Scholars Journal of Agriculture and Veterinary Sciences OPEN ACCESS
Abbreviated Key Title: Sch J Agric Vet Sci
ISSN 2348–8883 (Print) | ISSN 2348–1854 (Online)
Journal homepage: www.saspublishers.com

Integrated Makhana - Fish Aquaculture: A Sustainable Approach for Poverty Alleviation and Livelihood in the Rural Areas of North-Eastern Bihar

Meenu Sodi[1], Sanjib Kumar[2*]

[1]Research Scholar, B.S.S. College, Supaul-852131, Bihar, India
[2]Prof. of Botany and Principal, B.S.S. College, Supaul-852131, Bihar, India

***Corresponding author:** Sanjib Kumar
| **Received:** 10.04.2019 | **Accepted:** 15.04.2019 | **Published:** 30.04.2019
DOI: 10.36347/sjavs.2019.v06i04.001

Abstract **Original Research Article**

The northern part of Bihar has a myriad of scattered ponds and tanks mainly formed by hundreds of rivers and rivulets finally discharging into Koshi, Mahananda and the mighty river Ganga. The scattered and isolated water bodies are suitable for culturing aquatic organisms of high economic values under controlled and semicontrolled conditions. These aquatic bodies can profitably be managed for fish culture as well as cultivating water-fruits like makhana (*Euryale ferox* Salsb). and water chestnut (*Trapa natans var. bispinosa*)Roxb. Makino which are of high nutritive values and relished by the people of India and abroad too. On account of being fatless, aphrodisiac, spermatogenic and high carbohydrate and protein content makhana is in high demand in western and gulf countries. The cultivation of makhana is an age-old practice. It is an important source of income for poor fishermen in N-E Bihar. Out of total makhana produced in India, more than 80% is produced in Bihar. Purnea, Koshi and Darbhanga divisions of north Bihar are the major areas of its cultivation. The fishing community commonly called mallah, use to cultivate this water fruits as one of the cash crops in Katihar District. They have developed the expertise of its cultivation as well as its intricate harvest and post-harvest operations over generations. Majority of the farmers are cultivating makhana as the monocrop. After harvesting of the makhana crop some air breathing catfishes like mangur, singhi, kawai, garai, souri, gainchi etc. generally get access and enter through the paddy fields in the ponds and tanks. These fishes are also being harvested by the farmers as an additional animal crop without introducing the seeds of these fishes. However, some of the local farmers are also cultivating makhana along with fish culture. In the present investigation the control pond (C) yielded 4.72 tons of carp fishes per hectare whereas the experimental pond of makhana-fish integrated aquaculture covering the same area produced 5.26 tons of carp fishes, 0.23ton of wild fishes and 1.55 tons of makhana. Net profit was estimated to be Rs.59739/ha from sole makhana culture, Rs. 259195/ha from sole carp culture in non-integrated pond and Rs.329801/ha in integrated makhana-carp fishes aquaculture. Thus makhana aquaculture integrated with carp fishes can provide an additional food and major income to growers as a solution of poverty alleviation and livelihood security to the economically and nutritionally backward rural areas of Bihar.

Keywords: Integrated aquaculture, makhana, fish, North Bihar, livelihood security.

INTRODUCTION

Euryale ferox Salisb. (common name makhana/foxnut/gorgon nut/prickly waterlily) is an important wetland macrophyte which grows naturally in wild form or cultivated in ponds, low land stagnant waters etc. It belongs to the family Nymphaeaceae. Makhana is one of the important underutilized aquatic food crops next to deep-water rice and water chestnut [1]. The plant is widely prevalent in tropical and subtropical regions accomplished with humid to subhumid environment and mainly cultivated as a source of starch and protein [2, 3].

