active pool of carbon than the conventional rice-rice-fallow.

Systems of Cultivation

Makhana was traditionally gathered in the natural water bodies. Its cultivation is nowadays widely divided into two different agronomic systems:

Traditional Pond System

- Cultivated in perennial waters or natural depressions whose depth of water ranges between 4 and 6 feet against the earth.
- The planting material of the next cycle is the seeds that remain at the bottom due to the previous cycle.
- Although ecologically integrated (and in many cases naturally sustaining air-breathing fish), it is afflicted with low productivity, high harvesting tediousness, and low responsiveness to contemporary nutrient management.

Improved Field System

- Scientific paradigm shift in which makhana is grown in ordinary farming land altered to receive only 1 to 1.5 feet of water.
- Precision agriculture, systematic crop rotation (e.g. Makhana-Water Chestnut) and easier mechanization.
- The crop period is shortened by more than 4 months and yields are raised by as much as 45 % over the pond system.

High-Yielding Varieties

The traditional local genotypes tend to have low yield and low pop recovery. Research institutions have come up with standardized and high yield varieties in order to increase the commercial viability of agriculture.

Variety Name	Yield Potential	Pop Recovery	Key Agronomic Traits
Swarna Vaidehi	28 – 30 q/ha	35 – 40 %	Developed by ICAR-RC ER. Standard check variety for field systems. Good physiological resilience.
Sabour Makhana-1	32 – 35 q/ha	55 – 60 %	Developed by BAU, Sabour. Features very thin seed coats (0.29 mm), moderate resistance to leaf blight and aphids.

Nursery Management and Field Preparation

In the scientific field system, makhana is cultivated via a transplanting method, requiring meticulous nursery preparation.

Fig. 1: Benefits of Makhana

Nursery Raising

- **Sowing Time:** The nursery pond is sown during the month of December to January.
- **Area and Seed Rate:** 500 square meters nursery is needed to plant one hectare of land. In the case of healthy seeds, the broadcasts are approximately 20 to 22 kg. The number of seeds per hectare needed is 40 to 45 kg in the case of direct seeding (no nursery is used).
- **Nursery Conditions:** The depth of water is kept to 0.3 meters. Systemic insecticides (e.g., Imidacloprid) should be used to treat the seed in order to protect new shoots.

Preparation and Transplanting of Main Fields

- **Puddling:** Two or three further deep ploughings and the puddling of the main field are required to produce a loose muddy foundation.
- **Bunding:** Bunds of earth having heights of about 2 feet are placed to hold water at all times.
- **Transplanting:** Seedlings (bearing 1-2 leaves/flowers) are transplanted from February to April.
- **Space:** A good spacing geometry of 1.2m x 1.2m or 1.25m x 1.25m is upheld with the population density of the plant being about 6000 to 6500 plants per hectare to avoid the overlap of canopies.

INM: Integrated Nutrient Management

Makhana is a heavy feeder being an aquatic crop having a huge surface area on the leaf. Chemical fertilizers alone impair the ecology of wetlands, and the normative scientific practice is the Integrated Nutrient Management (INM).

Recommended Doses of Fertilizers

- **Organic Manure:** 100-200 tonnes of well decomposed Farm Yard Manure (FYM) or vermicompost is used in the preparation of fields. This does a better job in increasing the C:N ratio and improving the accessibility of micronutrients such as Zinc, which is essential at the flowering stage.
- **Chemical Fertilizers:** The normal recommendation is 100:60:40 kg/ha.
- **Agricultural Lime:** an average of 0.6 to 0.8 tonnes per hectare is commonly applied to render the soil moderately calcareous and friable therefore enabling aggressive root development.

Application Schedule

- **Basal Dose:** The whole amount of organic manure, full doses of Phosphorus (through DAP or SSP), Potassium (through MOP) and half the amount of Nitrogen (through Urea) are added before transplantation.

- **Split Application**: The rest of the Nitrogen is split into equal amounts and sprayed out as a foliar spray or sprayed out in the early stages of vegetation or sprayed out during the active flowering period.

