CLIMATE CHANGE and MAKHANA FARMERS of Bihar

Opportunities, Challenges and Solutions

Working Report

ASAR Social Impact Advisors, Bangalore, India
Prepared by Ishteyaque Ahmad and Munna Kumar Jha

Acknowledgements

This report is an outcome of contributions from many organisations, institutions, issue experts and most importantly the Makhana farmers therefore we are indebted to all the key stakeholders for their important roles in the completion of this process.

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Content

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Foreword

Makhana or Gorgon nut or Fox nut (*Euryale ferox*) is an unique aquatic crop grown organically in Bihar and a signature fruit of Mithilanchal. This region is famous for 3 "M" namely Makhana, Makkhan (Ghee) and Macchli (Fish) which are interlinked with the traditional ritual of local people. The plant is cultivated for its seeds in lowland ponds in India, China, and Japan. In India, this plant is confined to floodplain wetlands of Bihar, West Bengal, Odisha and Assam. The Indian state of Bihar produces 90% of the country's fox nuts. In Bihar, more than 15,000-50000 hectares of water land are set aside for cultivation of *Euryale*. The seed is highly nutritious, rich in protein, carbohydrates, fibre, magnesium, potassium, phosphorus, iron and zinc. The seed has significantly lower glycemic index than most high carbohydrate foods like rice or bread. The seeds are often roasted or fried, which causes them to pop like popcorn. They are also used in other types of cooking, especially to make a porridge or pudding called kheer. The seeds possess medicinal values in Ayurveda preparations, and in traditional Chinese medicine. Though it is grown in water but Makhana is not simple crop to cultivate and special skills are required for farming, harvesting and processing. Postharvest and processing of Makhana is still a challenging task which need to be addressed by the researchers and policymakers. The inherited skill of Makhana cultivation, harvesting and popping is still confined to the fishermen community of Bihar which needs further refinement and empowerment.

It is now a fact that global climate is changing very fast and its impact is severe on water resources. As a result the area under Makhana cultivation has been reducing year after year. New varieties, management practices and technology may save this unique crop. National Research Centre for Makhana, Darbhanga and RPCAU, Bihar have come out with new varieties and management practices for improving its productivity. Makhana based IFS has the potential to mitigate the impact of climate change through diversification of agriculture. The Centre has also developed popping machine for Makhana and is designing a harvesting machine. Recently, Govt. of India has announced to set up Makhana Development Board to boost up production, productivity, value addition and marketing of this unique crop.

The Working Report on Climate Change and Makhana Farmers, Opportunities, Challenges and Solutions is an outcome of humble attempt by ASAR Social Impact Advisor, Bangalore.to provide the valuable information from ground level on various aspects of Makhana fruits, cultivation practices and associated people. In this regard, I must complement Mr I. Ahmed, Mr M.K. Jha and team for bringing out this comprehensive document, which I believe will be useful for policymakers, researchers and extension workers with the aim of improving productivity of this economic crop and livelihood of associated farmers.

Amitav Dey 3/2/2025

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The Context

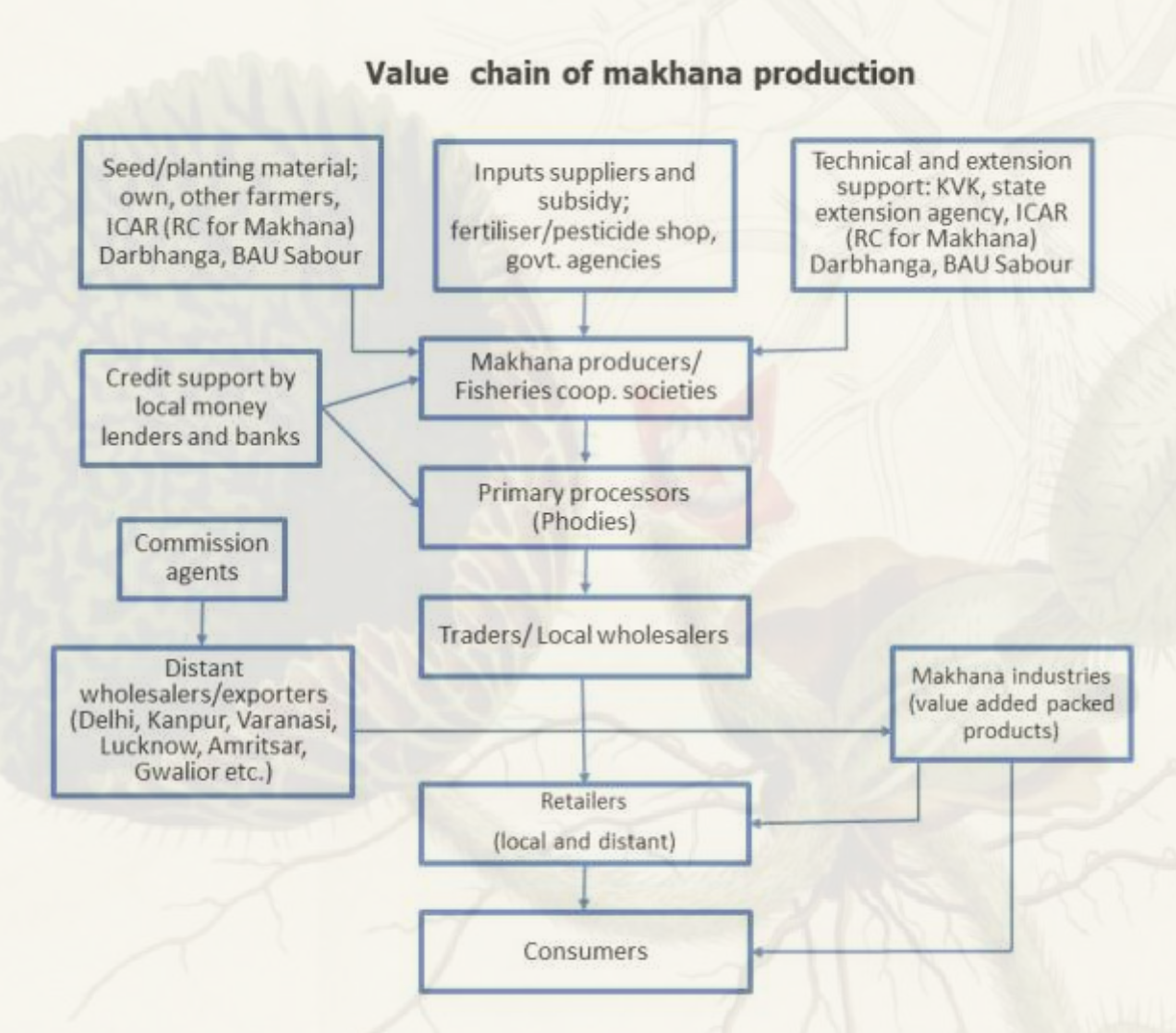
Makhana is a highly nutritious, easily digestible and tasty food. The pops are integral in many snacks, desserts, health food supplements and recipes in Bihar and other regions of India because of their health benefits and taste. The cultural importance of makhana is immense.It is essential in food prepared for all auspicious and inauspicious occasions in the regions where it is grown. Sanskrit scholars explain 'makhana' as *makh anna*or food offered during *yajna (Offerings to God)* which is offeredto the most respected guests.

Bihar grows around 85% of the makhana produced in India. The Mithila region of Bihar has traditionally been known for its makhana production, although districts such as Purnia, Katihar and Araria are also becoming hubs of makhana cultivation in the state. All these areas are water surplus and are drained by hundreds of small and big river channels. The region is known for its numerous lakes and ponds which help the makhana crop grow without too many external resources – it grows in stagnant water. Relatively high rainfall and Himalayan Riverchannels recharge these water bodies year after year, providing freshwater and essential minerals for good crop growth. Earlier these lakes and ponds were connected by numerous natural streams and human-made canals, ensuring that floods are mitigated and the groundwater is recharged.Because of its propensity for water bodies, this region is also known for its freshwater fish diversity. Overall, the soil and atmospheric conditions ensure good harvests and prosperity among landholders. Locals boast about their rich culture and economic status:“*Pag pag pokhar maachh makhaan, hoth pe muski muh mein paan, ee chhe Mithila ke pahchan*” (Innumerable ponds, fishes and makhana, along with smiling faces and betel leaf are the symbols of the Mithila region).

But with the past few decades of climate change, overexploitation of groundwater, destruction of water networks due to encroachment of river beds and ponds, and discharge of urban waste, greywater, and blackwater into ponds, circumstances are drastically deteriorating. Direct manifestations of this include a sharp decline in the land and marine biodiversity, fish catches, and the production of makhana and other food crops, and an increase in the parching of rivers and other water bodies and the incidence of high-intensity or flash floods. Additionally, due to long hot and dry spells, paan or betel leaf production is vastly impacted.

Still, the demand for makhana has increased manifold because of its nutritional value and other health benefits. As retail prices are also skyrocketing, there is immense pressure to increase its production. A wide range of agriculture experts, policy makers and institutional scientists are also promoting the makhana crop as a climate-resilient solution for small and marginal farmers.They reason that makhana plants are highly resilient to extreme weather events such as high temperatures, dry spells,excessive precipitation and hail storms.

