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Knowledge Gap and Path Analysis of Adoption of Makhana (*Euryale Ferox* Salisb) Growers in Bihar

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HIGHLIGHTS

- It was characteristic to note that variables landholding size, annual income, income from makhana and training exposure had positive and highly significant association with technology adoption and knowledge level of farmers.
- Farmers had relatively low knowledge, and adoption level with respect to the improved makhana cultivation technology.
- Based on the noticeable gap in the adoption of improved technology, the study emphasizes on developing and implementing innovative and appropriate location specific technologies tailored to the need of makhana growers.

ARTICLE INFO

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ABSTRACT

This study examined the knowledge gap and adoption of the improved makhana cultivation technology in Bihar. The research utilized a descriptive research design and focused on four districts viz. Purnia, Katihar, Darbhanga, and Madhubani. During 2022–24, eight villages were purposively selected from these blocks which included Pipra and Birpur from Purnea block, Mirzapur and Lachhmipur from Barari block, Ballupur and Kishunpur from Bhadurpur block, and Chanuraganj and Simra from Jhanjharpur block. The study included 120 sample, with fifteen makhana growing farmers randomly chosen from each of the eight villages. The findings revealed that plant protection component (disease and pest control) had the highest mean knowledge gap (61.88%), with a relatively low knowledge index of 24.10, and adoption index of 19.33. Further technology adoption and knowledge level of farmers had positive and significant association with landholding size, annual income, income from makhana and training exposure. Improvement in information dissemination on latest technical knowhow via focused campaigns and farmer engagement activities through need based trainings is crucial for increasing the adoption of improved makhana cultivation technology among the farmers for enhanced productivity and profitability.

INTRODUCTION

Makhana (*Euryale ferox* Salisb), is popularly known as fox nuts, in India and other parts of Asia. It is obtained from the seeds of the plant, which is native to India and other parts of Asia. Makhana is known as the global wonder nut for being nutritious and combating many diseases. It has been used in traditional Ayurvedic medicine for centuries and is known for its high nutritional value and health benefits. In recent years, Makhana has gained popularity as a health food due to its low calorie and fat content, high fibre content, and various other nutritional benefits. It is also grown in some other parts of Asia, including China, Japan, and Korea. The global Makhana market is expected to grow by USD 72.5 million, with a CAGR of almost 7% during 2019–2023. (APEDA)

Bihar is the main producer of Makhana in the country and produces more than 80 per cent of the country's total production (Kumar et al., 2020). According to the ICAR National Research Centre for Makhana Research in Darbhanga, the total area under

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makhana cultivation in India is around 15,000 hectares, with an average production of 1.5 t ha^{-1}. The total production of Makhana seeds is around 1,20,000 MT, which after processing becomes 40,000 MT of makhana pop. Makhana production is projected to be worth Rs. 250 crores at the farmer level, however, it earns Rs. 550 crores at the trader's level (Anonymous, 2022).

In Bihar, the area under makhana cultivation is about 13,000 hectares, contributing to 85 per cent of India's total production. Major producing districts include Darbhanga, Sitamarhi, Madhubani, Saharsa, Supaul, Araria, Kishanganj, Purnia, and Katihar. Darbhanga and Madhubani districts alone account for approximately 80 per cent of the processed Makhana production (Ahmad, 2020).

The adoption of improved technology for makhana cultivation in Bihar is low due to several factors. Primary among these is the small size and fragmentation of land holdings, which pose significant constraints to the adoption of modern horticultural technology (Singh et al., 2015). Additionally, the limited access to water resources, quality inputs, and credit for sub-marginal and marginal farmers further restricts the use of advanced technologies. Despite the presence of agricultural extension institutions like ATMA (Agricultural Technology Management Agency) and KVK (Krishi Vigyan Kendra), their outreach is limited, and they face challenges such as inadequate staff and infrequent supervision (Singh et al., 2015). The main objective of study was to find the knowledge gap and extent of adoption in improved makhana cultivation practices.