Makhana is a forced annual plant and aquatic bio-resource of India. Its cultivation is more pronounced in north- eastern part, particularly in North Bihar, where 80% of India's total production occurs [4, 5]. Makhana pop production in state is estimated to be around 20,000 MT with major producing districts being Darbhanga, Madhubani, Purnea and Katihar. The region of North Bihar has 2,69,418 ha area under wetlands, comprising an average of 4.96% of its total geographical area. In Bihar district Madhubani occupies the highest share of total production of makhana pop, which contributes about 20% of total production in state *i.e.*3000 MT followed by Katihar which accounts for 18%, Darbhanga, Purnea and others [6]. Katihar district has a maximum of 21,011 ha wetland area *i.e.*

about 10.30% of the geographical area of the district [7]. This district is known to produce good quality of makhana seeds [1] and the seeds of this district have the maximum sprouting capacity [8]. Makhana cultivation is done in the stagnant water bodies as well as in field conditions. Recently makhana-fish integrated crop farming is gaining popularity in N-E Bihar due to its high economic benefit.

Integration farming means mixed farming. In this complementary farming one practice does not affect another and yet both practices benefit mutually. Makhana and fish farming is eco-friendly integration in freshwater ponds. Proper scientific management offers immense scope for integrated fish farming attendants along with social, economic and ecological benefits [9]. It is an improved production systems which assures more return from water body then from cultivation of makhana. Farmers can get their income up to six times more by growing these two aquaculture crops simultaneously. Apart from revenues both these crops complement each other perfectly. Fish keeps makhana crop safe from pests while post-harvest of makhana the left behind leaves and stalks of the plant decomposes naturally and turns into organic matter that enhance the nutrient content in the water important for growth of the fish [10]. It offers greater efficiency in resource utilization and reduces risk by crop diversification. This also provides additional food and income to growers. Makhana system can be harnessed for integrated aquaculture with carp as well as air breathing catfishes [11, 12]. There has been an increasing awareness for harnessing their productivity at an optimum level under concurrent and rotational methods of integrated aquaculture with carp fishes as well. Presently makhana is being grown commercially only in approximately 13000 ha with approximately seed field of about 21000 tonnes in Darbhanga, Sitamarhi, Madhubani, Saharsa, Supual, Araria, Purnia and Katihar District of Bihar [13]. Hence, it was thought necessary to study the existing makhana and fish aquaculture integration, the possibility to increase their production and to find out whether they can profitably be used for poverty alleviation and livelihood in the rural areas of north – eastern Bihar.

MATERIALS AND METHODS

A detailed survey was conducted during 2012-15 in makhana cultivated fields/ponds situated in wetland areas of different blocks of Katihar district of Bihar. The survey involved methods of observations, interactions, interviews along with individual and group discussions to identify major cluster producing makhana and existing cultivation system and processing operation including integrated farming. The study was undertaken in two pond systems. The data was collected from selected farmers with the help of interview schedules. Focus group discussions were undertaken in makhana growing areas of Katihar district and interactions were made with fishermen, farmers & other various stakeholders including Department of Fisheries, Research Institutions, processing units etc. in order to get firsthand information.

For the purpose of integrated makhana-fish aquaculture Gorgamma pond (area about 2.5 ha) of Barari block of Katihar district was selected. From this pond an area of 1 ha was separated with help of bamboo nets. Now this area of 1 ha was divided into two equal parts with the help of bamboo nets. One part was selected as control plot (C) and other as experimental plot (E) having an equal area of 0.5 ha each. The control plot was used for rearing carp fishes only where as in experimental plot carp fishes were cultivated along with makhan from July to the end of December for 3 consecutive years *i.e.* 2012 – 13, 2013-14 and 2014 - 15. In this pond air-breathing fishes Mangur (*Claris batrachus*) Singhi **(***Heteropneustus fossilis*), Garai (*Channa lucius*), Sauri (*Channa striata*), Bhora (*Channa marulius*) and Tengara (*Mystus tengara*) generally get access and enter through the paddy fields in the pond. They are also being harvested by the farmers as an additional animal crop. After harvesting the makhana seeds by scanning the bottom mud, 3000 fingerlings consisting of Mrigal (*Cirrhinus mrigala*), Grass carp (*Ctenopharyngodon idella*), Silver carp (*Hypophthalmichthys molitrix*), Common carp (*Cyprinus carpio*), Rohu (*Labeo rohita*) and Catla (*Catla catla*) were stocked both in control and experimental plots separately in the ratio of 10:10:20:20:20:20. At monthly intervals increase in length and weight of stocked fish species were measured. After 6 months of stocking, fry / fingerlings usually grow up to juvenile stage and they were harvested by the end of December or first half of January. The weight of each fish species was taken separately.

