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Research Article

Input based indigenous technical knowledge (ITK) in inland aquaculture of Bankura district, West Bengal

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Abstract

The adoption of indigenous technologies has resulted in the development of sustainable and environmentally-friendly aquaculture practices, and hence helped the farmers to increase aquaculture production. The present study was conducted in five Blocks of Bankura district to document and to find out the genesis and scientific rationale of the natural input-based Indigenous Technical Knowledge (ITK) in the management aspects of fish farming. Practice of 15 natural input based ITKs were documented, with variable degrees of adoption level from one Block to another. 53% of the records are more than 20 years old, and 20% of them are of recent origin, within 10 years. All the documented ITKs were scientifically sound. Most of the ITKs were aimed towards achieving better production performance in hatchery and nursery management of carps. The fitted relationship between average number of ITK adopted and average annual yield has been established as ($y = 0.8722x+1.9192$; $R^2 = 0.86$), whereas, between number of ITK adopted and average fish farming experience of the farmers has been established as ($y = 0.5869x+1.6827$; $R^2 = 0.75$). However, number of ITKs adopted and level of education of the farmers has been established as ($y = -0.2497x^2+1.4027x+2.3056$; $R^2 = 0.6666$).

Key words: Aquaculture, Environmental management, Health management, Indigenous technical knowledge (ITK), Seed production

Highlights

- 15 natural input-based ITKs were documented.
- The ITKs were found with strong scientific rationale.
- ITKs were mostly applied in health management, disease control and hatchery operation.
- Adoption of ITKs directly from the ancestral lineage was found to be highest in Onda Block and lowest in Indpur Block.
- Farmers of the Onda Block were more progressive in adopting ITKs, which resulted in better productivity.

INTRODUCTION

Among the many environmental approaches in the management practices of aquaculture, Indigenous Technical Knowledges (ITKs) bears a strong genesis because of their eco-friendly impacts with limited residual effects and carbon footprints (Singh *et al.*, 2022). In many countries, proper documentation, valorization and adoption of indigenous technologies have resulted in the gradual evolution of sustainable and pro-nature aquaculture practices that helped increase productivity (Edwards, 2009). Indian aqua-farmers, with a rich genesis of traditional knowledge, transformed the farming and fishing techniques through amalgamation of scientific reasoning and hypothesis of using traditional knowledge (Das *et al.*, 2012a; Purkait *et al.*, 2018). Indigenous Technical Knowledge (ITK) remained as an integral facet of the culture and history of a local community (Goswami *et al.*, 2006; Basera, 2016), gradually evolved and refined through the ages of trial and error, with low-cost locally available natural resources in and around the ambience of the community. The

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rapid development of aquaculture up to the industrial scale has resulted from collective approaches and thrusts among farmers and scientists (De Silva and Davy, 2010). The process was continuous and faced both successes and failures. However, indigenous traditional knowledge in different sectors of environment-dependent production systems still needs to be addressed and documented systematically. As a result, they are depleting day by day because of a lack of awareness about their value, impact, and scientific validation as well (Ghosh and Sahoo, 2011).

Presently in Bankura district, the area available for fish farming is 22655 ha, annual fish production is 53450 MT, and annual fish seed production is 9912 million from 330 hatcheries. This district is bestowed with different herbs in the forest-covered areas, endowed with red, alluvial, and laterite soil that contribute a lot to developing Ingenious Technical Knowledge. The district Bankura is situated between 22°38´ and 23°38´ North latitude and between 86°36´ and 87°46´ East longitude. River Damodar flows along the northern boundary of the district. The adjacent districts are Bardhaman in the north, Purulia in the west and Paschim Medinipur in the south. Therefore, the present study aims to document the invaluable nature-based ITKs from the fish farmers of Bankura district, as fish farming with ITKs is highly prevalent among the fish farmers in the said district. As the fish farmers face diverse problems in the scientific management of disease, hatchery operation and environmental management of the culture ponds, the present study on ameliorating such problems with ITKs by the farmers felt judicious.

MATERIALS AND METHODS

Bankura district was purposively selected as freshwater aquaculture practice is highly popular and diverse in this district of West Bengal. Bankura district has also become renowned as a fish seed hub for quality carp seed production. Out of the 22 administrative Blocks in Bankura district, 5 Blocks were purposively selected, viz. Indas (A), Patrasayer (B), Taldangra (C), Onda (D), and Indpur (E) because of their ease of connectivity and accessibility. From each Block, 20 farmers were randomly selected without replacement, thereby comprising 100 farmers (N=100). The study duration was from 1st April 2021 to 1st July 2022. The study was executed by collecting primary data directly from the fish farmers to document the prevalence and perception of the ITKs being practiced by the farmers (respondents). Primary data collection was done with the pre-tested, structured interview schedule covering details of input-based ITKs being practiced by the farmers with their perceptive evaluation and rationality, basic socio-economic information, and aquaculture experiences of the farmers (respondents). Water samples from the five farm ponds at each selected Block (N=25) (where input-based ITKs were being practiced) were collected at monthly intervals for primary physicochemical parameters and analyzed following standard methods as described in American Public Health Association (APHA) (1998). Monthly production data of fish were also collected from each of the selected farmers of the respective Blocks.