Water and Weed Management

- **Depth of Water:** At the initial vegetative stage, the depth of water is kept at 0.3 to 0.5 meters to enable the sun rays warm-up the mud. The depth is slowly increased to 1 to 1.5 meters during the reproductive and fruiting stages.
- **Weed Control:** Aquatic weeds such as *Hydrilla* and *Sagittaria* are direct competitors of nutrients. Since the crop is aquatic in nature, it is best dealt with manually. The widespread coverage of full grown makhana ultimately becomes a natural mulch inhibiting the further photosynthesis of weeds.

Harvesting: A Measure of Physiological Maturity

The flowers begin to bloom in May and last until November. The fruits take 30-40 days of flowering to mature. When the spongy berry is ripe the rupture is natural, and this puffs off the seeds upon the surface of the water, which then sinks to the bottom.

The most labour-intensive process of makhana agronomy is harvesting.

- **Time of the day:** Mainly performed between August and October.
- **Procedure:** Expert workers either dive to the bottom of the pond or walk through the field mud which is shallow. A bamboo pole (*Kaara*) is their central point of reference and the bottom of the mud is swept out by hand. The mud and seed undergo a process of being rinsed by a special bamboo sieve (*Gaanja*) to remove silt and only the uncooked black seeds are acquired.
- **Yield Metrics:** Traditional pond systems produce 1.5 to 2.0 tonne of raw seed per hectare. The field system which is managed scientifically raises this yield to 3.0 to 3.5 tonnes per hectare.

Value Addition and Processing

Makhana seeds are not eaten raw. They need to be subjected to a complicated process of thermo-mechanical conversion to the edible puffed kernel. The process determines the ultimate sale price of the crop.

Step 1: Cleaning and Sun Drying

The fresh damp seeds are very carefully washed to collect the shells of snails and debris. They are then dried in the sun in mats over a period of time. This is a critical stage as it brings down the internal moisture level of about 37% to 31% so that the fungal growth does not happen during the temporary storage.

Step 2: Size Grading

The seeds are sorted through a range of rectangular iron sieves (*Jharna*) to sort them into the 5-7 homogeneous sizes. The importance of grading is mathematical in that the uniformity of the size implies uniformity of heat distribution that takes place in the next stage of roasting.

Step 3: Pre-Heating and Tempering

Cast-iron pans or earthen pitchers are heated on the surface at temperatures of 250ºC to 300ºC and grain is soaked in a 1:1 mixture of water over the course of 5 minutes. After this, the seed is held in ambient conditions, and then, it is stored between 48 and 72 hours. Such a process of tempering is a physiological precondition which softens the kernel endowed with a lot of starch, but under the hard, black outer shell.

Step 4: Roasting and Popping

The tempered seeds are roasted a second time under high intensity. After roasting, when the seed coat is very much pressurized with internal steam, the seed is struck vigorously with a wooden mallet (*Thaapi*). The shock wave breaks open the shell and the abrupt loss of pressure leads to the explosive expansion (gelatinization) of the superheated starchy endosperm into the white puff, called *Lawa*.

Step 5: Packaging and Polishing

The kernels are popped and do this in bamboo baskets until the surface becomes smooth and whitish. These are then graded in terms of volume and sealed in moisture free and nitrogen flushed laminated bags to maintain crunch and shelf life.

Conclusion

The practice of growing Makhana (*Euryale ferox*) is one of the rare examples of traditional aquatic foraging and contemporary precision farming. Due to the increasing global demand of plant-based, nutrient-dense functional foods, Makhana has a clear opportunity to be a high-quality agricultural export. Although the industry is economically viable and has a very high Benefit-Cost ratio, the growth rate of the industry has been limited to date due to the harsh physical labor involved in harvesting underwater, and the conventional popping technique. The future of commercial Makhana agronomy lies in never-ending institutional research to mechanize both the harvest and post-harvest stages. Makhana farming could guarantee healthy ecological sustainability in wetlands with scientific extension programs and modernization of the processing facilities in the wetlands to secure a yield gap in the area, and provide an unprecedented socioeconomic boost to the farming communities.

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