METHODOLOGY

The state of Bihar consists of a total of 38 districts. The present study was conducted in Bihar across four leading districts of makhana cultivation during 2022-24. Purnea, Katihar, Darbhanga, and Madhubani districts were purposively selected for the study because they are important districts for Makhana production. According to the Government of Bihar (2022), Purnea has a total area of 5549 hectares dedicated to makhana cultivation, resulting in a production of 11652.9 tons. In comparison, Katihar, Darbhanga and Madhubani has an area of 6143, 3534, 3467 hectares respectively under makhana cultivation, which yields a production of 12900.3, 7421.4, 7280.7 tons respectively. The study specifically examined the regions of Purnea East in Purnia, Barari in Katihar, Bahadurpur in Darbhanga, and Jhanjharpur in Madhubani. Two villages with higher productivity in makhana farming were deliberately chosen from each block, resulting in selection of eight villages. A thorough compilation of all households in these villages engaged in makhana cultivation was carried out, and 120 makhana growers were selected through random sampling. Primary data were acquired with help of a pre-tested structured interview schedule developed specifically for the study and direct observation methods. Secondary data were obtained from the official records of government, and gram panchayats. The interview schedule included 11 components and 24 issues with regards to improved makhana farming techniques which were used to evaluate the participants' knowledge. The scoring system for knowledge was as follows: full knowledge (2 points), medium knowledge (1 point) and no knowledge (0 point). The adoption level was also assessed for 11 aspects and 24 issues, using a scoring system of fully adopted (2 points), partially adopted (1 point), and not adopted (0 point). The highest attainable score for both knowledge and adoption was 48. A knowledge gap and adoption index was developed.

$$\text{Knowledge gap index} = \frac{\text{Total achievable score - Total score achieved}}{\text{Total achievable score}} \times 100$$

$$\text{Adoption index} = \frac{\text{Total score achieved}}{\text{Total achievable score}} \times 100$$

The respondents were classified into three groups, viz., low, medium and high based on their scores of mean and standard deviation. The study also examined the association between socio-economic status and levels of knowledge and adoption using Pearson correlation analysis. Path analysis, a precursor to and subset of structural equation modeling, was used to discern and assess the effects of a set of variables acting on technology adoption via multiple causal pathways. Data were subjected to path analysis in order to identify the potent variables and mechanism of influencing the adoption of improved makhana cultivation technology.

RESULTS

The data revealed that knowledge gap of makhana growers were manifested in eleven distinct aspects of improved makhana cultivation technology. It was revealed from Table 1 that with respect to plant protection including pest and disease management practices, the mean knowledge gap was 61.88 per cent. Further, the respondents didn't have adequate knowledge regarding soil characteristics with a special focus on appropriate soil types, and 60.84 per cent knowledge gap was observed in this aspect.

The mean knowledge gap on pond construction was found to be 60.14, followed by recommended seed rate and sowing time as 53 per cent. The mean knowledge gap on recommended varieties of makhana *viz.,* Swarna Videhi and Sabour Makhana-1, was found to be 52.09 per cent, followed by 51.67 per cent on seed yield, 43.71 per cent on marketing of makhana products, 42.50 per cent on recommended practice of harvesting, 37.23 per cent in case of weed control and 28.34 per cent on appropriate use and recommended doses of manures and fertilizers.

Farmers were classified according to their overall knowledge and adoption levels with respect to recommended makhana cultivation technology. Table 2 revealed that the mean knowledge index of farmers was 24.10 with a standard deviation of 3.97. Based on the overall knowledge score, 75.00 per cent of the respondents were classified under moderate knowledge level category. The mean adoption index was 19.33 with a standard deviation of 3.26. The study exhibited that 64.16 per cent of respondents had a moderate level of adoption meanwhile 15 per cent of them demonstrated a low level of technology adoption.