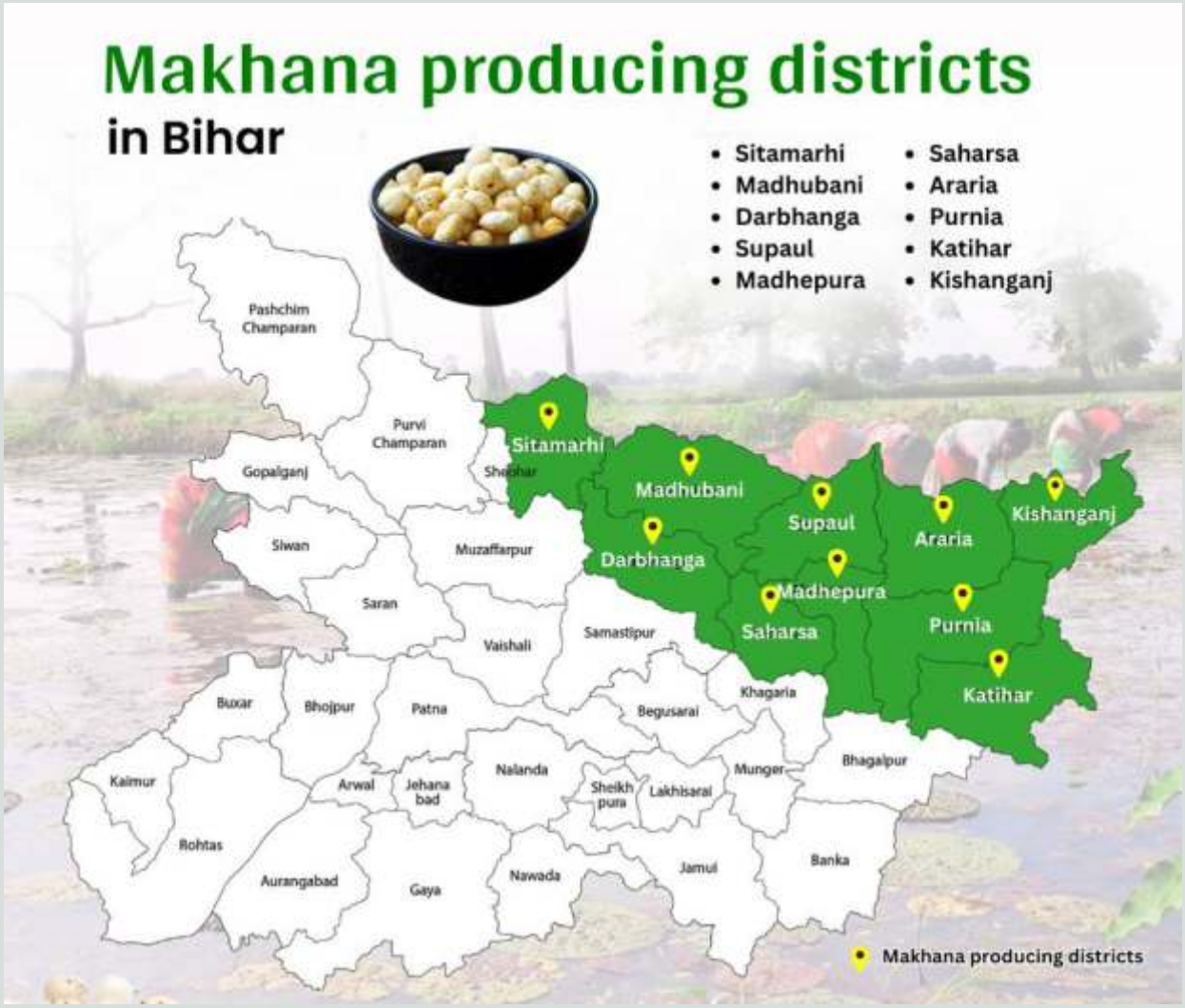
Recognising the need for research and development (R&D) to scale up the crop and its productivity, the National Research Centre for Makhana (NRC-M) in Darbhanga has been established by the government. New research and experiments are also being conducted and incentivised by various agencies. This includesnovel cultivation and processing techniques, which have promising outlooks. In fact, many new regions and cultivators are adopting the crop and demonstrating favourable results.



Geographical conditions and expansion

Euryale ferox Salisb (from the Nymphaeaceae family) is commonly known as makhana, Gorgon nut or fox nut. It is grown in stagnant perennial water bodies like ponds, land depressions, oxbow lakes, swamps and ditches. The plant grows in tropical and subtropical climates. Its proper growth requires a conducive air temperature range of 20–35°C, relative humidity of 50–90% and annual rainfall of 100–250cm (Mandal et al., 2010). Makhana is a cash crop (dry fruit) and marketed in the form of lawa (pops).

The makhana plant is a native of South-east Asia and China, but it can grow in almost every part of the world. In general, it is limited to the tropical and subtropical regions of South-east and East Asia in Japan, Korea, Nepal, Bangladesh and India. But it is also found in Russia and North America. In India, it is found inWest Bengal, Bihar, Manipur, Tripura, Assam, Jammu & Kashmir, eastern Odisha, Madhya Pradesh, Rajasthan and Uttar Pradesh. However, its commercial cultivation is limited to northern Bihar, Manipur, parts of West Bengal and Madhya Pradesh. In Bihar, major makhana-producing districts include Darbhanga, Sitamarhi, Madhubani, Saharsa, Supaul, Araria, Kishanganj, Purnia and Katihar. Approximately, 80% of all processed makhana in India comes from Darbhanga, Madhubani, Purnia and Katihar. The area under makhana cultivation in Bihar is about 15 thousand ha.[1]



Rationale of the study

Bihar is among the most climate-vulnerable regions in the world. Being an agricultural state, it needs to make a swift transition to climate-resilient agricultural practices to maintain its economic growth while ensuring food and livelihood security for its population. Bihar farmers earn significantly lower incomes, compared to the national average, which increases their vulnerability to climate crises. In such a scenario, if makhana cultivation enhances the scope for resilient production and remuneration for farmers, it might be a good solution in the face of low farm incomes and adverse impacts of climate change. The crop also has the potential tobe exported as a high-price commodity and boost the earning of the state.[2]

The study was aimed at obtaining a nuanced understanding of the diversity of perspectives on the environmental and economic sustainability of makhana cultivation for cultivators and its profitability for the state and other stakeholders. Through this study, ASAR has tried to document the perspectives of different stakeholders including traditional makhana cultivators, farmers who have adopted makhana as a commercial crop, Krishi Vigyan Kendra researchers, government extension officials and scientists from the Indian Council of Agricultural Research Krishi Bhavan – Research Complex for Eastern Region(ICAR-RCER) on the impacts of climate induced extreme weather events on makhana cultivation. The study was also aimed at documenting the traditional and modern practices which have potential in making the crop more climate resilient and profitable for farmers without compromising with the environment.
The study informs us about the various aspects and dimensions of the trade and, importantly, divergent and convergent perspectives. We identified ways to make makhana cultivation remunerative for farmers as well as sustainable and resilient to extreme weather events and market anomalies. This process also helped us appreciate farmers' perspectives and deep-rooted knowledge on the issues. The indigenous wisdom of makhana farmers includes an understanding of water bodies and marine ecology, as well as the impacts of related anthropogenic and environmental phenomena. Indeed, a convergence of such indigenous knowledge and modern science and technologies can be instrumental in the development of agriculture as a climate-appropriate and sustainable livelihood.

Methodology

We wanted to highlight the perspectives of different stakeholders. Therefore, the almost three-month-long listening exercise had different elements.

The first step was to gather information on makhana cultivation in Bihar, the basic processes and the challenges faced by farmers, aggregators and marketers. This phase included reviewing the documents produced by various government departments and research institutions.

The second phase involved remotely talking to a few leading makhana cultivators, scientists and extension staff to prepare a pointer questions for the consultations and interviews with different stakeholders with farmers in the centre stage.

The third phase was to organise face-to-face consultations with makhana farmers. There were three sets of makhana cultivators: traditional makhana growers, growers using modern techniques and aspirant makhana farmers.

Overall, the study involved more than 150 makhana farmers from 5 major producer districts of Bihar: Darbhanga, Madhubani, Supaul, Purnia and Araria.

A set of interviews with issue experts, researchers and policy influencers was also organised to get their perspectives and recommendations.

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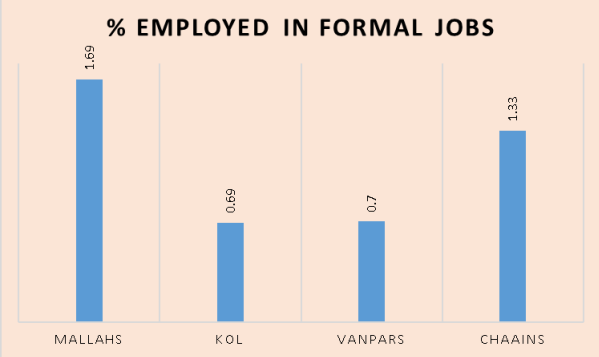
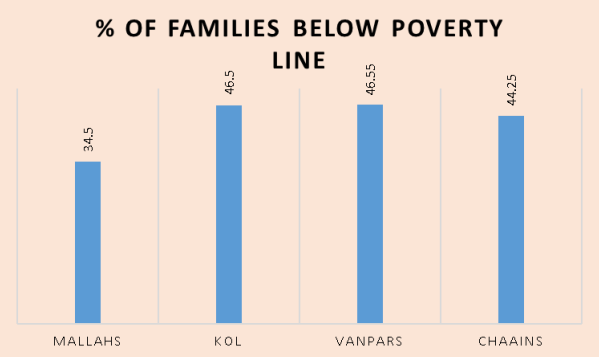
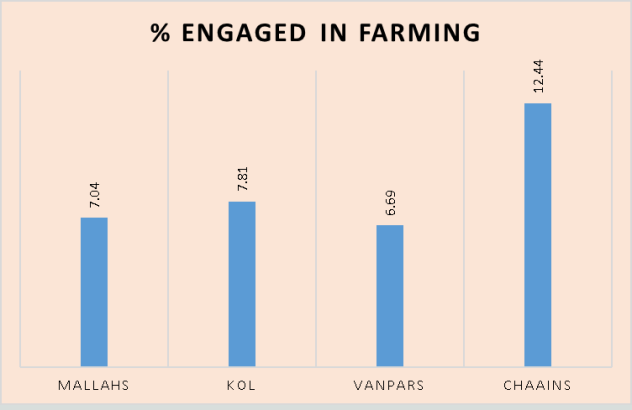
Traditional makhana growers

Rich in knowledge, impoverished in entitlements

Three communities such as Kols, Chaains and Vanpars (sub-castes of Mallahs or Sahnis) are the backbone of makhana production in Bihar. There is a confusion about the status of Kols. The community leaders of the Mallah community believe that Kol is a subcaste of Mallah however, they are enumerated as a Scheduled Tribe in the2022 Caste-based Survey Report of Bihar government. The report indicates that the overall population of Mallahs in the state is 2.6%.