Data analyses: Block-wise data for each variable were arranged in frequency and percentage. Data on water quality parameters and planktonic profile of each Blocks were subjected to statistical analyses applying ANOVA (MS-EXCEL) followed by DMRT (SPSS) if the variance ratio (F) is significant. The level of significance was accepted at 95% confidence level ($P<0.05$).

RESULTS

ITKs used: Practice of total 15 ITKs were recorded during the present study and categorized into 6 areas of concern as depicted in (Table 1). Farmers used to apply different ITKs in different areas of operation viz. seed production, seed transportation, health management, growth promotion, feeding management, environmental management, and harvesting of fish.

Targeted area and mode of application of ITKs: Majority of the documented ITKs (Table 1, 2) in Bankura district were targeted towards health management and disease control (33%), followed by seed production (20%), environmental management (20%), growth promotion and feeding management (13%), and in seed transportation and harvesting (6.66% each) (Fig. 1). Among the 15 documented ITKs, 66.66% were being applied directly in the pond followed by application as/with feed (13.33%) and heterogeneous mode of application (20%) (Fig. 2).

Time period of ITKs in practice: Among the 15 documented ITKs, 53% have been in practice for more than 20 years; 20% of them appeared recent that have been adopted within last 10 years, and no ITK that has been adopted within last 5 years in Bankura (Fig. 3).

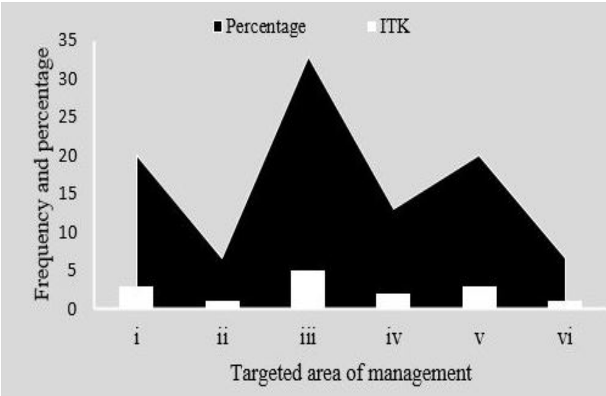


Fig.1. Targeted area of management of different ITKs (i: Seed production, ii: Seed transportation, iii: Health management and disease control, iv: Growth promotion and feeding management, v: Environmental management, vi: Harvesting)

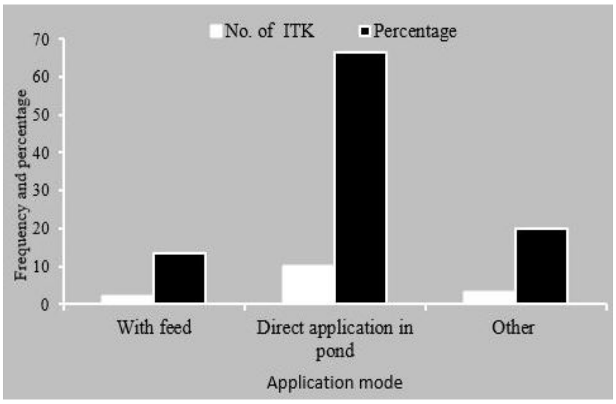


Fig. 2. Mode of application of different ITKs

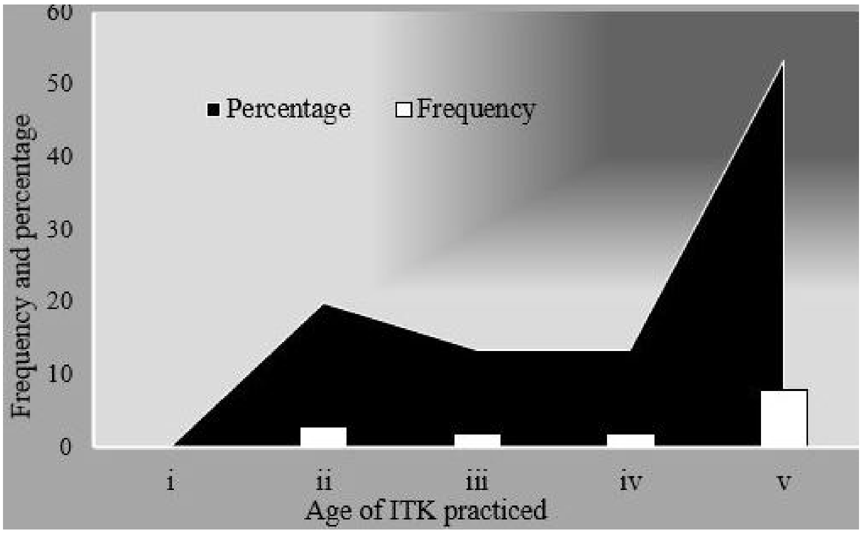


Fig. 3. Age of ITK being practiced in Bankura district. i: Most recent ITKs (up to 5 years), ii: Recent ITKs (up to 10 years), iii: Moderately old ITKs (up to 15 years), iv: Old ITKs (up to 20 years), v: Ancient practice (more than 20 years)