After harvesting of crap fishes, makhana plants of experimental plot were uprooted in the month of March and were transplanted to all over the available water space with a gap of 1m X 1m between two plants. Before transplanting all the seedlings were treated with fungicides 0.2% Bavistin + 0.1% Companion by dipping the seedling roots in the solution for 6-8 hours. This reduces the effect of fungi in the field condition. These makhana seedlings grew in January-February due to sprouting of abandoned makhana seeds of preceding crop lying at the bottom of the pond *i.e.* autoseeding. In the experimental plot about 10% of the total spaces were left vacant (50m x 10m) in the centre with the help of bamboo poles [14] to prevent the sprawling makhana leaves from occupying the vacant spaces in the middle. This also facilitated the solar radiation to fully penetrate inside the water body. The central vacant space also provides proper oxygenation and proper growth of fishes [5]. After 15-20 days of transplantation a mixture of DAP + Potash + Zyme + Urea was added @ 50kg/ha in the experimental plot. The makhana leaves were also washed with water to prevent the damage caused by

urea and potash. Boiled neem water was also used in place of insecticide so that it would not harm fishes. Additionally micronutrients were also used in the flowering stage.

Chemical Composition of Micronutrients		
Zn (Inorganic) : 5.0%	Mn : 02%	N : 1.0%
Zn (Chelated) : 3.0%	Cu : 0.5%	P2O5 : 0.5%
Fe (Chelated) : 0.5%	B : 0.5%	K_2 : 0.5%
Mo : 0.02%		
Extra: Mg, Ca, S.		

Before harvesting the makhana seeds the leaves of makhana plants were cut from the petiolar region with help of sickles by the end of June. The cutted leaves were kept inverted towards the margin of pond to get them decayed. The makhana seeds were finally lifted with the help of sieve like containers locally called polo or gaanj by the skilled labours that made numerous drives to collect the seeds from the bottom of the pond. After harvesting of makhana seeds in July, the carp fishes were allowed to grow further till the catching during the end of December - mid January. Usually air breathing fishes feed on rotten makhana leaves but for carp fishes rotten cowdung, mustard cake, rice bran and rotten mahua cake were used to feed through bag method of feeding.

RESULTS AND DISCUSSION

Production of Makhana: The total area under makhana cultivation in Govt. lease ponds in Katihar district is 1841.84 ha (District Fishery Department, Katihar). Total yield of makhana seeds in Katihar district was recorded to be 1.63, 1.44 and 1.57 t/ha in three consecutive years with an average production of about 1.55 t/ha/yr (Table 1). However, Dehadrai [15], Verma *et al*. [14] and Singh *et al*. [5] have reported 320 kg/ha, 1400 kg/ha and 1600-1700 kg/ha production of makhana seeds respectively from the makhana cultivated ponds. According to Pramanik *et al*. [1] the wetlands of Katihar district are very suitable for the cultivation of makhana as it produces good quality of makhana seeds which have the yield potentiality up to with a maximum production of 3.0 t/ha and the harvesting duration is about 240-250 days. Farmers usually sold these makhana seeds to businessmen @ 50-55/kg who used to prepare makhana pops through the skilled labourers on contract basis. The yield of the pop is around 30-35% of the seed's production. Out of 3-3.5 kg of makhana seeds these skilled labourers used to prepare 1kg of makhana pops after processing. Kumar [16] has also reported the production of 35 kg of pops from 100 kg of makhana nuts. The businessmen usually used to purchase makhana pops @ Rs.160-200/kg from the skilled labourers which was sold in the market @Rs.200-250/kg.