Table 3 exhibited the association of selected independent variables with the dependent variables Knowledge and technology adoption of farmers with respect to recommended makhana cultivation technology. It was revealed that the variables viz., family size and experience in makhana cultivation had positive and significant correlation with knowledge level at 5% level of probability whereas, scientific orientation had positive and

Table 1. Knowledge gap of farmers on improved makhana cultivation technology

S. No.	Aspects along with recommended practices of makhana cultivation	Knowledge level			Knowledge Gap (%)
		Full (%)	Partial (%)	No knowledge (%)	
1.	Soil				
	(i) Soil Quality	19.17	80.83	0.00	60.84[II]
	(ii) Type of Soil	0.00	0.00	100.00	
	(iii) Water holding Capacity of Soil	15.84	84.16	0.00	
2.	Pond construction				
	(i) Water capacity of Pond/field	10.83	89.13	0.00	60.14[III]
	(ii) Shape of Pond/field	10.00	90.00	0.00	
	(iii) Slope of Pond/ Field	1.66	15.00	83.33	
3.	Varieties				
	(i) Improved Varieties	5.83	89.16	5.00	52.09
	(ii) Seed Quality	3.33	84.16	12.50	
4.	Sowing				
	(i) Sowing Time	91.66	8.34	0.00	28.34
	(ii) Transplanting time	3.33	88.33	8.33	
5.	Seed rate				
	(i) Recommended seed rate	0.00	83.33	16.66	53.00
6.	Nutrient management				
	(i) Kind of fertilizer	5.83	51.66	42.50	53.47
	(ii) Manure and fertilizer dose	10.00	84.16	5.83	
	(iii) Quantity of manure	16.66	78.33	5.00	
7.	Weed management				
	(i) Types of weeds	90.00	10.00	0.00	37.23
	(ii) Method of weed treatment	8.33	66.66	25.00	
	(iii) Chemicals used	3.34	96.66	0.00	
8.	Disease and pest management				
	(i) Disease and pest name	19.16	80.83	0.00	61.88[I]
	(ii) Chemicals used	10.00	13.33	76.67	
9.	Harvesting of Makhana				
	(i) Ideal time for harvesting	13.33	85.83	0.00	42.50
	(ii) Method of harvesting	16.66	83.33	0.00	
10.	Yield of Makhana				
	(i) Potential yield	7.50	81.66	10.84	51.67
11.	Marketing of seeds				
	(i) Place to sell makhana seeds	11.67	88.33	0.00	43.71
	(ii) Marketing grade of Makhana pop	17.50	82.50	0.00	

Table 2. Knowledge and adoption level of farmers with respect to recommended makhana cultivation technology

S. No.	Categories	Knowledge			Adoption		
		Percentage	*Mean#	SD	Percentage	*Mean#	SD
1.	Low level (<mean – SD)	10			15		
2.	Medium level (mean – SD to mean + SD)	75	24.10	3.97	64.16	19.33	3.26
3.	High level (>mean + SD)	14.16			20.83		

significant association with technology adoption at 5% level of probability.

It was further revealed that variables viz., Land holding under makhana cultivation, annual income, income from makhana and training exposure had positive and highly significant association with knowledge level as well as technology adoption at 1% level of probability.

Path analysis was used to discern and assess the effects of a set of variables acting on technology adoption via multiple causal pathways. Table 4 revealed that the direct and indirect effects of each variable on adoption level of recommended makhana cultivation technology. It was found that income from makhana exerted maximum direct effect (-3.833) in negative direction. However, size of land under makhana cultivation exerted maximum direct effect (3.107) on technology adoption followed by annual income (1.238) in positive direction.

It was further revealed that the variable Annual income exerted maximum indirect effect (-3.82) in negative direction on adoption level and it was routed through income from makhana, size of land holding under makhana and knowledge.