Table 1. Different ITKs documented during the present study under Bankura District, West Bengal

Name of the District- Bankura					
Sl. No.	**Target area**	**ITK practiced**	**Hypothesis and targeted correction/benefits**	**Dosages, frequency and mode of application**	**Farmer's perception**
ITK-1	Seed production	Use of yellow soil/ laterite soil, locally called '*haludmati/ golamati/ rangmati*' in hatchling tank of carp. Practiced since more than 30 years.	To increase survivability of hatchlings in hatchling tank, locally called '*matirhapa*'.	For the tank of 15ft. length and 10 ft. width containing 30 '*bati*'/bowl of hatchlings (1 '*Bankurabati*'= 135 mL), 15 kg yellow soil/laterite soil is required. Mode of application: Direct in the water of hatchling tank.	Reduce mortality of hatchlings.
ITK-2		Use of yellow soil/ laterite soil in hatchery. Practiced since more than 18 years.	To prevent immature birth of carp by making outer membrane of the fertilized egg hard.	Before releasing the fertilized eggs into the incubation pool, 5-6 kg yellow soil/laterite soil is diluted in 10 L freshwater, from this dilution 500-600 mL is added into the aluminium hundi containing 35 L of fertilized eggs to make the outer membrane hard. Mode of application: Direct in the water of hundi containing fertilized egg.	Prevents immature birth of carp in hatchery.
ITK-3		*Use of 'Haritaki'* (*Terminalia chebula*) in hatchery. Practiced since more than 30 years.	To make the egg shell hard, preventing immature hatching of carp.	1.5-2 kg '*Haritaki*' (Terminalia chebula) is soaked overnight in 2 L of water. After boiling, the filtrate is used in the hatching pool for making the egg shell hard of 245-280 L of fertilized eggs. Mode of application: Direct in the water of hatching pool.	Prevents immature release of hatchlings.
ITK-4	Seed transportation	Use of yellow soil/ laterite soil during fish seed transportation.	To facilitate better survivability of spawn by maintaining optimum	Now a day, for long distance transportation, farmers use oxygen packaging in replacement of	Facilitates better survivability of spawn during long

Cont. Table 1

Table 1, Cont. ...

Name of the District- Bankura					
Sl. No.	**Target area**	**ITK practiced**	**Hypothesis and targeted correction/benefits**	**Dosages, frequency and mode of application**	**Farmer's perception**
		Practiced since more than 30 years but modified 10-12 years ago.	temperature and as toxin blocker.	aluminium hundi. They have modified the age old ITK practice of using '*haludmati*' during transportation in just different way. They reuse old 50 kg cement bag to transport one bowl egg (1 '*Bankurabati*'= 135 mL), by covering the inner wall with new plastic packet. The packet is filled with 15 L water, 50 mL of diluted (for making the dilution, 20 to 25 kg yellow soil is soaked overnight in 40 L of fresh water and stirred well) yellow soil is mixed with it, rest portion is filled with oxygen. Mode of application: Direct in the water of the packet for seed transportation.	transportation.
ITK-5	Health management and disease control	Use of neem (*Azadirachta indica*) brunches with leaves in pond. Practiced since more than 20 years.	To reduce the chances of different disease occurrences like '*gutibasanta*' by *Myxobolu* ssp. and ulcer in carp.	28-30 medium brunches of neem with leaves are immersed in one ha pond. Mode of application: Direct into the pond.	Just before winter aforesaid use of neem brunches reduces the chances of disease occurrences during winter.
ITK-6		Use of boiled neem fruit juice in pond. Practiced since more than 7-8 years.	To reduce the chances of different disease occurrence during winter.	500 g neem fruits are boiled in 2 L of water and kept overnight, next day the filtrate is mixed with 3 L of fresh water and spread over 0.13 ha pond area. Mode of application: Direct into the pond.	Use of this preparation along with periodic lime application keeps the pond disease free.

Cont. Table 1

Table 1., Cont. ...