Plate 1: Integrated Makhana-Fish Aquaculture in Katihar District

Fig-1: Makhana leaves floating on pond

Fig-2: Flower of makhana

Fig-3: Farmer sprinkling fertilizer in makhana field

Fig-4: Experimental pond showing central vacant space encircled with bamboo poles

Fig-5: Fishes in the net from Makhana cultivated pond

Fig-6: Farmer harvesting Makhana seeds from Makhana cultivated pond

Table-1: Net Income of Makhana Cultivation as Monocrop from Ponds (natural condition) in Katihar District

Year	Area Cultivated in ha	Total Cost in Cultivation/ha	Total Income of Makhana Seeds after Selling/ha	Net Income/ha	Production of makhana seeds ton/ha
2012-13	1841.84	Rs.18425	Rs.81500	Rs.63075	1.63
2013-14	1841.84	Rs.19678	Rs.72000	Rs.52322	1.44
2014-15	1841.84	Rs.22530	Rs.86350	Rs.63820	1.57
Average	1841.84	Rs.20211	Rs.79950	Rs.59739	1.55

Table-2: Income from Wild Fishes Naturally Grown in Makhana Ponds in Katihar District

Year	Area Cultivated in ha	Total cost in fish culture/ha	Total income after selling of air breathing fishes/ha	Net Income/ha	Production of wild fishes ton/ha
2012-13	1841.84	Rs.4300	Rs.13000	Rs.8700	0.18
2013-14	1841.84	Rs.4400	Rs.14500	Rs.10100	0.29
2014-15	1841.84	Rs.4300	Rs.15600	Rs.11300	0.22
Average	1841.84	Rs.4333	Rs.14367	Rs.10033	0.23

Table-3: Production of Carp Fishes in Control (C) and Experimental (E) Ponds (Area: ~0.5 ha each) in 2012 -13

S. N.	Name of Fish Species	No. of Fish Stocked		No. of Fish Harvested		Initial Wt. of Fish (gm.)		Final Wt. of Fish (gm.)		Growth Increment of fish (gm.)		Production of fish (Kg.)	
		C	E	C	E	C	E	C	E	C	E	C	E
1	Rohu (10%)	300	300	269	263	19.62	19.62	523	552	503	532	135	140
2	Catla (10%)	300	300	268	278	18.35	18.35	624	648	606	630	162	175
3	Silver carp (20%)	600	600	578	580	20.20	20.20	834	868	814	848	470	492
4	Mrigal (20%)	600	600	564	582	23.64	23.64	885	925	861	901	486	524
5	Common carp (20%)	600	600	576	588	23.43	23.43	1045	1298	1022	1275	589	749
6	Grass carp (20%)	600	600	578	586	20.85	20.85	955	1036	934	1015	540	595
	Total 100	3000	3000	2833	2877	126.1	126.1	4866	5327	4740	5201	2382	2675

Table-4: Production of Carp Fishes in Control (C) and Experimental (E) Ponds (Area: ~0.5 ha each) in 2013-14

S.N.	Name of Fish Species	No. of Fish Stocked		No. of Fish Harvested		Initial Wt. of Fish (gm.)		Final Wt. of Fish (gm.)		Growth Increment of fish (gm.)		Production of fish (Kg.)	
		C	E	C	E	C	E	C	E	C	E	C	E
1	Rohu (10%)	300	300	256	265	18.48	18.48	503	532	484	513	124	136
2	Catla (10%)	300	300	264	278	18.25	18.25	584	638	566	620	149	172
3	Silver carp (20%)	600	600	558	567	16.80	16.80	734	786	717	769	400	436
4	Mrigal (20%)	600	600	574	572	22.59	22.59	835	865	812	842	466	482
5	Common carp(20%)	600	600	562	588	24.13	24.13	945	1098	921	1074	518	631
6	Grass carp (20%)	600	600	566	582	19.92	19.92	948	996	928	976	525	568
Total	100	3000	3000	2780	2852	120.2	120.2	4549	4915	4428	4794	2182	2425

Table-5: Production of Carp Fishes in Control (C) and Experimental (E) Ponds (Area: ~0.5 ha each) in 2014-15

S. N.	Name of Fish Species	No. of Fish Stocked		No. of Fish Harvested		Initial Wt. of Fish (gm.)		Final Wt. of Fish (gm.)		Growth Increment of fish (gm.)		Production of fish (kg.)	
		C	E	C	E	C	E	C	E	C	E	C	E
1	Rohu (10%)	300	300	258	266	19.00	19.00	483	516	464	497	120	132
2	Catla (10%)	300	300	256	272	17.25	17.25	624	678	607	661	155	180
3	Silver carp (20%)	600	600	564	579	18.00	18.00	838	916	820	898	462	520
4	Mrigal (20%)	600	600	568	578	24.70	24.70	965	1015	940	990	534	572
5	Common carp(20%)	600	600	576	590	22.63	22.63	1145	1326	1122	1303	646	769
6	Grass carp (20%)	600	600	572	584	21.85	21.85	1068	1136	1046	1114	598	650
Total	100	3000	3000	2794	2869	123.4	123.4	5123	5587	4999	5463	2515	2823

