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Suitable Intervention for Improving Makhana-Based Farming for Higher Productivity and Profitability

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Abstract
Makhana (*Euryale ferox* Salisb) is a very spectacular, popular and medicinal plant to be found immensely in detritus rich hundred years old traditional ponds, ditches and *chaur* (bowl-shaped depressions) lands of northern Bihar. It is also a crop which is utilized in making a highly remunerative aquaculture system with other aquatic crops and Indian carp and catfishes. Some of the major makhana-based cropping systems are makhana-rice, makhana-wheat, makhana-water chestnut, makhana-water chestnut-berseem and makhana-water chestnut-fish. Makhana is such a peculiar aquatic crop whose all vegetative and root biomass get decomposed in the same fields/ponds where it is grown and in turn, adds handsome amounts of nutrients to the soil system.

Keywords: Makhana, Crop cultivation, Economics of Makhana, Integrated Nutrient Management

Introduction
Makhana (*Euryale ferox)*, an aquatic crop of the Family *Nymphaeaceae* is a unique, highly nutritious dry fruit mainly grown in stagnant perennial water bodies like ponds, land depressions, oxbow lakes, swamps and ditches. It has been classified as an annual aquatic herb with gigantic floating leaves, emergent macrophytes of a monotypic genus, growing in the littoral parts of the floodplain wetlands of stagnated water bodies of 1.5-2.0 m depth. It is commonly known as a *gorgon nut or fox nut.* It is considered as a native of South-East Asia and China, but distributed to almost every part of the world. In India, it is distributed in West Bengal, Bihar, Manipur, Tripura, Assam, Jammu & Kashmir, Eastern Orissa, Madhya Pradesh, Rajasthan and Uttar Pradesh. However, its commercial cultivation at a large scale is limited only in Bihar. This aquaphyte is a seed-propagated plant. Its seeds are also called as black diamond and the same is popped and eaten as roasted as well as used in the preparation of various kinds of sweets and recipes. It has immense nutritional [carbohydrate (70-80%), fat (0.1-0.2%), protein (9-12%), also rich in trypsine, cystine, phenylalanine, calcium, magnesium, sodium, iron and zinc and medicinal properties and as such it has great export potential.

Climate and Morphology
Makhana is a plant of tropical and subtropical climate. For its proper growth and development, the conducive range of air temperature (20°C-35°C), relative humidity (50-

90%), and annual rainfall (100 cm - 250 cm), organically reach water bodies with less than 50% water transparency. An important aquatic herb, prickly water plant with gigantic floating nature leaves of a size of 1-2 m and these leaves are born on 3-5 feet long petioles predominantly nerved and reticulated-veined beneath, green in upper and purple in the lower side, thorny in both sides of leaves even in entire plant. It has a thick rhizomatous stem, rooted in cluster form in sediment up to 20 cm depth.

Makhana at flowering stage

Makhana fruit

Riped makhana seed

Crop cultivation

Fox nut is cultivated either in water bodies/ponds having water depth of 1.20-1.80 m or in 30-60 cm deep shallow agricultural fields.

Ponds system of cultivation: Traditionally it is grown in naturally formed ponds where seed sowing is not required, since leftover seeds of previous crops serve as planting materials of subsequent crops. However, Makhana cultivation in new water bodies (ponds) requires an addition of FYM @ 20 t/ha followed by two to three wet ploughings of the field after that the fields must be filled with 45 cm depth of water. The seeds are broadcasted @ 80 kg/ha in the month of December. The transplanting of saplings is done in the month of March in agricultural fields. However, pond cultivation is linked with low productivity as the collection of seeds from the bottom of the pond is a very tedious process and poses drudgery to the health of makhana farmers. Under pond conditions, it takes a duration of complete one year. Thus, no other crop is grown.

Makhana pond at NRCM, Darbhanga

Makhana pond at farmer's field

Field system of makhana cultivation: The possibility of makhana cultivation in agriculture fields consisting of 30-60 cm depth of water has been standardized by the National Research Centre for Makhana, Darbhanga. This system is very easy to operate and provides opportunities to cultivate cereals and fodder crops in the same piece of land in the same year. It raises the crop intensity by 200-300%. The prerequisite for this system is to raise a nursery.