Name of the District- Bankura					
Sl. No.	**Target area**	**ITK practiced**	**Hypothesis and targeted correction/benefits**	**Dosages, frequency and mode of application**	**Farmer's perception**
ITK-7		Use of turmeric *(Curcuma longa* L.*)* powder and tunte ($CuSO_„$) in pond. Practiced since more than 20 years.	To reduce ulcer in carp.	125 g turmeric powder and 225 g $CuSO_4$ is tied with each bamboo pole, 12-14 bamboo poles/ha pond area. Mode of application: Ingredients are tied in a cloth and hung from a bamboo pole buried in pond.	Ulcer starts recovering within seven days.
ITK-8		Use of common salt (NaCl), turmeric *(Curcuma longa* L.*)* powder and $CuSO_4$ during netting. Practiced since more than 20 years.	To reduce ulcer in carp.	10-12 kg common salt (NaCl), 200 g turmeric (*Curcuma longa* L.) powder, 100 g $CuSO_4$ for single netting. Repetition once in 7 days up to 3 times as of necessity. Mode of application: Directly spread on the aggregated fish in one corner of the pond during netting.	Remarkably reduces red scars in carps.
ITK-9		Use of turmeric (*Curcuma longa* L.) powder in feed. Practiced since more than 15 years.	To treat dropsy.	10-12 g turmeric (*Curcuma longa* L.) powder in 1 kg feed for one week. Mode of application: With feed	Along with application of potassium permanganate ($KMnO_4$) 500 g/ha use of turmeric (*Curcuma longa* L.) powder in feed reduces dropsy effectively.
ITK-10	Growth promotion and feeding management	Use of organic juice in carp pond. Practiced since more than 7-8 years.	To enhance growth	For 1 ha pond, 15 kg ground nut oil cake (GOC), 30 kg mustard oil cake (MOC), 8 kg rice flour, 15 kg de oiled rice bran (DORB), 3 kg yeast, 8 kg	Promotes faster growth in carp.

Cont. Table 1

Table 1, Cont. ...

Sl. No.	Target area	ITK practiced	Hypothesis and targeted correction/benefits	Dosages, frequency and mode of application	Farmer's perception
			Name of the District- Bankura		
				molasses, 1 kg mineral is mixed with 80 L of freshwater (72 hrs aerobic fermentation). Application is continued monthly twice. Mode of application: Direct application in pond.	
ITK-11		Use of the liquid mixture of chickpeas, mustard oil and molasses. Practiced since more than 7-8 years.	To promote growth, agility and bright colouration of carp fry.	For the nursery pond having 0.06 ha water area, 1-1.5 m depth, 2 kg chickpeas, 1 kg molasses, 200 mL mustard oil and some fresh water are mixed together and spread into the pond for 6 days after yolk sac absorption. Mode of application: Direct in the water.	Promotes good growth, agility and bright colouration to carp fry.
ITK-12	Environ-mental management	Use of banana trunk in pond. Practiced since more than 30 years.	To control clay turbidity and mitigate oxygen depletion in pond.	18 to 20 banana trunks are used in 1ha pond to control clay turbidity and mitigate oxygen depletion in the pond after sudden rainfall. Mode of application: Direct into the water.	Clears the water, increase oxygen level also reduce the chances of bacterial and parasitic disease outbreak. Reduces toxicity after using chemical herbicide or insecticide in the pond.
ITK-13		Use of black carp, *Mylopharyngodon*	To control fresh water snails	80-90 numbers of black carp, *Mylopharyngodon piceus*is used to	Controls snails effectively.

Cont. Table 1

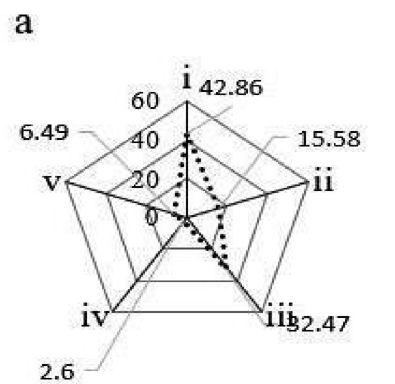
Table 1, Cont. ...

Name of the District- Bankura					
Sl. No.	**Target area**	**ITK practiced**	**Hypothesis and targeted correction/benefits**	**Dosages, frequency and mode of application**	**Farmer's perception**
		piceus in carp culture pond. Practiced since more than 10-12 years.	(Ampu- llariidae).	control snail in 1 ha pond as a biological control measure. Mode of application: Culture along with carp in the pond.	
ITK-14		Use of the brunches of *Semecarpu anacardium* locally called '*bhalai/ bhela*' in pond. Practiced since more than 30 years.	To prevent oxygen depletion in pond by controlling filamentous algal bloom.	For 0.13 ha pond area, freshly cut raw small brunches (6-8 no.) of *Semecarpus anacardium*are tied in a bundle, likewise 5 bundles are immersed in different places of the pond. Mode of application: Direct into the water.	Clears algal bloom within 10-12 hrs.; application of lime is done subsequently.
ITK-15	Harvesting in large water body	Use of herbal mixture as fish attractant. Practiced since more than 30 years.	To increase harvesting yield.	100 g *Ekangi* (*Kaempferia galanga L.*), 150g *kasturi* (*Abelmoschus moschatus*), 4 pieces *jayfol,* 10 g *joyitr*i (*Myristica fragrans*), 25 g *daruchini* (*Cinnamomum verum*), 10 g *elach* (*Elettaria cardamomum*) is mixed with 500 g of roasted mustard oil cake. This kind of mixture attracts fishes when spread into the water during netting. Mode of application: With feed	Increases harvesting yield than usual.