Table-6: Net Income from Carp Fish Culture in Control Pond

Year	Area Cultivated	Production of Fish	Expenditure (Rs.) a. Water filling & cleaning b. Fingerlings cost c. Feeding d. Guards e. Lease f. Netting* etc.	Total Cost (a+b+c+d+e+f)	Total Gross Profit	Net Profit
2012-13	0.5 ha	2.4 ton	a. Rs.2200 b. Rs.9200 c. Rs.2800 d. Rs.30000 e. Rs.5000 f. Rs.48980	Rs.106180	Rs.216000 @Rs.90/kg	Rs.109820 =Rs.219640/ha
2013-14	0.5 ha	2.2 ton	a. Rs.1800 b. Rs.9700 c. Rs.3100 d. Rs.36000 e. Rs.5000 f. Rs.49377	Rs.103977	Rs.220000 @Rs. 100/kg	Rs.116023 =Rs.232046/ha
2014-15	0.5 ha	2.5 ton	a. Rs.2500 b. Rs.10200 c. Rs.3500 d. Rs.36000 e. Rs.5000 f. Rs.51100	Rs.108300	Rs.250000 @100/kg	Rs.141700 = Rs.283400/ha
Avr.	0.5 ha	2.36 ton	Rs.106152	Rs.106152	Rs.228666	Rs.122514
Avr.	1.0 ha	4.72 ton	Rs.212304	Rs.212304	Rs.457332	Rs.245028

*Netting includes prestocking and harvesting of fishes

Table-7: Net Income from Carp Fish Culture in Makhana Cultivated Pond

Year	Area Cultivated	Average Production of Fish	Expenditure (Rs.) a. Water filling & cleaning b. Fingerlings cost c. Feeding d.Labour charges* e. Lease f. Netting** etc.	Total Cost (a+b+c+d+e+f)	Total Gross Profit	Net Profit
2012-13	0.5 ha	2.7 ton	a. Rs.2200 b. Rs.9200 c. Rs.1800 d. Rs.58000 e. Rs.5000 f. Rs.48980	Rs.120180	Rs.243000 @Rs.90/kg	Rs.122820 = Rs.245640/ha
2013-14	0.5 ha	2.4 ton	a. Rs. 2300 b. Rs.9700 c. Rs.1800 d. Rs.55000 e. Rs.5000 f. Rs.49377	Rs.123177	Rs.240000 @Rs.100/kg	Rs.116823 =Rs.233646/ha
2014-15	0.5 ha	2.8 ton	a. Rs.2500 b. Rs.10200 c. Rs.2050 d. Rs.60000 e. Rs.5000 f. Rs.51100	Rs.130850	Rs.280000 @100/kg	Rs.149150 =Rs.298300/ha
Avr.	0.5 ha	2.63 ton	Rs.124736	Rs.124736	Rs.254333	Rs.129598
Avr.	1.0 ha	5.26 ton	Rs.249472	Rs.249472	Rs.508666	Rs.259196

*Labour charges include transplantation of makhana, cutting of leaves, harvesting of makhana seeds etc.
**Netting includes prestocking and harvesting of fishes

Table-8: Total Net Income from Integrated Makhana Culture with Wild Fishes & Carp Fishes in Katihar District (/ha/yr)

Year	Total net income from Makhana seeds/ha/yr	Total net income from wild fish/ha/yr	Total net income from carp fish/ha/yr	Total net income/ha/yr
2012 -13	Rs.63075	Rs.8700	Rs.245640	Rs.291119
2013 -14	Rs.52322	Rs.10100	Rs.233646	Rs.278925
2014 -15	Rs.63820	Rs.13800	Rs.298300	Rs.348789
Average	Rs.59739	Rs.10867	Rs.259195	Rs.329801

Production of Wild Fishes

Air breathing fishes thrive well in makhana cultivating ponds because of presence of accessory respiratory organs. The production of wild air breathing fishes in makhana pond was up to 0.18 t/ha in 2012-13, 0.29 t/ha in 2013-14 and 0.22 t/ha in 2014-15 with an average production of 0.23 t/ha/yr only (Table 2). Although Dehadrai [15] recorded a total production of 1200 kg/ha/yr air-breathing wild fishes from swamp. However, Verma *et al*. [17] reported 3600 kg/ha/yr production of air-breathing wild carnivorouan fishes from makhana ponds.