The Kols, Chaains and Vanpars are known for their skills related to, and knowledge of, various forms of surface water, e.g., rivers, lowlands, lakes, ponds and seas. Their knowledge systems are based on intergenerational oral knowledge transfers. Water has been a facilitator of their income for generations – they work as fisherfolk, boat and ship-makers, boaters, sailors, navigators and makhana cultivators. These communities are responsible for most makhana cultivation in lakes, ponds and lowlands.

The government report does not include caste-based landholding. Therefore, there are no verified or updated numbers for this variable. But we can refer to the number of farmers for landholding data.

Difficult work for paltry remuneration

Makhana cultivation is one of the toughest farming exercises. Men do all the underwater and transplantation work, while all other responsibilities such as cleaning, drying, sorting, roasting, popping and grading are done by highly skilled women. The Kols grow and harvest the crop.

We were told by almost all the respondents that only Mallahs, fisherfolk and people from Scheduled Castes or Scheduled tribes (who live adjacent to the water bodies) are entitled to lease lakes and ponds for fishing and cultivation of makhana and water chestnut. Each lease is for a period of five years. After the period a fresh tender is opened and a new lease is contracted. There is no renewal process for the lease.

After securing a lease, the farmer has to clean up the pond/lake and treat it with limestone powder and neem oil cakes. Seeds are sown in November and the saplings transplanted the following March–April, if necessary. All parts of this water crop – the roots, leaves, buds, flowers and fruits – are full of thorns. There is always a risk of getting pricked by the thorns. The good thing about makhana cultivation is, however, that during the crop cycle, human interaction with the plants is limited. But sometimes transplantation is required because of environmental or anthropogenic disturbances like the drying up of water bodies or extreme chemical contamination of ponds, lakes and lowlands. In such cases, transplantation becomes a tough task for farmers.

Organic or synthetic fertilisers are implemented to ensure healthy growth of the plants in the first year of makhana cultivation. April to August is when makhana plants grow to their full extent. With the advent of heavy rains in July and August, the plants start decaying and the seeds settle down in the pond beds. Diving into the pond is the only way to harvest, in the traditional practice. It takes 30 to 40 man-days to harvest the seeds from a 1 acre pond. Late August till October is the ideal time to harvest the seeds, though harvesting continues till December. But December is not the preferred month for harvesting as the water gets very cold and the chance of divers experiencing hypothermia increases. Another big reason for harvesting earlier in the season is that the drying of the seeds require moderate sunlight.

In the traditional makhana cultivation method, no external fertilisers are required as the crop residue of the makhana plants is enough. Therefore, from the second year onwards the production costs reduce sharply as there is no need to procure seeds and fertilisers. In this practice additional water is also not required as the crop needs 1.5–2 ft of water for optimal production. The crop can stand in 12–15 ft of water too, with a slightly lower yield. Apparently the quality of deepwater makhana is superior to that of shallow water.

The Chaains do the processing, which involves a long list of tedious jobs that require high skill. The process starts with cleaning the seeds, which is done by kneading with the feet. Groups of four or five persons perform this job together, holding each other's shoulders. They sing to match their rhythms. After cleaning, the seeds are dried in the sunlight on mats, made of date palm leaves, to maintain a moderate temperature above and below. High temperatures can compromise the quality and nutrition values of the makhana. Sorting is the next step – the seeds are segregated using sieves of seven sizes. The different quality of seeds are separately roasted and crushed. The seeds are roasted at a temperature of 250°C. The workers toss these hot seeds on their palms and then crush them on a wooden platform using a wooden hammer when the seeds are still hot. This helps the seeds become the pops – the final product. Maintenance of heat is very crucial in the process as lower heat can lead to improper popping and toughening of the makhana and higher temperatures can burn the makhana. After this, another round of sorting and grading is done before the food is sent to the market.

The Vanpars are the aggregators and suppliers to the local *mandis* (markets) and other buyers. They collect the popped makhana from producers and sell it to merchants. Although 85% of makhana is produced in Bihar, the biggest market is in Delhi and the second biggest is in Kanpur. Patna Mandi comes fourth, after Benaras, with less than 10% of the market share.

There are 7–14 grades and top quality makhana can cost as much as Rs. 2,000 per kg. Flavoured makhana is usually priced at Rs. 3,000–4,000 per kg. Producers earn a meagre share of less than 25% of the market price. Farmers earn Rs. 100–250 per kg, depending on the quality of makhana. This is all they get for all their skills, risks and hard work.

Insights from farmers

We were able to engage with over 200 odd farmers a from different geographical and social set ups during the study. We observed that different segments have diverse and some times divergent things to share. Information coming from traditional farmers were different from the modern makhana farmers which is easily explainable as the practices are significantly different in the two systems. Insights coming from the Darbhanga-Madhubani region was markedly different from the Katihar-Purnia region because of the different topographies and the natural drainage patterns. What was intriguing to note that observations of landowners and affluent farmers were diametrically different from the landless and impoverished makhana growers. Therefore, we are noting all the observations as it is.

Here insights from traditional makhana growers are documented. These are mostly landless farmers coming from Mallah communities.

Sitaram Sahni is a traditional makhana grower. He shared that most makhana cultivation is done in ponds and lakes using traditional techniques. After getting the tender for a pond/lake a makhana grower has to invest a significant amount of money to prepare the pond for makhana production. Since the lease is only for three years this investment is not fully utilised. He also shared that shallow water is better for higher production of the crop but deep water makhana is quality wise far more superior. He also talked about the challenges and risks the harvesters had to face, 'Makhana harvesting is challenging. Nowadays, because people dump their waste, especially broken glass and bottles into the water bodies, harvesting has become quite risky. Mechanisation could be a solution, though machine-based makhana processing has not yet succeeded. He also talked about the required regular desilting of tanks and ponds is needed to produce good quality makhana and there is financial support for the work. Regarding integrating the traditional methods of fish production with makhana cultivation he said that there is no infrastructural support which can reduce farmers risks and make the crop more resilient and remunerative for small and landless farmers.

Kusheshwar Sahni, another traditional farmer informed that they are not entitled to the benefits and support provided by the government because they are not the landowners. An amount of Rs. 80,000 is provided to farmers who produce makhana over 1 acre every year, but none of the landless traditional makhana growers are able to access this benefit. He also informed that the water tax is higher for landless makhana growers. Having to pay taxes further diminishes their returns. Small and marginal farmers develop tanks and ponds with huge investments and effort. But once these tanks and ponds are perfected for makhana and fish cultivation, they are leased to someone else. These are often proxies for Dhoti and Pant Wallahs (landowners from non-Mallah communities) who are eligible to take out leases. Responding to the physical risks associated with weeding and harvesting of makhana he said that mechanisation will not help with harvesting as there is a huge diversity in the size of makhana seeds.

Ramvriksha Sahni, the third respondent informed that due to the long hot and dry spells, even deep ponds and lakes have water shortages these days. In such situations, the amount of organic matter in the water increases drastically. This can decrease the oxygen level in the water, which is not suitable for makhana cultivation. To maintain the appropriate ratio, additional water (through irrigation) is needed. But in the absence of irrigation facilities, the quality and quantity of the makhana yield are compromised. He reiterated that the current lease system is not conducive to traditional makhana farmers' participation. Indeed, when a pond starts yielding good crops, it is leased to influential people through proxies.

Comparing the inputs costs of the traditional and the modern makhana cultivation practices he said that the traditional method requires the least amount of investment as there is no need for regular irrigation, seeds, fertilisers and pesticides. He also said that plants grown using traditional seeds are more resilient to weather extremities and different types of pests and diseases. He highlighted that the newer varieties of makhana seeds need a lot more care and investment.

Ruplal Sahni echoed Ramvriksha's opinion on the new hybrid seeds, saying that the new varieties are more productive and need a different set of skills and expertise as well as extra care. He informed that sewage and grey water are being discharged into the lakes and ponds where makhana is grown. Sometimes, municipal waste, including medical waste, is also disposed of in these water bodies. This chokes the aquatic life and contaminates the water. Additionally, it may badly impact the quality of makhana produced. Due to the extreme heat conditions water scarcity is becoming rampant making the situation even worse. Responding to a question related to climate change he said 'we will have to learn new skills to deal with the increasing extreme weather events. Unfortunately, there is no system for skill up gradation and adaptation.'

Mahadev Sahni is a leader of the makhana growers and fishworker groups. He is also known as the indigenous scientist on the water-based food systems. He informed that just 25–35% of the income of traditional makhana growers comes from makhana cultivation. The rest is from fishing and related work. He said, 'all our livelihood options are directly linked to various forms of surface water, which are under great threat due to several anthropogenic and environmental factors. Abrupt changes in temperature are becoming more problematic for sustainable fish and makhana production. Siltation of rivers is another challenge before the water-based food system which is peaking because of restricted flow of water channels, including rivers; destruction of forests in the catchment areas of the rivers and water channels; construction of dams on major rivers and increased soil erosion in agricultural fields. Moreover, weather extremities are amplifying all these issues. It is the modern farming techniques and lifestyles that are responsible for this crisis.'