Field system of makhana cultivation

Effect of makhana cultivation on fertility status of soil

On the whole, on a dry weight basis (w/w), makhana plants contain 0.31% nitrogen (N), 0.48% phosphorus (P), 0.40% potassium (K), 2200 mg/kg iron (Fe), 1000 mg/kg manganese (Mn), 8.0 mg/Kg copper (Cu) and 105 mg/Kg zinc (Zn). While the seeds of Makhana contain 1.67% nitrogen (N), 0.40% phosphorus (P), 0.12% potassium (K), 960 mg/kg iron (Fe), 40 mg/kg manganese (Mn), 12.0 mg/Kg copper (Cu) and 125 mg/Kg zinc (Zn). Makhana cropping adds 7.0 t/ha/yr (Dry weight basis w/w) biomass to the soil which significantly helps in sustainable management of soil. Makhana significantly contributes 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 system per year. Nutrient contribution through makhana plants to the soil is presented in Table 1.

Table 1. Nutrient contribution through makhana (*Euryale ferox*) plants to the soil

Plant parts	Dry weight kg/ha	N kg/ha	P kg/ha	K kg/ha	S kg/ha	Fe kg/ha	Mn kg/ha	Cu kg/ha	Zn kg/ha
Leaf	4750	14.72	22.80	19.00	0.95	10.45	4.75	0.038	0.50
Petiole	1690	4.05	7.77	6.42	0.17	3.85	1.67	0.01	0.13
Root	4240	11.87	16.96	23.32	0.42	10.19	4.45	0.04	0.039
Fruit sheath	1548	3.71	8.51	4.33	0.31	2.77	1.44	0.01	0.14
Total contribution	12228	34.35	56.04	53.07	1.85	27.26	12.31	0.10	1.16
Seed	2100	35.07	8.40	2.52	0.84	2.016	0.08	0.02	0.26
Total uptake	14328	69.42	64.44	55.59	2.69	29.27	12.39	0.12	1.42

The following aspects are taken under consideration for producing healthy plants.

1. Improved plant type
2. Soil and water properties
3. Improved cultural practices
4. Cultivation in cropping system mode
5. Climate (Rainfall)

1. **Improved plant type:** The first ever variety of makhana crop namely *"Swarna Vaidehi"* was released on 15.11.2013 by ICAR Research Complex for Eastern Region, Research Centre for Makhana, Darbhanga. The variety has a potential yield of 2.8 t/ha while the variety yielded 1.6 t/ha. The variety has been developed by pure line selection. *Swarna Vaidehi* is also highly resistant to leaf blight disease.
2. **Soil and water properties:** The most suitable soil for its cultivation is clayey soil type as such soil retains water for a longer time. The soil should also be rich in nutrients like nitrogen, phosphorus, potassium, iron, manganese, zinc, and organic matter. The makhana plant is primarily highly responsive to organic matter as well as nitrogen content. It has also been noticed that the plants growing in nutrient-rich soil are very less affected by any kind of disease. The irrigation water should not be salty; the pH of irrigation water should vary around neutrality.
3. **Improved cultural practices**

Nursery raising: It is well known that nursery-raised plants have higher yield potential than direct-sown crops. Thus, the nursery raising technology in makhana crop was also introduced by the National Research Centre for Makhana, Darbhanga. Under this technology, the field is well prepared by two to three deep ploughing, however, before ploughing, for the proper nourishment of seedlings, fertilizers @ 100:60:40 Kg/ha, respectively, of N, P and K in a combination of 20 t/ha compost is applied. Prior to puddling the soil should also be treated with cakes of neem/mahua /karanj @ 0.8-1.0 t/ha. These cakes help in keeping soil-born

diseases away from the rhizospheric region of plants. It would be more fruitful if the mixtures of these cakes (in equal proportion) are applied in the soil. The field is filled with water up to the 45 cm height of the bund and the seeds are sown in the month of December. An amount of 20 Kg healthy seed is broadcasted uniformly in the entire nursery plot. For transplanting in one-hectare area, an area of 500 m^2 is enough for raising the nursery. A water level of 45 cm height is maintained throughout the growing period of seedlings, i.e., from December to March. The seedlings are transferred from the nursery plot to the already prepared main field in the first week of April and transplanted at a distance of 1.20 x 1.25 m. The same doses of nutrients are also applied in the main field where transplanting has to be done.

