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Cultivation Practices of Makhana (*Euryale ferox* Salisb.) and Their Contribution to Sustainable Development Goals

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INTRODUCTION

Makhana, also called as fox nut or gorgon nut, is a vital aquatic crop belonging to the family of Nymphaeaceae. Its scientific name is *Euryale ferox* Salisb. and it is primarily grown in wetlands, ponds, oxbows, and waterlogged fields. India is the largest producer of makhana with the contribution of over 80-90% of makhana produced in India being provided by the state of Bihar. Makhana crop is considered valuable due to its nutritional value, medicinal value and growing demand both domestically and internationally. Makhana crop was traditionally grown in natural ponds and wetlands wherein the plant regenerated naturally from the residual seed. However, modern innovations have resulted in the emergence of an advanced field cultivation system which makes crop management easier, nutrients utilization efficient, weed management easy, and increase its yield.

Fig. 1 Makhana cultivation at Bhola Paswan Shastri Agricultural College, Purnea, Bihar

Climate Conditions

The climate conditions needed for the growth of Makhana include tropical and sub-tropical climate, which are indicated by relatively high temperatures and humidity. This particular crop thrives in temperatures ranging from 20 to 35°C and relative humidity of 50–90%. Annual precipitation of 1,000 to 2,500 mm is considered to be ideal because it will provide enough water for the growth of the plant. Warm and humid climate promote good vegetative growth, flowering and fruiting of the crop. Excessively high temperatures over 40°C, dry spells and lack of water negatively impact growth, fertilization and overall productivity of the plant.

Soil and Water Requirements

This particular crop grows better in rich clay and clay-loam soils. Optimum pH for the growth of the crop varies from 6.5 to 7.5. As Makhana is an aquatic crop, it needs continuous access to water during the period of its development. In the traditional pond planting method, water depths of 1.0 to 1.8 meters are used, while in the new field planting method, 0.30 to 0.60 meters of water is sufficient. This crop needs stagnant or slowly moving clean water.

Varieties

There are some local varieties of makhana that are being grown in the Mithila area of Bihar. Along with the above indigenous varieties of makhana, there are some improved varieties like Sabour Makhana-1 and Swarna Vaidehi which have been developed by scientific breeding programmes. Out of the above, Sabour Makhana-1 is known for its higher yield of seeds, high popping percentage, and ability to grow in the field. Presently the main target of the breeding programme of makhana is the development of varieties having good yield, maximum pop recovery disease resistance, and field adaptability.

Methods of Cultivation

There are two methods of cultivation of makhana, i.e., the traditional pond system and the improved field cultivation system. In the traditional pond system, the crop is raised in natural ponds, wetlands, and oxbow lakes wherein the crops are regenerated from the seeds which are left in the pond bed. The system requires relatively lesser external input but does not provide many options for crop management and hence produces relatively lesser output. Harvesting is extremely labour intensive because the seeds are handpicked from the muddy pond floor. In contrast, the improved field cultivation system has been developed by research institutions to facilitate scientific crop production. This system provides better nutrient management, effective weed control, uniform plant population, easier intercultural operations, and opportunities for mechanization, ultimately resulting in higher yield and greater economic returns.

Land and Pond Preparation

Pond and land preparations are very crucial if one wishes to successfully establish his crops. In the traditional pond method of cultivation, all aquatic weeds like water hyacinth and other weeds are cleared in October-November. The bottom of the pond is cleaned, appropriate water depth maintained and any broken bunds fixed to avoid water seepage. In the improved field method of cultivation, the land is properly ploughed and leveled and bunds made around the field to retain water within the field. Well decomposed farm yard manure is mixed into the soil before flooding of the field.

Seed Rate

The seed rate that will be used varies depending on the method of cultivation that is employed. 50-80 kg of seed per hectare is required when using the new ponds since there are no seeds left over from the previous harvest, but seed not required in case of established ponds owing to the availability of residual seeds. In case of the improved field method, the seed rate is 30 kg per hectare.

Seed Treatment

Healthy and vigorous seeds without any infection should be chosen for sowing to get good germination and seedling vigour. The damaged and immature seeds are removed before planting. The chosen seeds are then treated with NSKE 1500 ppm @ 5 ml/kg of seed or bio-agents to prevent seed infections.

Nursery Raising

In the improved farming practice, the seedlings are raised in shallow low laying nursery fields or pond. The nursery sowing is done during first week of December and seedlings are ready for transplanting after 85-90 days. Healthy and vigorous seedlings are then selected for transplantation during February-March due to favorable environmental conditions that facilitate establishment and further growth.