'High siltation and choking of the drainage system intensify soil degradation and erosion, creating a cycle of destruction. Due to increased silt levels, the water-bearing capacity of rivers has decreased drastically, leaving little scope for fish to survive and grow. This also causes flash floods, which are detrimental to makhana production, as the high-velocity water flow flushes away the plants. Flash floods have increased manifold in the recent past, partly because of heavy and erratic rainfall in short spans of time', he added.

He said that the speed of rise in the water level in rivers, speed of water flow, duration of the high water level and rate of decline in the water level are real indicators of the climate crisis and predictors of the income of freshwater fishworkers and makhana growers from fish catches, makhana production, rowing and boat-making. Unfortunately, these indicators have not been in their favour for the past few decades and they do not have any control over the situation.

He further continued, 'we as a community have lived with the water for thousands of years and survived numerous floods, droughts and disruptions. The rivers and other water bodies are our second home, so we have developed the sensitivity and sensibility needed to deal with a diversity of extreme conditions. But the current climate crisis and other anthropogenic disasters are difficult for us to handle because our traditional knowledge is not integrated into the policies and programmes created for us.

He said, 'we acknowledge the limitations of our knowledge system but modern science does not recognise its own limits. Therefore, what we have to contribute to the global fight against hunger, impoverishment and the marginalisation of people caused by climate change is brushed aside. I thank ASAR and Regenerative Bihar for organising this workshop and listening to our perspectives. I hope this will somehow feed into policy-making and planning.

Talking about the climate change he added, 'the impacts of climate change can be ameliorated and mitigated through big-ticket changes. But this needs a lot of courage among people in powerful positions. Power in this case does not necessarily mean political power but also knowledge and control in decision and policy-making. People in power need courage to accept the follies of past and present planning and policy-making, acknowledge the disasters caused by those wrong decisions and undo them before pursuing corrective measures. One such blunder was the construction of Farakka Dam, which has been a slow poison for the whole Gangetic River Basin. Initially the bed of the Ganga got silted because the flow of the river was distorted – this decreased its silt-carrying capacity. It also restricted or stopped altogether the movement of migratory sea fishes that swim up to Haridwar and Rishikesh for reproduction.

'As a result, fish catches have dropped, not only in the Ganga River but also in all its tributaries due to siltation and restricted migration of sea fishes. There were previously more than 370 types of fish in our rivers, but now there are hardly 30–35. Apart from fish, there were more than 60 varieties of aquatic animals that are not eaten by humans but are crucial to the aquatic system. These are barely found anymore, and this adversely impacts our food security and livelihoods.'

Talking about the benefits of higher financial allocations for makhana cultivation for a stable income from exports, he said that various food products from India get rejected by quality inspectors in other countries because of high maximum residue levels (MRLs) of pollutants or pesticides. But Indian makhana is in high demand everywhere because of its purity and quality. These two requirements can be ensured only by traditional farming methods which are largely free from synthetic chemicals. The quality of deepwater makhana is also superior.

Highlighting the adverse impacts of river embankments he said, 'since most major rivers in this region are surrounded by embankments, there is no freshwater recharge of lakes and ponds which is in a way slow death for makhana, freshwater fish and their producers.'

Recommendations from Traditional makhana growers

- All the support and benefits offered under different government schemes should be extended to Mallah community farmers, who are the traditional makhana growers and processors, even if they are landless.
- Lake and pond leases should be long term to ensure a secure the livelihoods of farmers and their families.
- The government should assist makhana growers in the regular desilting and cleaning of lakes and ponds to maintain the quality of makhana. This will protect farmers and the product from the adverse effects of water contamination.
- Lakes, ponds and chaurs (lowland and waterlogged fields) should be connected to ensure regular recharge of freshwater.
- No new embankments should be built or extended and rivers should be allowed to flow freely. Additionally, older embankments should be gradually removed. This will help with desilting rivers and recharging lakes, ponds and chaurs with freshwater. It will also facilitate the rejuvenation of perennial rivers.
- Collectives or farmer producer organisations(FPOs)for makhana growers should be formed and assisted by the government the way Jeevika groups are.
- Confederations of such collectives need to be formed at the block level, and three basic support facilities provided: banking and financing, processing and warehousing, and crop insurance.
- Educated youth from makhana grower communities should be supported with skill building in marketing, branding and packaging so that they can take charge of marketing the product.
- District-wise quality control should be done and packaging centres developed for the smooth export of the product. This would increase remuneration for farmers and revenue for the state government.
- Makhana producers should be allotted dedicated stalls at major railway stations, tourist spots and religious pilgrimage sites to attract crowds.
- Fish and water chestnut production should be clubbed with makhana production to enhance the income resilience of farmers.
- Makhana producers should be equipped with the skills required for climate adaptation, mitigation and resilience.
- Traditional makhana growers should be involved in policy-making processes related to the crop and its farmers.
- Mallah women play a significant and a very critical role in makhana cultivation as they perform numerous labour-intensive activities such as seed collection, cleaning, drying, gradation, roasting, frying, popping, rubbing, storage and most importantly seed conservation. Hence their insights and inputs are crucial for an impactful policy making and planning.

Lowland cultivators

The worst-impacted makhana farmers

Chaurs or lowlands areas are abundant in northern Bihar because of its alluvial plains and dense drainage system. Thousands of small and big Himalayan streams drain this region, which has a very low gradient. The water in streams flows into this region at high velocity and, unable to follow a fixed path, spreads all over the place. The gushing water often digs large pits in the alluvial plains, creating swathes of waterlogged lowlands.

Before embankments forced the rivers to flow along fixed routes, these chaurs were inherently linked to the rivers. The two would replenish each other with water whenever needed. During the rainy season when the rivers had surplus water, they would recharge the chaurs with freshwater. And, during dry seasons, when there was little water in the rivers, the chaurs would supply water to the rivers. The two systems survived because of this seasonal give and take. But since the breakdown of this relationship, both systems have been at a loss for water when they need it desperately.

In 2024, as many as 40 rivers in Bihar have not had water since March. Moreover, last monsoon there was a rainfall deficit and the chaurs did not get fully recharged. Still, farmers used the chaur water to irrigate their drying crops. As a result, almost all the chaurs had dried up by the beginning of this summer. April is when the transplantation of makhana seedlings is done, and there was no water available in most of the chaurs. The prospect of chaur makhana cultivation this year appears bleak due to the weather extremities.

Social profile of chaur makhana farmers

Most chaur makhana farmers are landowners. In this region, Brahmins, Kshatriyas and a few Other Backward Classes (OBC) own the majority of chaurs in the makhana-producing areas. Some Muslims also work in makhana cultivation – they hire makhana growers from the Mallah community for the work. These landowning farmers are entitled to access government programmes and schemes to promote makhana cultivation, and hence enjoy the benefits.

Since makhana cultivation requires specialised work, the labour for it is fairly expensive. These farmers are, therefore, eagerly looking to mechanisation as a solution to the high labour charges. The demand for the various government schemes and programmes – such as the Mahatma Gandhi National Rural Employment Guarantee Scheme (MGNREGS) and Jal Jeevan Hariyali Mission to clean private tanks, ponds and lowlands and irrigation – is quite high among these farmers.

With rising uncertainty about water availability and humidity due to erratic rainfall and variable temperature patterns, chaur makhana farms are facing multiple issues:

- high investment on irrigation,
- dwindling groundwater levels,
- pest infestations due to inadequate recharge of freshwater and, hence, the need to invest extra on pest and disease control,
- the necessity of large investments in mechanisation and labour and, hence, high production costs,

- elevated climate vulnerability, and
- frequent destruction of crops.

All these together make chaur makhana cultivation a risky occupation. When climate conditions are conducive and production is good, markets are flooded with the product. But in such situations, there is labour scarcity and the charges rise because only a restricted number of people have the required skills. With surplus production, market prices plummet and farmers earn a paltry income, with only meagre returns on their investments. In 2022, many farmers had to sell their cropat throwaway prices as they did not have space to store it. Makhana is a bulky crop that takes up a lot of storage space. Also, it cannot be stored for long due to its susceptibility to various microbial and pest attacks. When the weather is hot and dry for a considerable period, cultivation costs rise rapidly. This is because of the increased demand for irrigation and pest control. In such conditions, both productivity and production go down. In extreme heat and dry conditions chaurs dry up, whichmakes the prospects of makhana production bleak. Thus, farmers face huge losses. On the other hand, heavy rainfall in the fields or in the far-off reaches of the Himalayas, and consecutive flash floods, wash the crop away. Ultimately, farmers face the same impact as if there is no rain: destruction of the crop. In the last two or three decades, the incidences of such extreme events have increased.

Observations from farmers

Most of the chaur makhana farmerswere found to be landowners. Interestingly, most of them belong to non-Mallahs communities. Being landowners, they are entitled for most of the ongoing government programmes and schemes therefore their aspirations and experiences are significantly different. Their capacity to access and capacity to influence government programmes are also different. Therefore, we have separately documented their perspectives and suggestions here.

Maheshwar Thakur is a retired professor and one of the leading voices of lowland makhana growers. He said that the lowlands and waterlogged areas of four north-central and north-eastern districts of Bihar are suitable for scaling up makhana cultivation. There is a growing demand for makhana in the international market and,therefore, a widespread demand for mechanisation to increase productivity and production is being raised by different quarters.Depending solely on traditional methods will diminish the chances of increasing exports.