Table 3. Relationship between independent variables and the dependent variables

Independent Variables	Knowledge 'r'	Adoption 'r'
Age	0.078	0.077
Gender	-0.123	-0.050
Marital status	-0.076	-0.076
Family size	0.217*	0.115
Education	-0.019	0.005
Experience	0.228*	0.055
Size of land holding under Makhana	0.440**	0.506**
Annual income	0.424**	0.495**
Income from Makhana	0.404**	0.484**
Attitude	0.062	0.105
Scientific Orientation	0.055	0.375**
Training exposure	0.370**	0.260**

* - Significant at 5 % level of probability, ** - Significant at 1 % level of probability

DISCUSSION

It was evident that makhana growers had the highest gap in mean knowledge with respect to disease and pest management practices. It was characteristic to note the prevalence of pests like singhara beetle, aphids, caseworms, fruit borer, root borer and fruit rot and some fungal diseases like leaf blight as new occurrences in makhana but most of the farmers were ignorant about their control methods. This result was in consonance with the findings of Toure et al., (2023); Roy & Bandyopadhyay (2019), which indicated that due to lack of knowledge about management practices, extensive extension works were needed to raise awareness of disease and pests of crops while seeking effective control strategies. The finding was further supported by Bhagat et al., (2002) & Assgba et al., (2015) who reported the presence of various diseases of which the most important were viruses, and leaf and petiole yellowing. However, findings of Kumar & Jahanara (2021) emphasized that farmer's knowledge related to disease and pest control increases by imparting trainings and other capacity building programmes. The knowledge gap exceeded 50 per cent in other important technical domains as well like suitable soil with adequate water holding capacity, modern methods of pond preparation, recommended seed rate, sowing time as well as recommended varieties. These findings are supported by several studies highlighting significant gaps in farmers' knowledge and adoption of best practices in these areas. Gap in Knowledge and technology adoption can be abridged by capacity building of farmers and associated stakeholders, public–private partnerships, and actors within the value chain. There should be a provision of technical guidance, establishment of market connections, and training programs. The interventions can be reinforced through on-farm demonstrations and use of information and communication technology (ICT) tools.

Liu et al., (2022) reported that participation in technical training can significantly enhance the probability of the adoption of improved farm technologies. The study revealed that most of the farmers had moderate level of knowledge with respect to recommended technology of makhana cultivation. Similar findings were reported by Kumar & Kumar (2021); Manoj et al., (2024); Moulasab & Sudhakara (2017). Lairenjam & Bose (2024) reported that farmers have limited formal education, which can affect their capacity to understand and implement advanced agricultural technologies. This educational gap contributes to a moderate level of knowledge regarding recommended practices. Farmers also often lack regular interaction with agricultural extension services, which are crucial for disseminating updated cultivation practices. This limited access hindered their ability to acquire comprehensive knowledge about recommended technologies of makhana. The relationship between land holding size and adoption of recommended makhana cultivation technology was positively correlated, suggesting that larger land holdings may facilitate the adoption of makhana cultivation practices. This could be due to the fact that larger landowners have more resources and space to diversify their crops and experiment with makhana cultivation, which is a cash crop providing significant economic benefits (Ahmad, 2020; Kumar et al., 2021).

Higher income levels were linked to greater knowledge of recommended cultivation practices, indicating that wealthier farmers might have better access to information about new technologies. Training exposure had positive and significant association with knowledge and technology adoption of farmers. Participation in training programs enhances farmers' knowledge and adoption of

Table 4. Path analysis of independent variables with adoption of recommended makhana cultivation technology