Planting

The Makhana crop can be raised by both sowing and transplanting methods. In the pond method, the seeds are directly sown into pond water where they germinate naturally. But in the field system, the nursery raised seedlings are then transplanted at proper spacing of 1.25 × 1.25 m. Spacing helps to get sufficient sunlight penetration, aeration, and effective nutrient utilization and results in higher seed yield.

Nutrient Management

A balanced nutrient management system is very important to attain the optimum yield of the crop. Farmyard manure that is well decomposed is added to the field as a basal dose @ 10-15 tonnes/ha before planting the crop in order to improve soil fertility and organic matter contents. The amount of the fertilizer to be applied is around 75 kg nitrogen, 45 kg phosphorus (P_2O_5) and 30 kg potassium (K_2O)/ ha in general. The total amounts of phosphorus, potassium along with farmyard manure are applied as a basal dose and nitrogen is applied in two or three splits. Use of an integrated nutrient management system including use of organic manures, bio-fertilizers and chemical fertilizers further improves the condition of the soil and its fertility.

Water Management

Water management is the most important part of makhana cultivation as the crop is grown under aqua conditions. An even water level must be maintained throughout the growing period of the crop. Complete drying of the field must be avoided, adversely Polluted stagnant water should be replaced whenever possible, and proper drainage arrangements should be made after heavy rainfall to avoid waterlogging beyond the desired level.

Management of Weeds

Aquatic weeds are competitors of the makhana plants since they compete for nutrients, sunlight and space, which negatively impacts the yield of the crop. Examples of common weeds include the water hyacinth, hydrilla, duckweed, and various types of aquatic grasses. Weed management is mainly through hand weeding, rope dragging, mechanical cleaning and maintaining optimum plant density. Rope dragging prior to transplantation is a traditional method widely used by farmers for disturbing and controlling aquatic weeds.

Intercultural Operations

Inter-cultural operations should be regularly done to ensure proper growth of the crop. Seedlings should be replaced where there is seedling death to ensure optimum plant population. Thinning should be done where there is excess seedling population. Diseased or dead plants are uprooted while regular monitoring of the crop is done to ensure that it is free from pests and diseases throughout the growing period.

Pests Management

The makhana plant has relatively low susceptibility to insect pests compared to other crops grown on land. However, there are various insect pests that may affect the crop economically. Examples of important pests are aphid (*Rhopalosiphum nymphaeae*), case worms, *Elophila depunctalis* W, *E. crisonalis* and Rib borer, *Chironomous* Spp. Effective pest management involves maintaining field sanitation, encouraging biological control agents, regularly monitoring pest populations, and applying insecticides. The foliar spray of NSKE-1500 ppm @5% was done three times by Knapsack Sprayer or drone sprayer @ 500L water per ha at 25 days' interval starting from 40 days after transplanting. only when pest populations exceed the economic threshold. Adoption of Integrated Pest Management (IPM) practices helps reduce pesticide use while ensuring sustainable crop production.

Management of Diseases

A number of fungi-related plant diseases including leaf spot disease, root rot disease, and seed rot disease can infect makhana under favorable climatic conditions. These can be controlled by using disease-free planting material, treating the seeds with proper fungicide or biological control measures, proper sanitation in the fields, balanced fertilizer application, and proper water management.

Flowering and Fruiting

Makhana flowering usually occurs during the months of May to June depending on climatic conditions. Fruit formation normally occurs from May to July when proper pollination and fertilization have been achieved. Maturation and bursting of fruits will occur underwater resulting in the dispersal of seeds which will sink into the bottom of ponds or fields and stay there until harvest or for future germination.

Harvesting

The harvesting usually begins around second fortnight of July-November when the seeds become mature enough. Harvesting of makhana in traditional pond culture is done manually whereby mature seeds are scooped up from the bottom of the field/pond. Harvesting is a laborious activity requiring experienced laborers to carry out the work effectively.

Processing

Processing is an important stage of makhana production process since it determines the quality and market value of the final product. Firstly, the harvested seeds are cleaned, dried and graded based on the size of the seeds. Secondly, the seeds are roasted between the temperatures of 250-320 degree centigrade. Thirdly, tempering is carried out to distribute the heat evenly in the seeds. Lastly, manual popping of the roasted seeds is done. Finally, the popped makhana is graded, packed, and marketed. Proper roasting temperature and skilled handling are essential for achieving a high popping percentage and superior product quality.