He informed 'makhana and fish complement each other because decaying makhana leaves and stems serve as good feed for the fish.'

Hemchandra Thakuris a celebrated farmers of the region and is on the panel of trainers of sustainable farming practices. He said that climate change is silently destroying makhana cultivation in the lowlands and chaurs of the north Bihar. Moreover, the absence of crop insurance and any scheme that compensates farmers for losses makes the impacts seem even bigger.

Talking about the instability in the makhana prices he said, 'there is no consistency in makhana

prices. A complete dependence on middlemen and traders to access the markets make us more vulnerable to losses.'

Connecting the environmental and social factors he said, 'climate vulnerability and resilience are directly related to various social and financial realities as well as the support systems comprising stakeholders from the government and trader communities. Indeed, traders may have to limit their income to account for climate- and weather-related calamities and their impacts while fixing the rates for farmers. Farmers cannot be left to fight the climate vagaries alone as makhana cultivation cannot be sustained only by mechanisation. In fact, we will have to strike a balance between making a profit and exploiting natural resources. Failing to do so will destroy the prospects of this crop.

Responding to the question on the comparative costs of the modern and traditional makhana production systems he said, 'external inputs–based makhana cultivation is becoming costlier and the profit margin of farmers is shrinking as traders are not ready to consider the increasing input costs for farmers.

He informed that in the last few years, novel pests and diseases have been adversely impacting the makhana plants. Synthetic pesticides cannot control these new diseases as they have become resistant. Excessive use of synthetic pesticides is not only impacting makhana production but also causing fish populations to decline.

Recommendations from Chaur Area farmers

- The government should announce a minimum support price (MSP) to standardise the rates.
- Crop insurance and crop loss compensations should be extended to makhana growers.
- Middlemen are reaping all the profits from this industry and farmers are constantly accruing losses. Therefore, the markets should be under the control of makhana farmers.
- Skill building among makhana producers for quality enhancement, packaging and marketing should be prioritised.
- Makhana cultivation should be covered under Kisan Credit Cards.
- The NRC-M should take the lead to develop machines for all the steps of makhana production, including processing. Although a wide range of such machines are being tested by various institutions including the Rajendra Prasad Central Agricultural University, a lot more work is required.
- There is a need to increase the investment in R&D in this field.
- New producers need to be incentivised and encouraged to increase production.
- Since makhana cultivation entails health risks for producers, they should have health insurance.

Makhana cultivation as an enterprise

High demand for makhana in local and international markets has encouraged many young and educated farmers to adopt the crop as a commercial venture. They are elevating the process using modern technologies and improved seeds. Since these farmers do not come from any legacy of traditional cultivation practices, they are open to adopting new techniques. Researchers and scientists prefer these enterprising farmers.

The technique

Modern makhana farms are like any other farms, with at least three different crops. Since makhana is grown in the six summer months from April to August–September, the fields are free for the cultivation of other crops in the remaining six months. This technique is largely adopted by farmers who have both resources and access to scientists and government officials. Through the use of modern methods, makhana cultivation is expanding to unconventional areas like Purnia, Araria and Katihar.

In this method, the fields are prepared and filled with 1–3 ft of water from streams or the ground. Since these artificial ponds do not hold stagnant water for long, treatment is not needed. Seedlings are prepared outside the fields, from October to March, and the saplings are transplanted in the fields in April. Typically, the fields are sprayed with synthetic fertilisers and bleach before the transplantation is done. But some knowledgeable farmers utilise the crop residue of makhana and hyacinth to prepare an organic compost. This helps reduce their input costs and the agrochemical residue levels in their products.

Weeds are a big menace in this form of makhana cultivation. At least three weedings are necessary to keep the farms clean and suitable for the crop. The first two weedings are most often performed by women because hiring women labourers works out cheaper than hiring men. The third weeding is only ever done by men as it involves the constant risk of being pricked by thorns. When the labourers come out of the ponds they are frequently badly wounded, with blood oozing from cuts all over their bodies. Therefore, this phase of weeding is extremely expensive compared to the previous two.

By the end of August, the makhana plants decay and decompose in the water, while the seeds sink to the bottom. Before the crop is harvested, the water is released from these artificial ponds. Harvesting is easy – no diving is required in this technique. This reduces the demand for skilled labour for harvesting. Meanwhile, researchers are working on machines which can harvest the seeds and segregate them into different categories. So far, however, they have yet to achieve success.

When makhana cultivation first began in the North-Eastern districts such as Purnia, Katihar and Araria, labourers from the Madhubani–Darbhanga or Saharsa–Supaul–Madhepura regions were hired for the cultivation. But now local labourers have the skills required; this has reduced the associated costs a bit. Still, post-harvest processing is performed by migrant workers from Darbhanga and Madhubani, known as Phodis. Phodi families stay in the area for four months. Traders create isolated shelters for them for that period. Workers come with their whole families, as each member of the family performs different duties. Their shelters are completely isolated,

with tin sheet separators. Nobody else is allowed to enter the temporary shelters except the families and traders who hire them.

Post-harvesting jobs are totally under the control of traders, who purchase the harvested crops from the farmers. They set the prices of the raw and popped makhana. They bear all the quality-related risks but earn at least a 25–40% profit in just four or five months.

The price of unprocessed makhana is highly unpredictable. Unlike other crops, the price is not linked to the quantum of production because the demand is too high and always insatiable. The fluctuations in price are majorly determined by the quality of seeds. When the monsoon is delayed and farmers' capacity for irrigating their fields is exhausted, the fields dry up. In such conditions, the quality of seeds declines drastically. Also, the plants sometimes do not yield makhana at all. Although 80% of makhana farmers make sure that the fields have at least 1 ft of water, even in the worst-case scenario, traders use delayed rains as an opportunity to reduce the prices for all farmers. Hence, when the monsoon is delayed, the price of makhana plummets drastically. This leaves the farmers in complete distress as they have already invested in keeping the crop well hydrated through hot and dry spells. Normally, a farmer has to irrigate the field 20–25 times before the arrival of monsoon. In the case of a failed monsoon (low or erratic rainfall), this figure can go up to 40–50, increasing the cost of production immensely.

Scientists and agricultural university engineers are working to develop post-harvest processing machines. This is aimed at reducing the inherent drudgery for women and men farmers involved in the processing. However, traditional makhana growers feel that such machines may render them redundant in the profession. But since much advancement is yet to be achieved in the field, the processing is still done by skilled migrant labourers from the traditional makhana-growing districts, such as Madhubani and Darbhanga. A few large-scale processing machines have been installed in Purnia.

Scientists and researchers, supported by universities and government, are organising exposure visits for traditional farmers to these farms and facilities. The intention is to introduce them to new technologies and persuade them to adopt modern tools and methods.

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Insights from farmers

These are modern farmers cum entrepreneurs. They are well aware of the ground realities as well as the opportunities markets offer. They are pragmatic enough to synthesise and accommodate the requirements, sentiments and values of both the ends (the traditional producers and the consumers). Since they cater as the bridges between two ends, their perspectives and recommendations are crucial.

Chinmay Kumar Singh is an educated professional who opted makhana production agriculture as his livelihood after considering all the dominant factors of the sector. He said that makhana is among the most resilient crops and, hence, can be a good source of income for farmers. Makhana plants can survive extreme heat, temperature fluctuations and heavy rainfall and hailstorms. The main thing a farmer has to ensure is continuous availability of water in the field.

According to him, R&D in makhana production started very late, in 2013–14.Hence, it is still in its nascent stage. There is only one institution, Bhola Paswan Shastri Agricultural College, Purnia, which has been working on it for the past few years. But with paltry resources, the institution's pursuit of research is limited.

He also said that the machines that have been developed to reduce labour costs are more expensive than manual labour.

Recommendations

- If R&D in makhana production and post-harvest processing is to be properly pursued, the government should earmark resources and employ competent research organisations like the Indian Institutes of Technology(IITs).
- Forming and financing self-help groups (SHGs) for makhana farmers should be prioritised. This will help farmers realise dignified and remunerative incomes for their investments and labour.
- Long-term support for makhana farmers is necessary to reap the desired results; the off-and-on approach is not working.

Institutional Research & Development in makhana cultivation

The global climate is changing rapidly and its impact on water resources is severe. Makhana-based integrated farming systems have the potential to mitigate the effects of climate change through natural resource management and diversification of agriculture, besides providing nutritional and environmental security. Considering the importance of makhana to the economic sustainability of its growers and the state of Bihar, National Research Centre – Makhana (NRC-M) has been setup in the Darbhanga district, under the administrative control of ICAR-RCER.The centre is responsible for conducting research on germplasm collection and evaluation, varietal development, farming system model and agro-technique development, post-harvest processing, diversification and value addition in makhana.

NRC-M is proactively working on the integration of makhana cultivation and fish production. Integrating makhana with fish and water chestnut cultivation is a viable farming system model for the eastern region of the country. Also, makhana cultivation in a cropping system offers a unique opportunity to grow the crop in shallow water with optimum yield. Water chestnut, paddy, wheat, berseem and other crops can also be successfully cultivated in makhana fields. According to NRCM findings this diverse approach provides gainful employment and food security to farming families. Still, scientists and experts are of the opinion that improved technologies are available for cultivation, processing of makhana is still carried out manually.