Production of Carp Fishes

Table - 3,4 and 5 show the total production of carp fishes (Rohu and Catla, Silver carp, Mrigal, Common carp and Grass carp) in control and experimental plots for three consecutive years (2012-13, 2013-14 and 2014-15) separately. The average production of carp fishes was recorded as 4.72 t/ha/yr in control pond (Table 6) and 5.26 t/ha/yr in experimental pond(Table-7). However, Verma *et al*. [14] have reported 1.94 t/ha/yr production of carp fishes in control pond and 2.1 t/ha/yr carp fishes in experimental pond in Darbhanga city of north Bihar.

Expenditure - Income Analysis

The expenditure-income analysis of culture of carp fishes for three consecutive years in control and experimental plots are depicted in Table 6 and 7 respectively. The experimental plot exhibited higher input cost due to extra labour charges during post-harvest processing of makhana cultivation. Abandoned makhana seeds on bottom of the pond start sprouting in Dec. – Jan. Hence, due to autoseeding in makhana ponds no expenditure was made to purchase for makhana seeds. Total net profit and average net profit from integrated makhana carp fish aquaculture (makhana + wild fishes + carp fishes) are depicted in Table – 8. Average net profit from this integrated culture was Rs.329801/ha/yr, sole makhana cultivation including wild fishes Rs.70606/ha/yr and

Rs.245028/ha/yr from sole carp fish culture. In previous works Verma *et al*. [17] reported a net profit of Rs.49171/ha/yr from integrated culture of makhana – air breathing fishes. In other findings Verma *et al*. [14] reported a net benefit of Rs.26480 and Rs.41480 from integrated farming in control and experimental ponds respectively. However, Singh *et al*. [5] reported a net profit of Rs.102635/ha/yr from makhana – carp fish combination as compared to Rs.57960/ha from sole makhana cultivation from pond system of Darbhanga district.

Besides government ponds, integrated makhana with fish aquaculture is also done in some private ponds by the farmers of this region. Day by day, this integration is becoming more popular among the farmers because in this type of integration they can take care of both makhana cum fish at the same time and get maximum benefit than that of makhana cultivation or fish culture only. However, makhana cultivation is done in both field cum pond system but integrated farming is done only in pond system of cultivation.

CONCLUSION

The makhana - fish aquaculture is an example of crop diversification and biomass productivity based on the interaction of the naturally occurring trophic chain of food links within the limits of the carrying capacity of the aquatic system. This process utilizes the production of 2 crops at the same time and in the same pond. It is able to raise the economic status of the farmers by not only reducing the risk of failure of makhana or fish but also enhances the productivity of crops. Both the crops support each other in mutual relationship. Decay of the faeces released by the fishes enhances the nutritional status of the pond which supports the growth of the makhana plants. Similarly decay of the makhana plants also enriches the nutritional status of the pond which supports the production of phytoplankton, zooplankton, nematodes, gastropods, insects *etc*. and in turn they become the natural food of the carp fishes. The carp fishes also protect makhana plants by feeding upon the larvae of insect pests like *Elophia* spp., *Plea litruata*, *Galerucella biramica*, *Frankiniela intonsia* and others [18, 19, 14]. In addition makhana plants safeguard the illegal fishing [20], provide habitat and suitable substrata for the growth and reproduction of phytoplankton, zooplankton and periphyton.

Makhana is an important underutilized and underinvestigated crop among the aquatic food crops. Thus makhana cultivation integrated with fish production can play a very important role in the economy of makhana growers of north - eastern Bihar. However, reliable quantitative production and management guidelines are yet to be generated, recorded and disseminated to serve as a baseline for development programme. The establishment of makhana based industries may also prove as a boon to solve the problem of rural unemployment in this district which can be exploited in other districts too.