4. **Cultivation in cropping system mode:** The disease incidence in the makhana crop may be decreased up to a certain level through its cultivation in cropping system mode. The National Research Centre for Makhana has developed some popular makhana-based cropping systems such as makhana-rice, makhana-wheat, makhana-berseem, makhana-water chestnut, makhana-water chestnut-berseem. The makhana-water chestnut-berseem has been found most economical and sustainable cropping system in terms of maintaining soil fertility.

Following suitable interventions should be made to improve the productivity and profitability:

a) Use of high-yielding varieties
b) Removal of weeds during the early growth period i.e. up to the first two months after the emergence of leaves over the water surface
c) Judicious use of fertilizers: N:P:K @ 100:60:40 kg/ha and FYM @ 20 t/ha
d) Cultivation in cropping system mode

Traditional makhana ponds having a depth of 1-2 m can be utilized for fish and water chestnut crops in cropping sequence. Due to this high water depth in Makhana water bodies, the agronomic management of this crop is very tedious and as a result, the productivity of this crop is very low (1.0-1.5 t/ha). Further cultivation of other crops such as rice, wheat, lentil, and berseem except some other aquatic crops such as water chestnut and Indian Lotus is not possible.

In order to address this problem an experiment was conducted to find out the possibilities of successful cultivation of the Makhana crop in field conditions. In the field system, in addition to Makhana, various other crops including cereals and forages can be grown successfully. While 4-5 months are sufficient for Makhana cultivation, other crops could be cultivated during the rest of the months. In general, Makhana is transplanted in the second week of April and harvested by the second week of August. Thereafter, short-duration varieties of rice are cultivated in the same field. After harvesting of rice (November), wheat is sown by mid-December and harvested by the second week of April and the field is prepared for the subsequent crop of Makhana. Hence, cultivation of two to three crops per year is possible in the field method of cultivation. Makhana-based cropping systems, i.e., Makhana-Water chestnut, Makhana-Berseem, and Makhana-Rice-Wheat have been developed which are being adopted by the farmers. Economics of different Makhana-based cropping systems have been worked out and net monetary returns have been recorded highest through the Makhana-rice-wheat cropping system (Rs 1,22,570.00 per ha), followed by the Makhana-barseem (Rs 98,465.00 per ha) and Makhana-water chestnut (Rs 88,790.00 per ha). Other Makhana-based cropping systems are also developed:

(i) Makhana (March – July) – Rice (July – Nov.)
(ii) Makhana (April-Aug.) – Wheat (Nov. – April)
(iii) Makhana (March – July) – Water chestnut (July – November)
(iv) Makhana (April – Aug.) – Berseem (Nov. – April)

Integrated mode of cultivation of makhana cum fish culture: In the cultivation of makhana in integrated mode with fish culture (Aquaculture), the depth of water should be

maintained up to 1.20 m only. The details of the cultivation of makhana + fish culture are given as under:

It has been found that apart from Indian carp fishes [Rohu (*Labeo rohita)*, Catla (*Catla catla)* & Mrigal (*Cirrhinus mrigala)*], air-breathing fishes such as catfishes [Magur (*Clarias batrachus*), Channa (*Channa striatus)*, Singhi, Garai) can easily be included in water chestnut growing ponds. Fish rearing with makhana offers a benefit to the fish growers from its (fish) possibility of theft. Generally, farmers show reluctance in cultivating fish in makhana growing ponds as they think that the growth of fish will not be proper due to a lesser infusion of oxygen into the water surface covered by gigantic leaves of makhana. In this regard, farmers need to be educated that air-breathing fishes like catfishes fit well in such a situation due to their additional respiratory organs as well as habitat preference and nature of growth. Further, they also need to be informed that a technology has been standardized that the 10% area in the middle of the pond is kept vacant as a refuge area for proper oxygenation for fishes. Magur is released into the pond during mid-March when the makhana crop attains nascent vegetative growth and is harvested in the last week of August. Whereas, the carp fish species (*Rohu*, *Katla*, *Common carp* and *Mrigal*) were integrated @ 6,000 numbers/ha as fingerlings in the ratio of 40:20:20:20, respectively in March-April and again in the month of September after harvest of Fox nut. The harvesting of fishes gets completed in the month of December-January before the emergence of the Fox nut crop. To get better fish yield locally available fish feed must be fed to the fishes. However, one-fourth of the total fish feed requirement is met through decomposed plant tissues of the makhana crop and other weeds and associated fauna and benthic organisms and insects.