Table 2. Frequency and percentage of the use of different ITKs by the farmers under 5 selected Blocks of the district Bankura, West Bengal

ITK number	Indas		Patrasayer		Taldangra		Onda		Indpur		District Total
	Freq.*	%	Freq.	%	Freq.	%	Freq.	%	Freq.	%	Freq. and %
ITK-1	0	0	3	15	6	30	12	60	0	0	21
ITK-2	0	0	2	10	2	10	4	20	0	0	8
ITK-3	0	0	0	0	1	5	3	15	0	0	4
ITK-4	0	0	3	15	6	30	6	30	0	0	15
ITK-5	3	15	3	15	3	15	2	10	4	20	15
ITK-6	2	10	0	0	3	15	0	0	0	0	5
ITK-7	0	0	2	10	2	10	0	0	1	5	5
ITK-8	2	10	1	5	2	10	0	0	3	15	8
ITK-9	2	10	2	10	0	0	3	15	1	5	8
ITK-10	6	30	0	0	4	20	12	60	2	10	24
ITK-11	3	15	0	0	3	15	2	10	0	0	8
ITK-12	5	25	7	35	3	15	2	10	5	25	22
ITK-13	4	20	2	10	2	10	0	0	0	0	8
ITK-14	0	0	0	0	3	15	0	0	0	0	3
ITK-15	1	5	0	0	1	5	0	0	0	0	2
No ITK	4	20	6	30	2	10	2	10	9	45	23

*Frequency> Freq.; Percentage > %



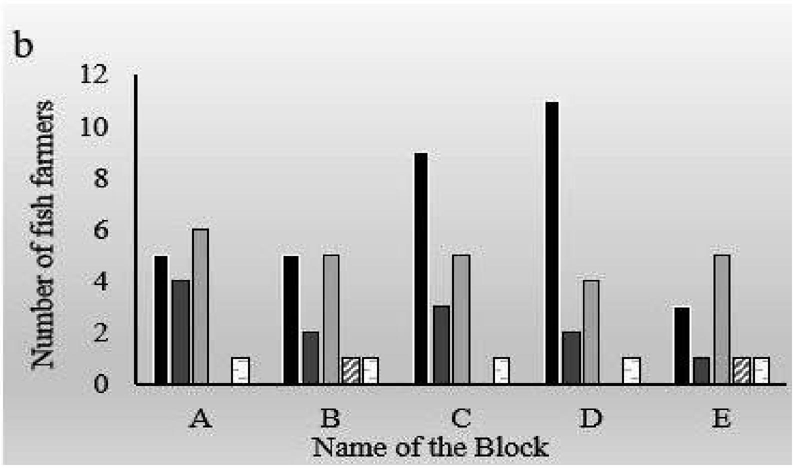


Fig. 4. District (a) and Block (b) wise sources of motivation behind different ITKs used in Bankura. Indus (A), Patrasayar (B), Taldangra (C), Onda (D), Indpur (E); i: Direct ancestor, ii: From elderly person of local farming community, iii: From own and other fellow farmers experience, iv: Mass media, v: Other Govt. and Non-Govt. organizations

Sources of motivation: In Bankura, 42.86% of total ITKs documented under the present study have been adopted through the ancestral passage; 15.58% through the elderly, experienced person of the farming community; 32.46% have been developed by the farmers themselves based on their experiences upon trial and error; knowledge source from the mass media contributed only in 2.59% cases, and contribution of different Govt. and Non-Govt. organization is 6.49% (Fig. 4a).

Adoption profile of different ITKs: 77% of the farmers in the present study were found to practice different ITKs in different management fields in the Bankura district. Among them, 28% were single ITK users, and 49% were multiple ITK user. However, 23% were non-user of any ITKs (Fig. 5). Adoption of ITKs related to health management and disease control contributed in highest percentage (26.28%), followed by seed production and environmental management, contributing 21.15% each. Adoption of ITK related to harvesting contributed lowest with only 1.28% in Bankura district (Fig. 6). The highest (14) and lowest (6) number of ITK adoption were observed in Taldangra and Indpur Block, respectively. Among the 15