Yield

Depending upon the mode of cultivation and management strategies, the seed yield of makhana shows variations. The traditional method of cultivation results in average seed yields of 1.5–2.5 tonnes per hectare. On the other hand, the improved field cultivation strategy, with use of HYV of good quality seeds, balanced nutrition, water management, and varieties like Sabour Makhana-1, can give yield of approximately 3.0–3.5 tonnes per hectare, or more, if conditions are favorable.

Role of makhana in the achievement of sustainable development goals

The United Nations adopted the 17 Sustainable Development Goals (SDGs) in 2015, out of these, some SDGs are supported by Makhana cultivation and its processed products. A number of SDGs, such as poverty alleviation, food security, health enhancement, economic expansion, and environmental sustainability, might play an important role in makhana consumption. Makhana has a significant relationship between sustainable goals like SDG-1 (No Poverty), SDG-2 (Zero Hunger), SDG-3 (Good Health and Well Being), SDG-8 (Decent Work and Economic Growth), and SDG-12 (Responsible Consumption and Production). In addition to these goals, there are other SDGs that can be grouped under the relationship of makhana with the SDGs, such as SDG-5 (Gender equality), SDG-9 (Industry, innovation and infrastructure), SDG-13 (Climate action), and SDG-14 (Life below water). A brief overview of makhana and its relationship with the SDGs is provided below.

1. **SDG-1 (No Poverty):** Makhana cultivation and processing provide employment and livelihood opportunities for rural communities in the Mithila, Kosi and Seemanchal regions of Bihar. It helps to reduce poverty and strengthen rural economies through improved production and market access.
2. **SDG-2 (Zero Hunger):** The popped Makhana is nutritious food rich in minerals and protein, which helps to reduce malnutrition and food insecurity among the population

3. **SDG-3 (Good Health and Well Being):** Nutrient-enriched food makhana has several medicinal compounds that improve digestion, reduce heart and inflammatory diseases,
4. **SDG-5 (Gender equality):** Due to lack of mechanization in transplanting, harvesting, traditional processing (washing, sun drying, grading of seeds, preheating, roasting, popping, etc.), value addition (sorting and grading of pop, snacking, packaging), the uprooting of seedlings from the nursery and transplanting in the main fields is mainly done by both women and men. The harvesting of makhana seed from the bottom of a muddy pond or field is more labor-intensive, which is mainly done by men, but after that, traditional processing, like washing, sun drying, grading of seeds, preheating, roasting, popping, etc., value addition (sorting and grading of pop, snacking, packaging) is mainly done by women. Hence, the makhana value chain helps achieve gender equality by creating equal opportunities for men and women in employment and income-generating activities.
5. **SDG-8 (Decent Work and Economic Growth):** From sowing to reaching consumers, a lot of labor and value chains are required. Investment in infrastructure, technology development, and skill development further increases productivity, which ultimately helps to decent work and economic growth.
6. **SDG-9 (Industry, innovation and infrastructure):** Now a days Makhana is known as "*superfood*" in the world market. Makhana promotes food processing industries, encourages technological innovation in cultivation and processing and strengthen rural infrastructure, thereby contributing to regional and national industrial growth.
7. **SDG-12 (Responsible Consumption and Production):** Makhana cultivation is an environmentally sustainable practice that uses minimal chemical pesticides, as it has low insect pest and disease incidence. It helps the aquatic ecosystem and intercropping with crops like water chestnut. Ultimately, these points are taken into consideration that makhana promotes responsible consumption while supporting sustainable production.

8. **SDG-13 (Climate action):** Due to the heavy rainfall, the low-lying areas are completely inundated throughout the year. Agricultural and horticultural crops, except makhana, are very difficult to grow under stagnant water conditions. The makhana and makhana-based cropping/farming systems enhance production, productivity, and profitability in waterlogged areas. The climate change and untimely heavy rains in these areas creates an opportunity to grow makhana, as it requires 1m-1.5m depth of stagnant water throughout the life cycle from sowing to harvesting. Therefore, we can say that makhana-based cropping and farming systems provide a way to overcome climate change and reduce its impact.

CONCLUSION

With scientific cultivation techniques, makhana production has been revolutionized in terms of improvement in management, productivity, and profitability. Improved field cultivation techniques, superior varieties like Sabour Makhana-1, balanced nutrition, proper water management, pest and disease management, as well as harvesting and processing methods, have greatly increased seed yields and popped quality. As a result of domestic demand, international marketing options, and technological developments, makhana is becoming a potential high-value aquatic crop that could increase farmers' income. Makhana is an important crop which helps to achieve sustainable development goals.