e) Dynamics of nutrients under makhana-based cropping systems grown in inceptisols of northern Bihar

Soil organic carbon under makhana-water chestnut-berseem was observed to be 10-25% higher compared to the other makhana-based cropping systems. The makhana-water chestnut-berseem cropping system significantly registered 7.86-27.54% N, 23.33-50% P and 6.38-10.63% K higher than other cropping systems. The makhana-water chestnut-berseem cropping system was identified as the most suitable, sustainable and remunerative cropping system regarding maintaining soil health and productivity of makhana under field-based cultivation of makhana crop.

f) Measures to control highly damaging insect i.e. aphids

Integrated management of aphids: Several natural enemies such as Coccinellid predators and parasitoids have been identified as growth suppressors of the aphid populations in the makhana growing fields. Hence, conservation of these natural enemies in the field is very much essential. The natural enemies of aphids recorded from makhana growing fields and ponds are presented in Table 2.

Table 2. Natural enemies of aphid recorded from makhana growing fields and ponds

Sr.	Common	Scientific name,	Period of	Predatory/Parasitic	Occurrence

No.	name	family, order	activity	stage	status
1	Ladybird beetles	Coccinella septumpunctata (Coccinellidae: Coleoptera)	Mid January to first week of April	Grub and Adult	Moderate
2	Lady bird beetles	Menochiluss examaculatus (Coccinellidae: Coleoptera)	Mid January to first week of April	Grub and Adult	Moderate
3	Lady bird beetles	Scymnus sp.(Coccinellidae: Coleoptera)	Mid January to March	Grub and Adult	Major
4	Ground beetle	Bembidion nilotiecus(Carabidae: Coleoptera)	February to March	Grub and adult	Moderate
5	Aphid Parasitoid	Ademonde crescens (Braconidae: Hymenoptera)	January-February	Adult	Minor

Many insecticides available in the market are not safe for the natural enemies of aphids. Therefore, one should be cautious that the general or broad spectrum of insecticides should only be applied when the presence of natural enemies is very less. As preventive measures, seed treatment with imidacloprid 70 WS @ 5 g/kg seed or root dipping in imidacloprid 70 WS @ 5 g/L of water for half an hour at the time transplanting should be followed. Organically, it can be controlled by spraying wood ashes during its infestation period i.e February to March.

g) **Integrated Nutrient Management practices in Makhana cropping:** The treatment 100% NPK (100:60:40 kg/ha) + 100% compost i.e. 20 t/ha was found to be the best in improving the yield potential of the Makhana crop and recorded 31.25% higher yield (3.2 t/ha) than the control plots (2.2 t/ha).

5. **Climate (Rainfall):** Makhana is suitably grown in regions having annual rainfall in the range of 100-250 cm. In the region that receives precipitation less than 100 cm, the cultivation of the crop may not be appreciably economical since from the date of sowing/transplanting to harvesting a constant water level i.e. 45 cm is essentially required for getting good yield. Further, in the context of required climatic conditions for its cultivation, the things that need to be taken care of are that frost is the major cause of makhana leaf mortality in temperate regions. Further, salinity is a major constraint on makhana growth in coastal regions. Makhana also does not respond well in acidic soil and water conditions.

Summary

The most important conclusion to be drawn from this study is that makhana can conveniently and sustainably be grown in cropping system mode with crops like rice, wheat, water chestnut and berseem. The monetary gain obtained from the makhana-based cropping systems is significantly much higher than the crops like rice, wheat, water chestnut and berseem grown alone. The makhana-water chestnut-berseem cropping system has been identified as the most suitable, sustainable and remunerative cropping system regarding maintaining soil health and productivity of makhana under field-based cultivation of makhana crop.