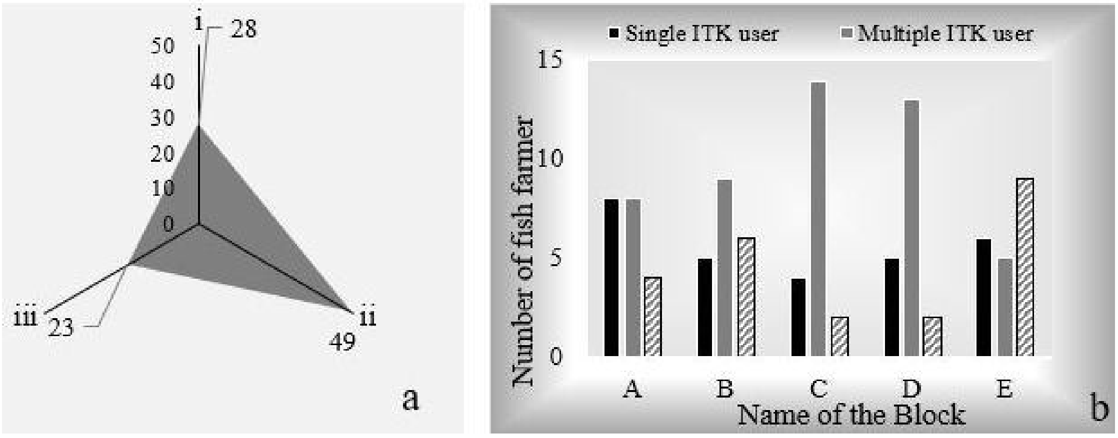


Fig. 5. District (a) and Block (b) wise ITK users' profiles under different Blocks of Bankura district. Indus (A), Patrasayar (B), Taldangra (C), Onda (D), Indpur (E); i: Single ITK user, ii: Multiple ITK user, iii: non-users

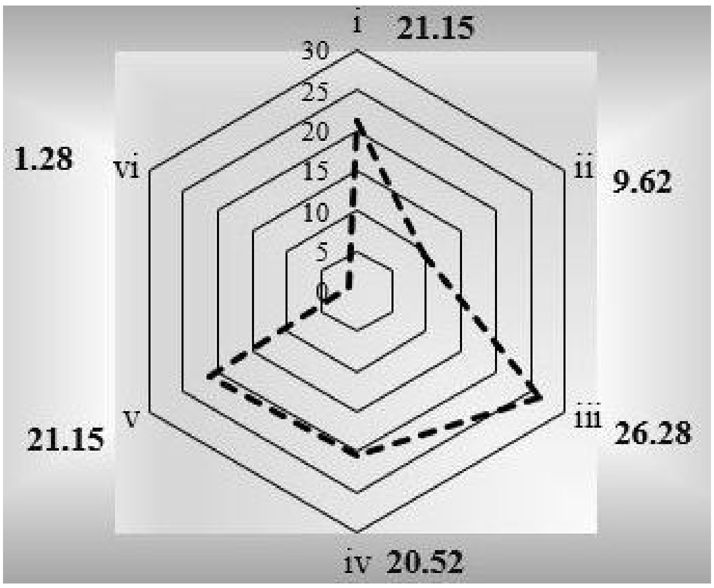


Fig. 6. Differential adoption rate (%) of ITKs in different management areas in Bankura district. i: Seed production, ii: Seed transportation, iii: Health management and disease control, iv: Growth promotion and feeding management, v: Environmental management, vi: Harvesting

documented ITKs, 9 each were adopted in Indus, Patrasayar, and Onda Blocks (Fig. 7). Therefore, Taldangra Block appeared richer with diverse type of ITKs among the five in Bankura under this investigation.

Socioeconomic and fish culture profile of the farmers: Under the study area, primary livelihood of 85% of farmers was fish farming, and the rest (15%) opted for fish farming as their secondary source of livelihood. Educational profile of the farmers revealed that 33% were graduate, 26% completed primary education and only 1% was functionally literate (Fig. 8a). Age-wise distribution shows that 50% of farmers belonged to the middle age group (35 to 54 years), 4% were < 25 years and 2% were >74 years (Fig. 8b). 25% of farmers were trained in fish farming. 38% of farmers were practicing fish culture in their own ponds, 37% in leased-in ponds, and 25% practice both in their own and leased-in ponds. 37% of the farmers were practicing fish culture in small ponds (≤0.5 ha), 15% in large ponds (>2 ha) and the rest were practicing in medium size ponds.

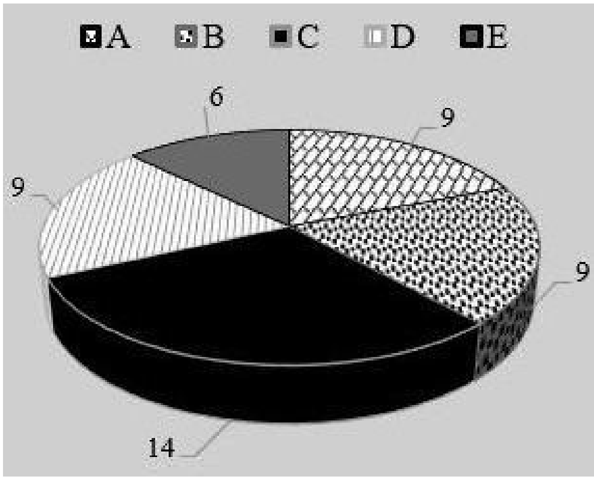


Fig. 7. Number of ITKs adopted in different Blocks of Bankura district. Indus (A), Patrasayer (B), Taldangra (C), Onda (D), Indpur (E)