Recent R&D achievements

- A total of 112 germplasms of makhana have been collected and evaluated, and 24 pure lines have been isolated. Of these, six have been found most promising for high productivity.
- The seed yield of the promising strains is 2.8 t/ha compared to 1.6 t/ha in local check (indigenous seed varieties). A promising line of makhana seeds is in the pipeline for release.
- In general, makhana is a crop of the pond ecosystem. However, to enhance productivity and facilitate the horizontal expansion of makhana, a field-based cultivation technology has been standardised, and is being adopted by the farmers mostly in the non-traditional regions of makhana cultivation.
- Makhana, makhana–water chestnut, makhana–berseem, and makhana–rice–wheat cropping systems have been developed.
- A makhana–fish–water chestnut integrated farming system has also been developed. This model is gaining popularity among farmers.
- The economics of different makhana-based cropping systems have been worked out. The net monetary returns of different cropping systems are as follows:
    - Makhana–rice–wheat: Rs. 1,22,570/ha,
    - Makhana–berseem: Rs. 98,465/ha,
    - Makhana–water chestnut: Rs. 88,790/ha, and
    - Makhana–fish–water chestnut: Rs. 88,910/ha.

Improved technology for makhana cultivation developed by ICAR-RCER scientists

A new system of makhana cultivation has been standardised by the institute. In this system, makhana cultivation is carried out in agricultural fields with 1 ft of water (Kumar et al., 2011). This system provides farmers the opportunity to sow cereals and other crops in the same field each year. The makhana seedlings are first raised in a nursery and then transplanted in the field at the optimal time. Depending upon the availability of the fields and nursery, the transplanting can be done between the first week of February and the third week of April. With this system, the duration of the makhana crop is reduced to four months.

Following are the key elements of this cropping system

Nursery

Being an aquatic crop, makhana thrives in water-retentive soil that is rich in organic matter. Thus, clay or clay loam soils are most suited for makhana cultivation. For proper nourishment of the seedlings, fertilisers with 100:60:40 kg/ha of nitrogen, phosphorus and potassium (NPK) are applied. The field is prepared with two or three rounds of deep ploughing. Thereafter, the field is levelled and an earthen bund about 2 ft high is made around the field. The field is filled with 2 ft of water, up to the height of the bund.

The seeds are sown in December. About 20 kg of healthy seed is broadcasted uniformly over the entire field. To transplant in a 1 ha area, about 500 m^2 is sufficient for the nursery plot. The water level is maintained at 1 ft throughout the growing period of the seedling, i.e., from December to April. Young seedlings may be vulnerable to aphids. However, aphids can be controlled by spraying a 0.2% solution of Endosulfan. By the end of March, the seedlings are ready to be transplanted.

Land preparation

The land is prepared with two or three rounds of deep ploughing, followed by planting with tractor-drawn implements or a traditional plough. Depending upon the availability of the field, this can be done from the first week of February to the second week of April. To retain sufficient water, an earthen bund of 2 ft is constructed around the field, and water is filled up to 1 ft. The field is puddled with two or three runs of a tractor-based puddler. For makhana cultivation, puddling is essential because it checks the downward percolation of water to lower layers in the field.

Manure and fertilisers

Makhana does not need manure or fertiliser when grown in a pond. In a field, however, manure and fertilisers are essential to provide proper nourishment to the heavy feeder plants. As an aquatic crop with large and heavy leaves, makhana has a high nutrient requirement. On average, a crop of makhana needs approximately 100:60:40 kg of NPK. To meet these requirements, both organic (15 t/ha) and synthetic fertilisers are used.

[3] https://www.researchgate.net/publication/362529227_Status_of_Makhana_Cultivation_in_India

Transplanting

Healthy seedlings are uprooted from the nursery and immediately transplanted in the prepared fields. On the basis of availability of the field, the crop can be transplanted from the first week of February to the second week of April. About 1.5 m^2 is the ideal space for proper growth and development of a makhana plant. Therefore, a distance of 1.2 m is maintained between plants and 1.25 m between rows.

Water management

A sure supply of water is a prerequisite for makhana cultivation. The transplanted makhana seedlings take four months to gain full maturity. Since transplanting is done in April, the main growing period (April–August) aligns with the monsoon rains. Nevertheless, farmers need to irrigate four or five times, depending on the requirement of the crop, particularly when rainfall is erratic.

Weed management

Rapid weed infestations take place in the initial stage of development of the makhana crop. Therefore, regular weeding during this phase is vital. However, because of the luxurious growth of the makhana leaves 30–40 days after transplantation, the weed infestations reduce. In an integrated makhana–fish–water chestnut farming system, weeds are reduced because of the use of nets while harvesting the fishes in December–January.

Flowering and fruiting

Flowering and fruiting start in May and continue up to October–November. After 35–40 days of flowering, the fruits develop and mature. Upon maturity, the fruits start rupturing. As a result of this, the seeds appear to float on the surface of the water. After two or three days, the seeds settle at the bottom of the field. The process of fruits bursting and seeds accumulating continues till the end of the crop period.

Harvesting

Harvesting involves collecting the scattered seeds from the bottom of the pond or field. In the traditional system, harvesting is done from August to October, but in the field system, it is carried out in August. The reason for the earlier harvest in the field system is the minimal depth of water, i.e., 1–2 ft. Generally, harvesting is done in the morning hours (6–11 am), which is the age-old practice. Usually, a group of four or five people start collecting the seeds from the bottom of the pond. The time required for collection depends upon the number of seeds at the bottom of the pond or fields. In the field system, because the water is shallow, collecting the seeds is simple and not very time consuming.

Cleaning and storage

The collected seeds are put into a crescent-shaped container locally known as *gaanja*, which is then swung and shaken repeatedly over the water's surface until all seeds get clean. This practice removes the waste that sticks to the seeds. Then the seeds are poured into a cylindrical container

locally known as *auka*or *khanjhi*, which is rolled on the ground to rub and smoothen the seed coats. The workers thresh the seedswith their feet to remove the mud and other materials. Then the seeds are thoroughly washed. After a proper cleaning, the seeds are put into gunny bags. Water is sprinkled on the seeds at regular intervals to maintain the optimum moisture in them until the process of popping starts.

Seed yield

Depending upon the genetic potential of the seed material, on average, the seed yield in the pond system is about 1.4–2.2 t/ha.In the field system, the yield potential of the same seeds is 2.6–3.0 t/ha. Till date, there is no improved variety of makhana in the country. However, the work on varietal development is underway and some pure lines have been developed with a yield potential of 2.8–3.0 t/ha.

Comparative analysis of makhana cultivation in pond ecosystems and agricultural fields

Parameter	Pond ecosystems	Agricultural fields
Water requirement	At least 4–6 ft	Just 1 ft
Seed requirement	80–90 kg/ha	20 kg/ha
Source of water	Naturally occurring water from perennial water bodies	Irrigation water or any other perennial source of water
Fertilisers and manure	Not required and not possible due to the great depth of standing water	Can easily be applied before and after transplantation
Weed management	Tedious	Easy
Crop duration	Long (8–10 months)	Short (4–5 months)
Seed yield	1.8–2.0 t/ha	2.6–3.0 t/ha
Scope for grain and fodder production	Not possible	Water chestnut, rice, wheat, berseem and other crops can be grown in rotation
Maximum number of crops possible in a year	Two	Three
Crop protection measures	Tedious	Feasible
Intensification of cropping system	Makhana–water chestnut	Makhana–water chestnut, makhana–berseem and makhana–rice–wheat
Cropping intensity	In general, 100% in the traditional system	200–300%
Net income	Low to medium in the traditional system	High to very high
Feasibility of harvesting	Tedious –it can be done only by trained labourers	Simple –it can even be done by unskilled labours
Capital investment	High to very high, depending on the situation	Invariably low to medium
Scope of horizontal expansion of makhana cultivation	Limited because it would depend upon the availability of natural water bodies	Wide

Insights from experts

Dr. Mangalanand Jha, Principal Scientist, Basaith Krishi Vigyan Kendra, Madhubani, shared his views on the topic and said, 'the impacts of climate change on makhana cultivation is becoming clearer every day. For makhana to properly grow and develop,a conducive air temperature of 20–35°C, relative humidity of 50–90% and annual rainfall of 1,000–2,500mm is necessary. But the temperature in Bihar has increased significantly,oftengoing up to 40–42℃, with the humidity dipping to 40–45%. The average annual rainfall has reduced to 800mm over the last a few decades.The overall rainfall pattern has also changed. Earlier it was well distributed over four months. Thishelped maintain the moisture and temperature levels. Now precipitation happens erratically and rainfall is concentrated in a few days. Rest periods are hot and sunny with very high humidity. These conditions are not ideal for the crop.

The changing weather conditions are conducive to pest and disease growth,which is rising. On the other hand, acidification of water is happening at an alarming rate due to high agrochemical and microbial contamination of the surface water bodies. Increased evaporation due to extreme heat and dry weather is another major cause for the decline in the soluble oxygen and rapid acidification.

To control the pests and diseases we recommendpesticides like Bavistin and Gatka formakhana cultivation. But organic solutions like neem oil, neem oilcakes, turmeric and limestone water are more effective and sustainable.'

According to him, more than 4,000 ha of land is covered by different types of water bodies in this region. About 50% of these water bodiesare being used for makhana cultivation and the rest for fishing. He also talked about the irrigation needs for different types of ponds and water bodies. He said, 'shallow water bodies up to 6 ft deep need assured irrigationdue to the changing climatic conditions, whereas ponds with 6–15 ft of water need no irrigation.Concentrated rainfall in the region or catchment areas of rivers are causing flash floods more often. This is proving disastrous for the makhana crop.'

Dr Pramodh Kumar Jha, Horticultural Scientist, Basaith Krishi Vigyan Kendra, Madhubani said that more than 80% of makhana is produced in pond ecosystems using traditional cultivars and farming practices. He highlighted the need to embrace improved techniques, cultivars and tools to rapidly increase the productivity and production of makhana. He also shared about the progress in the R&d of makhana, 'Around 60

germplasms are being developed by NRC-M, Darbhanga. A new high-yieldingcultivar Swarna Vaidehi is ready for cultivation. As a Crop rotation is effective for controlling pests like aphids, case worms, beetles and snails in the field method. In the pond ecosystem the use of chemical pesticides has proven counterproductive. Instead, traditional practices of pest management are more effective. Contrarily, in the field ecosystem both pest and disease control can easily be done using synthetic pesticides.