Variables	Direct effect	Indirect effect	Substantial indirect effect through single variables		
			I	II	II
Age (X1)	-0.1311	-1.4107	-0.098(X6)	-0.049(X7)	-0.047(X8)
Gender (X2)	-0.0012	0.1165	0.009(X5)	0.008(X1)	0.007(X6)
Marital status (X3)	-0.0221	-0.1886	-0.008(X6)	-0.006(X1)	-0.004(X5)
Family size (X4)	-0.0711	-0.7780	-0.022(X1)	-0.150(X7)	-0.14(X6)
Education (X5)	-0.0610	0.5433	-0.017(X1)	0.0116(6)	0.011(X3)
Experience (X6)	0.0222	-0.8819	0.016(X1)	0.008(X3)	0.005(X7)
Size of land holding under Makhana (X7)	3.1078	-3.8187	3.095(X9)	3.091(X8)	1.362(X13)
Annual income (X8)	1.2389	-3.8236	1.23(X9)	1.24(X7)	0.521(X13)
Income from Makhana (X9)	-3.8337	3.0957	-3.82(X8)	-3.817(X7)	-1.613(X13)
Attitude level (X10)	-0.0547	-0.3633	-0.020(X11)	-0.011(X6)	-0.007(X1)
Scientific orientation (X11)	0.3443	-0.3365	0.0131(X10)	0.131(X6)	-0.570(X3)
Training exposure (X12)	-0.0991	-1.3144	-0.035(X7)	-0.034(X8)	-0.032(X13)
Knowledge (X13)	0.1406	-1.6134	0.061(X7)	0.059(X8)	0.051(X9)

recommended practices (Lairenjam & Bose, 2024). High negative direct effect of income from makhana on the adoption level indicated that as income increased, the likelihood of adopting new practices significantly decreased. This relationship might be explained by various factors. Initially, farmers with a high income from makhana believed to be confident in their existing practices and perceived no necessity for adopting new technologies, considering such adoption not rewarding or possibly risky. Furthermore, successful farmers might have thoroughly assessed the cost-benefit ratio of adoption and determined that the marginal benefits exceeded the corresponding costs in terms of time, resources, or effort as reported by Ahamad (2020); Ali & Karim (2009). High-income farmers also appeared to lack the urgency to improve productivity further, as they were already earning well through traditional methods. This sense of complacency contrasted with low-income farmers, who viewed adoption as essential for improving their livelihoods. Furthermore, wealthier farmers might have resisted change due to cultural or social preferences, fearing disruptions to their successful traditional practices. They might have diversified into other income sources or prioritized investments outside agriculture rather than adopting innovations in makhana farming.

Size of land under makhana cultivation exerted maximum direct effect on technology adoption in positive direction. Larger land sizes positively affect farmers' technology adoption behavior, suggesting that farmers with more extensive landholdings are more inclined to implement integrated land management technologies as reported by Haile et al., (2024).

It was found that a significant proportion of respondents exhibited a medium level of adoption of recommended makhana cultivation technology. This could imply that medium-level adoption across different agricultural sectors may be attributed to factors such as limited educational levels, economic motivations, and access to technology and information as reported by Nain & Bhagat (2005); Nain et al., (2013); Ghaghas et al., (2017); Mariyappan et al., (2018); Melkeri (2018); Sathisha et al., (2018); Antim et al., (2022); Wasu et al., (2022); Khawale & Chinchmalatpure (2023); Kumari & Mazhar (2023); Sangeetha et al., (2023); Pongener & Jha (2024); Thangjam et al., (2024). Many farmers continue to depend on traditional methods passed down through generations. This reliance can impede the adoption of new technologies, as traditional practices may not align with current recommendations (Kumar et al., 2020).

CONCLUSION

Knowledge and adoption of recommended technologies in makhana cultivation play a pivotal role in enhancing both the productivity and profitability of farmers. Empowering farmers with adequate knowledge through targeted capacity-building programs, need based training programmes, is essential for bridging the existing knowledge gap. Encouraging the adoption of innovative and scientifically backed practices, such as improved seed varieties, modern pond preparation techniques, and efficient post-harvest management, will significantly boost yields and economic returns. A comprehensive strategy that integrates farmer-centric extension services, market linkages, and support for smallholder farmers is crucial to achieving sustainable growth in makhana cultivation. By focusing on these aspects, policymakers, researchers, and agricultural stakeholders can ensure that farmers maximize their potential and contribute to the overall development of the makhana industry.

Author contributions

Conceptualization of research (KKJ, KS); Designing of the experiments (KKJ, KS); Contribution of experimental materials (KKJ, KS); Execution of field survey and data collection (KS); Analysis of data and interpretation (KS); Preparation of manuscript (KKJ, KS).

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