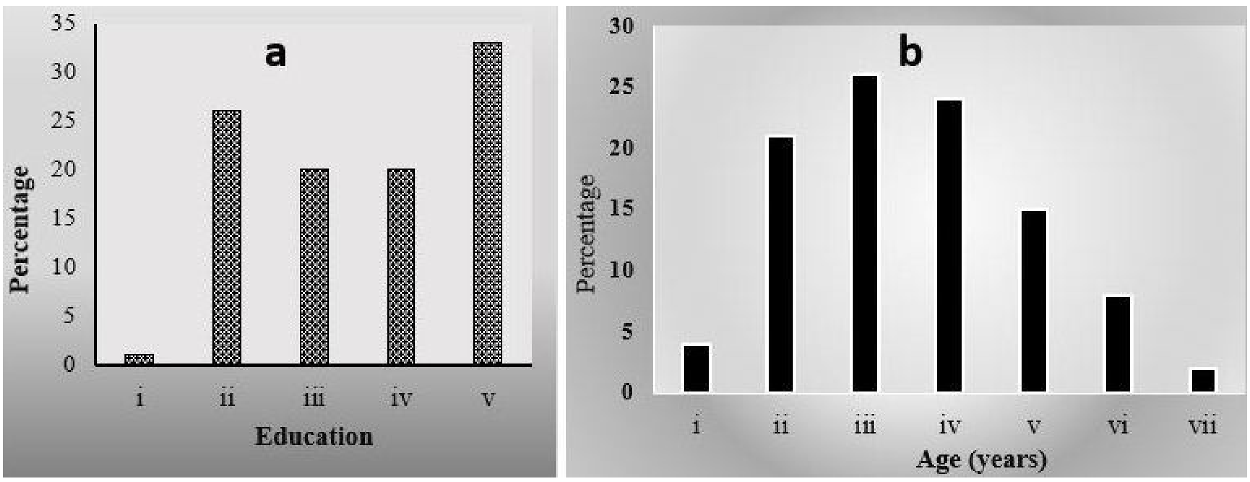
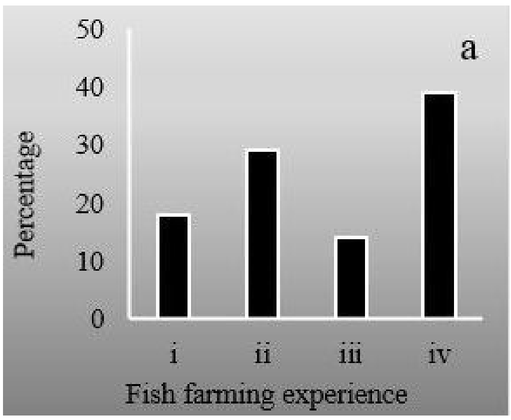


Fig. 8. Formal education (a) and age profile (b) of the surveyed farmers under Bankura district. [a: (i) functionally literate, (ii) primary, (iii) secondary, (iv) higher secondary, (v) graduates; b: i: 15-24, ii: 25-34, iii: 35-44, iv: 45-54, v: 55-64, vi: 65-74, vii: ≥75]

77% of farmers were involved in a traditional type of fish farming. Only 8% of the farmers were engaged in classical six species composite culture, whereas, culture of Indian major carps (IMCs) with exotic silver carp (*Hypophthalmichthys molitrix*) and bata (*Labeo bata*) was practised by 15% of the farmers. A total of 23% of the farmers operate in hatchery, of which, 30.43% were involved in seed production of IMC (*Labeo rohita*, *Gibelion catla*, *Cirrhinus mrigala*) along with bata (*Labeo bata*), silver carp (*Hypophthalmichthys molitrix*), grass carp (*Ctenopharyngodon idella*) and Japani punti (*Barbonymus gonionotus*). Seed production of magur (*Clarias magur*) and pangas (*Pangasianodon hypophthalmus*) was done by only 8.69 percent. In nursery ponds, only 3% of farmers practice the ideal mono species culture of IMC. Culture of only air breathing fish was done only by 2%.

Fish farming experience: 39% of farmers reported high fish farming experience of more than 15 years, whereas, 18% have very low fish farming experience up to 5 years (Fig. 9a). Therefore, it was clear that the surveyed fishermen were highly skilled because of their vast experience in fish farming over the years. Such profile acted as a determinant in adopting different ITKs in their farming practices. Among the Blocks, Onda contributed the highest percentage of fish farmers with high fish farming experience of more than 15 years. Taldangra Block contributed the highest number of fish farmers with medium fish farming experience of 11-15 years. Indus Block contributed the highest number of fish farmers with a low fish farming experience of 6-10 years (Fig. 9b).