He batted for the modern techniques in makhana cultivation because he sees huge potential for upscaling makhana production using them. He said, 'It can remove many impediments such as a lack of skilled labour, dependence on a few skilled people and communities, and reliance on deepwater ponds. The modern methods are cost effective too.'

Dr Amitava Dey, Principal Scientist, Livestock & Fishery Management, ICAR-RCER, Patna said that around 15000-18000 ha land is under makhana production in Bihar.Due to shifts in land use and climate change, the number of water bodies is drastically shrinking. He shared, 'if we do not check this trend, there will be no sustainable future for makhana cultivation.'

Dr Amitava gives credit to improved quality seeds, higher application of agrochemicals, controlled irrigation, intensive labour and harvesting most of the seeds for slightly higher yields from field ecosystems. He said, 'in the traditional practice, hardly any seeds need to be bought for future cultivationas 10–20% are left in the pond after the harvest. Agrochemicals are not advised or used; this reduces the yield but lowers the input costs.

Talking about the existing mechanisation in makhana cultivation he said, 'there is no mechanical solution for weeding or harvesting as of now. Several machines have been tested but their performance has not yet been deemed satisfactory by researchers and farmers. Scientists are also experimenting with several popping machines. One such machine is installed by a company, Shakti Sudha in Purnia.'

He was optimistic of the makhana–fish–water chestnut experiment which has been successful in most trials and could prove a good solution for farmers. But he expressed his concerns for the imprudent exploitation of groundwater, especially from the aquifers used to irrigate makhana fields, as it is an unsustainable trend. 'It has a huge depleting impact on the groundwater tables, rendering the future of the crop bleak.'

Responding to a query on making makhana cultivation more resilient and profitable for traditional growers he said, 'planting fruit trees along pond bunds facilitates crop intensification and diversification. The leaf litter improves the soil organic carbon content of the ponds and reduces the need for synthetic fertilisers. These trees are also useful for diversifying farmers' sources of income, making their work more economically viable and climate resilient. Big and tall trees should not be planted to the south and west of the ponds as they cast undesirable shadows on the makhana plants, which need sun.'

His concerns regarding the dependence on synthetic agrochemicals was quite obvious. He said, 'synthetic pesticides disrupt the whole ecosystem, the healthy functioning of which is essential for makhana production. The indigenous knowledge system of makhana cultivation has

successfully kept the crop alive. Traditional farmers will play a huge role in designing the practices necessary to face the current realities of climate change.'

Recommendations

- Weeding and harvesting entail health risks and difficult labour. Therefore, sincere efforts are needed to develop mechanical solutions. Mechanisation is particularly needed for seed grading.
- Popping is a tedious and painstaking task that requires high skill. It is only done by a few fishing communities in Bihar. But for large-scale commercial production of makhana, mechanisation of the process is the only solution.
- Even for the horizontal expansion of makhana production, mechanisation is required. Otherwise, this important crop go extinct because of the complete dependence on a limited number of skilled workers. This number is also dwindling due to high risks and low remunerations.
- Credit and marketing facilities for makhana growers need to be ensured and existing ones strengthened.
- Partnerships must be forged with different stakeholders in the supply chain along with value addition for makhana at the regional, national and international levels. This will spark a paradigm shift for makhana on a global scale.
- More research should be done on pest management methods that do not employ pesticides for makhana and associated crops.
- There is a need to converge traditional knowledge and modern technologies to create a comprehensive and holistic solution to climate change.

Key observations

Makhana is one of the most important traditional foods in Bihar. The crop is closely connected to the physical and socio-cultural environment of northern Bihar, especially the Mithila and Seemanchal regions. It is an important cultural signature of the state. It got a geographical indication (GI) tag in 2020. [4] It provides a livelihood to lakhs of resource-poor farmers. Makhana is grown across almost 15,000 ha in Bihar. The state produces nearly 10,000 tonnes of popped makhana per year.

This crop is mostly produced by resource-poor farmers and processors therefore they borrow money from private money lenders and local wholesalers at high monthly interest rates of 3–5%. In the absence of institutional financing to traditional makhana farmers and producers, they end up paying extraordinarily high annual interest rates which has a direct impact on their incomes and they become highly vulnerable to the external disruptions such as climate induced extreme weather events and market fluctuations.

The makhana market is dominated by a few large wholesalers who purchase the popped makhana in large quantities. They decide the prices of the seeds and pops in the local markets. Due to the lack of farmer organisations and organised processing industry, producers and processors do not get their due share of the benefits from the makhana value chain.

Makhana is supposed to be effective in strengthening heart, spleen and kidneys, and is useful for alleviating anaemia. It contains low sodium and high potassium which helps reduce blood pressure. Since it has a low level of monounsaturated fat, it helps prevent rises in blood sugar levels and diabetes. It also helps control issues like neuralgia, incontinence, chronic diarrhoea and arthritis. Makhana is a rich source of macronutrients such as calcium and magnesium as well as many micronutrients. It is easily digested. Due to multiple health benefits makhana is in high demands in many countries including USA, UK, EU and UAE. These countries have stringent food safety norms. For an example the European Food Safety Authority recently listed 467 Indian products as unsafe for human consumption. However, makhana is not mentioned on the list.[5] The increased use of agrochemicals, especially pesticides such as Endosulfan, in the field cropping method can lower the quality and acceptability of the food in international markets. Contamination of pond ecosystems due to the discharge of blackwater, greywater and other waste can also lead to a decline in the quality and safety of makhana as an edible crop.[6]
The level of awareness of the environmental and health risks associated with the overuse of end consumers. High use of agrochemicals in makhana cultivation might get this section of the comsumers disenchanted from the crop.

Considering the increasing demand and its climate-resilient properties, makhana is gaining importance in the R&D for agricultural products. On the other hand the crop provides jobs to a sizable population of people from economically vulnerable communities. Therefore, any technological advancement should be designed to simultaneously empower the communities

both socially and economically.

Considering the increasing demand and its climate-resilient properties, makhana is gaining importance in the R&D for agricultural products. On the other hand the crop provides jobs to a sizable population of people from economically vulnerable communities. Therefore, any technological advancement should be designed to simultaneously empower the communities both socially and economically.

Makhana cultivation is largely performed by highly skilled farmers and fisherfolk. Their knowledge of water ecosystems is indispensable Moreover, their technologies and methods are outcomes of generations of experience and expertise. Their pond cultivation system is more cost effective for farmers and safe for the environment compared to the field cultivation method. Pond ecosystems are more resilient to the vagaries of the weather also. Since the community has developed a farming system which is suitable for farmers and environment equally, the R&D community should ensure dignified and equitable convergence of the two knowledge systems can be instrumental in ushering a paradigm shift in favour of a socially empowered and environmentally sustainable advancement of makhana cultivation.

4 https://search.ipindia.gov.in/GIRPublic/Application/Details/696

5 https://images.assettype.com/deccanherald/2024-05/73c5eaad-c2fb-4d07-80ce-a8a00b2a0a67/Full_list.pdf

6 https://www.deccanherald.com/india/heavy-metals-pesticide-cocktails-found-in-over-400-indian-products-here-is-full-list-3010123

https://expora.in/makhana-exports-from-india/

Recommendations

Climate change is impacting socially and economically vulnerable communities and gender groups in the worst way. Technical solutions for climate related issues need resources that vulnerable communities are unable to afford for many obvious reasons. In these conditions, communities are forced to leave their traditional occupations and livelihoods and are displaced from their cultural and environmental habitats. Makhana growers expressed that the proposed field system of makhana cultivation is resource and energy intensive which they are not unable to afford.

During the study, it was also repeatedly told by respondents that there is a little space for indigenous knowledge systems in the present policy-making process, although these have helped communities survive for thousands of years through several environmental disasters.

Gender justice and equity must be one of the guiding principles of any climate justice and transition programme. It should be an integral part of all planning, implementation, evaluation and capacity-building measures.

Indigenous communities have acquired intricate skills and expertise over thousands of years in their occupations. hey have a kind of control over their product, which empowers them and provides them with security and a dignified life. Makhana producers and processors are among these communities. A climate-resilient programme for makhana cultivation should clearly reduce the climate vulnerability of the community. Any infrastructural and technological advancement should aim to empower the community and make them climate champions. Any process which disempowers or displaces them from their occupation or cultural habitats can never be climate resilient.

Recommendations for climate-resilient makhana communities

- Economic and social empowerment is an elementary step towards climate resilience in makhana cultivation. *Therefore, all R&D, policy and administrative efforts should be designed to empower makhana producer collectives and communities.*
- There are multiple important stakeholders and enablers in the makhana value chain, such as farmers; processors or Phodis; local traders and wholesalers responsible for aggregation; distant wholesalers, traders and exporters; makhana industries and value adders; local money lenders; banks; R&D agencies; technical and extension support systems; input suppliers; and government financial and subsidy frameworks. *A remodelled production system should be viable for all stakeholders. It should distribute equitable shares and profits among stakeholders so that none are left vulnerable to climate or financial crises.*
- Collectives (SHGs/ FPOs/ farmer producer companies [FPCs]) for makhana farmers, farm workers, processors and local traders and aggregators should be developed with institutional credit and financing.
- The formed collectives should be directly connected to R&D institutions, such as ICAR and Rajendra Prasad Central Agricultural University, to combine local wisdom and

technological advancements. Such cooperation, including government extension officials, should be leveraged to develop models and prototypes and for knowledge co-creation.