Acknowledgements

Authors are very much thankful to the Director JRS, Katihar for providing laboratory facilities, DFO Department of Fishery, Katihar and DSO Department of Statistics Katihar, Chairman of Fisherman Cooperative Societies, Korha, Barari and Katihar and Farmer Advisors, Barari for extending helps and some important information in the present research work.

REFERENCES

1. Pramanik BR, Puste AM, Jana K, Banerjee K, Das DK, Dasgupta M. Makhana (Euryale ferox Salisb.)-Cum-fish culture: An integrated management for better yield. Bangladesh Journal of Scientific and Industrial Research. 2013;48(4):281-6.
2. Jha V, Barat GK, Jha UN. Nutritional evaluation of *E. ferox* Salisb (Makhana). J. Food Sci. Technol. 1990.
3. Puste AM. In: *Agronomic Management of Wetland Crops*. Kalyani Publishers, Ludhiana, India. 2004.
4. Misra RL. Gorgon plant: an aquatic ornamental. Indian Horticulture. 1998;42:20-1.
5. Singh IS, Kumar L, Bhatt BP, Thakur AK, Choudhary AK, Kumar A. Integrated Aquaculture with Fox Nut-A Case Study from North Bihar, India. Int. J. Curr. Microbiol. App. Sci. 2017;6(10):4906-12.
6. Udyog Mitra. Businessplan of makhana cluster in Bihar.www.udhyogmitra./asserts/uploads/2012/06/ makhana-report.pdf, 2012.
7. Panigrahy S, Murthy TV, Patel GJ, Suthar NM, Kundu N, Paul M, Basu N. National wetland atlas: Bihar. Space applications centre (ISRO). Ahmedabad and Institute of Environmental Studies and Wetland Management (IESWM), Kolkata. 2010; 222.
8. Sinha KK. Mycotoxin induced physiological responses in crop plants. MD Publications Pvt. Ltd. 1996.
9. Verma AM. Integrated fish farming with makhana (*Euryale ferox*). *Fishing Chimes.* 1994; 14(2):13.
10. Editorial Team. Fishery clinic - specializes in Makhana cum fish farming. *Agriculture Information*. www.agricultureinformation.com. 2017.
11. Jha V, Singh T, Shashi SB. Management strategies in Makhana based integrated aquaculture. Fishing chimes. 2006; 26:16-9.
12. Jha V, Shashi SB, Singh TT, Verma AB. Aquatic biodiversity as a basis for sustainable livelihood. International Journal of Pharmacology & Biological Sciences. 2015 Aug 1;9(2).
13. ICAR. Swarna Vaidehi: The First Makhana Variety of India. *ICAR News* October-December. 2013; 19(4): 22.
14. Verma AM, Jha V, Ahmad SH. Fish-makhana (Euryale salisb) integration: a case study of

sustainable aquafarming system in north Bihar. Journal of the Indian Fisheries Association. 2008; 35:87-96.
15. Dehadrai PV. Annual report on the All India Co-ordinated Research Project on Airbreathing fishes for culture of swamps. In2rid workshop at Patna 1972 Dec (pp. 20-21).
16. Kumar Arvind. Cultivation of makhana, *Euryale ferox* for potential utilization of wetland and its management in north Bihar, India. *Flora and Fauna.* 2017; 23(2): 316-318.
17. Verma AM, Ahmad SH, Jha V. Integrated Culture of air breathing carnivorous fishes with Makhana (Euryale ferox Salisb) in a derelict wetland of North Bihar, India. J. Freshwater Biol. 1996;8(2):117-20.
18. Banerji SR. Infestation of Euryale ferox Salisb by larvae of Nymphula crisonalis Walker and trials on its control. Bombay Natur Hist Soc J. 1972.
19. Mishra RK, Jha BP, Jha V, Singh SK, Mahato A. Insect associations of Euryale ferox Salisb. in the ponds of Darbhanga, North Bihar. Journal of Freshwater Biology. 1992;4(3):199-208.
20. Verma AM. Inland fish culture in Koshi division, North Bihar: Problems and prospects. *J. Freshwater Biol.* 1995; **7**(3): 207-216.