- A confederation of all such collectives should be formed at the state level. It can function as a consultancy resource for policy-making, designing programmes and schemes and monitoring the implementation of the programmes and schemes.
- Since makhana cultivation entails health risks, farmers and farm workers should have health insurance.
- All the support and benefits of different government schemes should be extended to the Mallah community farmers, who are the traditional makhana growers and processors, even if they are landless.
- Lake and pond leases should be long term so that farming families have livelihood security.
- Makhana producers should be equipped with the skill required for climate adaptation, mitigation and resilience.

Recommendations for R&D

- There is a need to converge traditional knowledge and modern technologies to create a comprehensive and holistic solution to climate change.
- A dedicated team of experts – climatologists, agronomists, entomologists, hydrologists, experienced makhana farmers and community experts – should be constituted to assess the impacts of climate change and extreme weather conditions on makhana production. The team should also develop short-, medium- and long-term projections to facilitate designing climate change mitigation and sustainability programmes.
- The programmes should have policy backup.
- Extension programmes for knowledge co-creation on climate change mitigation and sustainability should be implemented for all makhana farmers and farm workers.
- Investments in R&D in this field must be increased.
- Institutions that are leading the R&D programmes for makhana need adequate finances and resources.
- R&D institutions such as the IITs should be involved in designing fuel-efficient and low-emission mechanisation for makhana. The main focus should be on the efficacy of the machines in ponds and fields of various sizes. Another consideration is the affordability of mechanical solutions for economically vulnerable communities, which do 90% of the production and processing.
- Weeding and harvesting include health risks and difficult labour. Therefore, sincere efforts are needed to develop mechanical solutions.
- Even for the horizontal expansion of makhana cultivation, mechanisation is required. Mechanical advancement should reduce the risks and drudgery of farmers and farm workers without negatively impacting their job prospects.
- With increased weather extremities and changing climatic conditions, there has been a marked increase in pests and diseases. Often, synthetic pesticides are rendered ineffective by mutations of pests and disease-causing organisms. Moreover, the indiscriminate use of synthetic pesticides posesa severe threat to the microbial and marine biodiversity of pond and field ecosystems. To achieve high production targets without compromising on

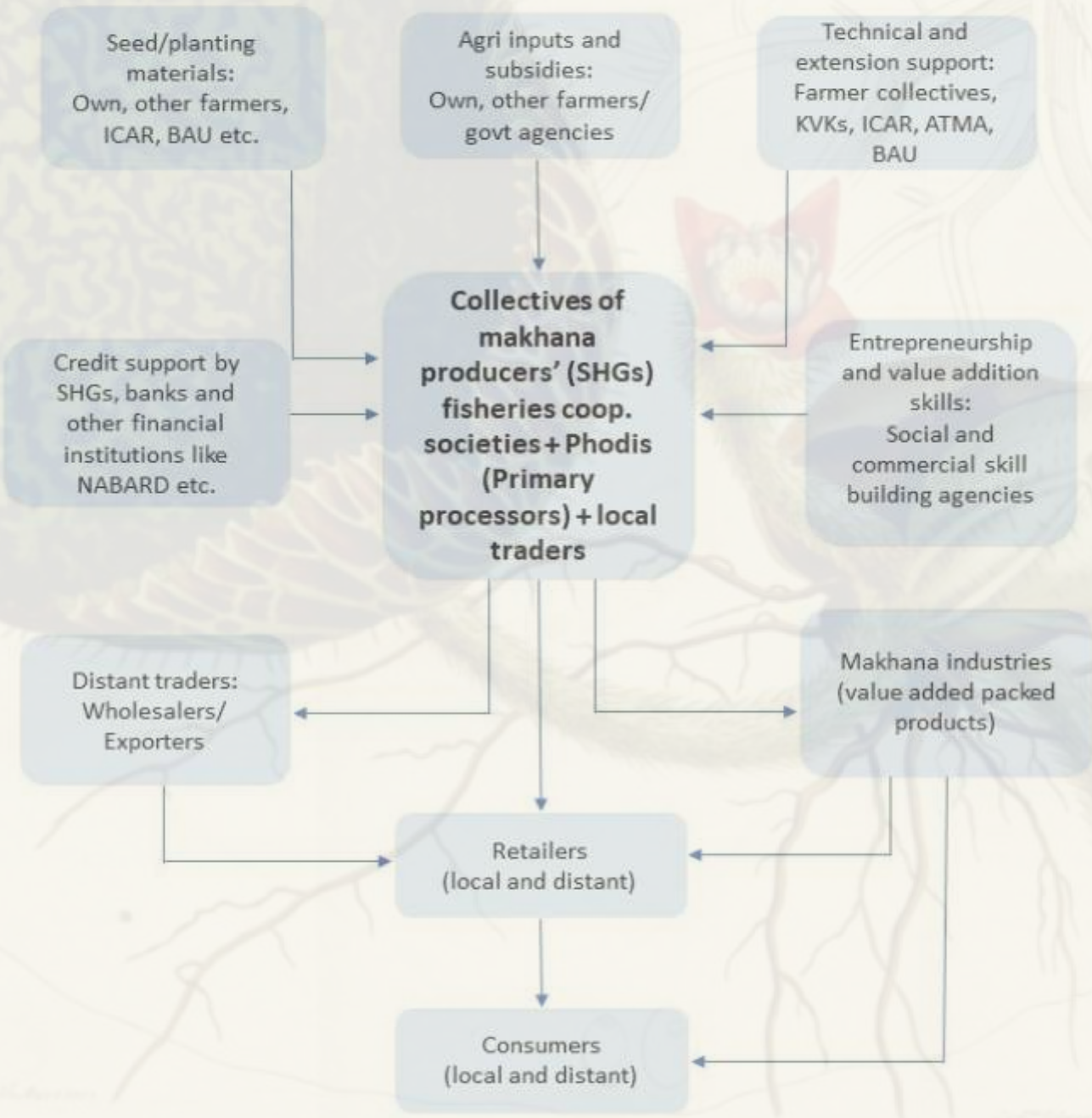
biodiversity, more research on alternative methods of pest management for makhana and associated crops must be done.

- Makhana requires water in abundance. Water is needed both to cultivate the crop and store the harvested seeds. Hence, it is primarily produced in regions with a water surplus. However, the water availability in these regions has changed drastically due to various developmental projects and climate change. At times, these regions are vulnerable to a steep decline in groundwater levels and extreme water deficiency. Therefore, there is a need to keep an eye on the changing availability of water in surface channels and groundwater reservoirs while designing a programme to scale up makhana production.
- R&D should be commissioned to enhance water conservation, surface water management and groundwater recharge in Bihar, to increase the water available for makhana farmers.
- Lakes, ponds and chaurs should be connected to ensure regular recharge of freshwater.
- No new embankments should be built or existing ones extended, and rivers should be allowed to flow freely. Additionally, older embankments should be gradually removed. ajor railway stations, tourist spots and pilgrimage sites to sell their products.

Recommendations for value addition and market access

- In the existing value chain, farmers and farm workers do not have any control over the processed or value-added products and their prices. Yet they are exposed to all kinds of environmental and market risks. To reduce their vulnerability and enhance their income, their control over the value chain will have to be increased. ust like Jeevika groups, collectives of makhana growers should be formed and assisted by the government under the National Rural Livelihood Mission(NRLM) and Bihar Rural Livelihoods Promotion Society (BRLPS) programmes.
- A confederation of these collectives needs to be formed at the block level, and the basic facilities provided: banking and financing, processing and warehousing, and crop insurance.
- Skill building of makhana producers for quality enhancement, value addition, packaging and marketing should be started immediately.
- Skill building of educated youth from makhana grower communities should target marketing, branding and packaging so that they can take charge of marketing the product. Institutions such as the Indian Institute of Management (IIM) and National Institute of Design (NID) should be included in such skill-building exercises.
- District-wise quality control and packaging centres should be developed to ensure smooth export of the product. This might increase the remuneration for farmers and revenue for the state government.
- Makhana producers should be allotted dedicated stalls at all major railway stations, tourist spots and pilgrimage sites to sell their products.

Recommended climate responsive and remunerative Makhana Value Chain



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1 https://horticulture.bihar.gov.in/HORTMIS/BAIPP/Downloads/ModelDPRMakhana.pdf

2 https://marcellus.in/story/long-read-made-in-bihar-how-superfood-makhana-works-its-magic/

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4 https://images.assettype.com/deccanherald/2024-05/73c5eaad-c2fb-4d07-80ce-a8a00b2a0a67/Full_list.pdf

5 https://www.deccanherald.com/india/heavy-metals-pesticide-cocktails-found-in-over-400-indian-products-here-is-full-list-3010123

6 https://expora.in/makhana-exports-from-india/

Asar Social Impact Advisors (Asar) is a start-up in the social and environmental impact space in India. We are incorporated as a for-profit company under Indian law.

Our focus is the challenge and opportunity facing India today. The coming decade is critical to define the actions that the country and its people take in building a prosperous and climate-resilient future. Our solutions are predicated on the understanding that the systemic and transformative changes we require can only be catalysed by collaborative problem-solving and implementation.

Asar exists to empower Individuals, organisations, and networks working on the climate crisis by collaborating, coordinating, and collectivising their efforts to amplify their effectiveness and impact.

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Regenerative Bihar is a collective of agroecology practitioners and promoters, farmers, civil society organisations, climate campaigners and concerned consumers. The collective works for creating an enabling environment for small and marginal farmers to move towards climate resilient and sustainable farming practices.

We are working in 9 districts of Bihar with women and men farmers to assist them in conserving farmers' seeds, growing regenerative nutrition gardens, establishing Bio-input Resource Centres and evolving women ecopreneurship models.

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