Water quality: Surface water temperature did not differ much among the 5 (five) selected Blocks and ranged between18.5-32°C during the investigation period (Table 3). Water pH remained alkaline in all the Blocks under the present study in Bankura (Table 3). Dissolve oxygen and alkalinity of water did not differ significantly (P>0.05) among the Blocks (Table 3). Water hardness was lowest in Taldangra Block, and differences with Indus, Patrasayer and Indpur Blocks remained significant (ANOVA; $P < 0.05$) (Table 3). An insignificant difference was observed in the ortho-P concentration of water among the 5 (five) selected Blocks of the Bankura district (Table 3). All the water quality parameters irrespective of locations remained within the congenial levels of fish production. Mean total phytoplankton density was highest (3277.35±1064.35) in Onda Block, followed by Indus (2935.05±1095.22), Patrasayer (2728.8±790.60), Taldangra (2540.85± 867.21) and lowest in Indpur (2391.85±1058.65)



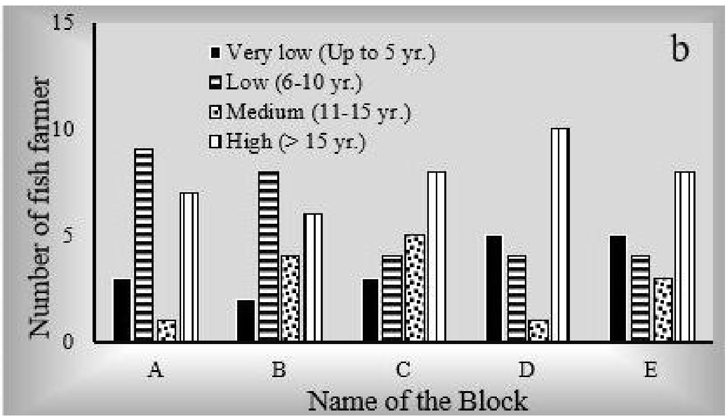


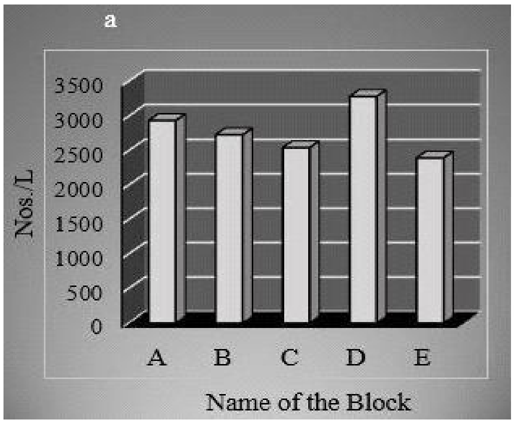
Fig. 9. District (a) and Block (b) wise profile of fish farming experience under the district Bankura (i), Very low (Up to 5 yr.) (ii), Low (6-10 yr.) (iii), Medium (11-15 yr.) (iv), High (> 15 yr.); Indus (A), Patrasayer (B), Taldangra (C), Onda (D), Indpur (E)

Table 3. Range and mean (± SD) of water quality parameters under the district Bankura

Parameter	Indas		Patrasayer		Taldangra		Onda		Indpur	
	Range ± SD	Mean	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD	Range	Mean ± SD
Temp. (^{0} C)	18.5 -32	26.93 ±3.97^a	19 -32	27.03 ±3.84^a	18.5 -31	26.85 ±3.78^a	19 -32	26.99 ±3.79^a	19 -31	27.09 ±3.73^a
pH	6.22 -8.53	–	7.3 -8.46	–	6.1 -8.31	–	6.4 -8.26	–	6.7- 8.12	–
DO (mg L^{-1})	4.66 -7.36	6.50 ±0.99^a	4.71 -7.42	5.98 ±0.98^a	5.14 -8.11	6.08 ±0.87^a	5.20 -7.83	6.14 ±0.93^a	4.83 -7.68	6.01 ±0.98^a
Alkalinity (mg L^{-1})	136.24 -206	168.11 ±21.55^a	142.1 -210	172.87 ±22.04^a	130 -191.2	169.45 ±17.33^a	111.6 -178.5	166.69 ±20.72^a	124.5 -189.4	165.36 ±19.36^a
Hardness (mg L^{-1})	74.41 -226.15	160.15 ±52.02^{ab}	78.3 -263	170.53 ±59.52^b	67 -152	127.56 ±29.73^c	69 -163.92	131.62 ±32.06^c	71.3 -186.92	150.57 ±37.26^a
Ortho -P (mg L^{-1})	0.051 -0.074	0.062 ±0.007^a	0.048 -0.076	0.063 ±0.008^a	0.042 -0.068	0.058 ±0.007^a	0.043 -0.089	0.061 ±0.009^a	0.045 -0.072	0.061 ±0.007^a

(Fig. 10a). Overall differences among the Blocks remained marginally significant (P<0.05). The mean population of total zooplankton was highest (312.8±68.45) in Patrasayer Block, followed by Onda (296.1±51.19), Indus (269.85±59.01), Indpur (264.2±53.36) and lowest in Taldangra (247.35±66.99) (Fig. 10b). Overall differences among the Blocks remained insignificant (P>0.95).

Profile of average ITK adoption and average annual yield: In Bankura district under the present purview of the study, the average number of ITK adoption by the individual farmer was highest (2.5 nos./farmer)



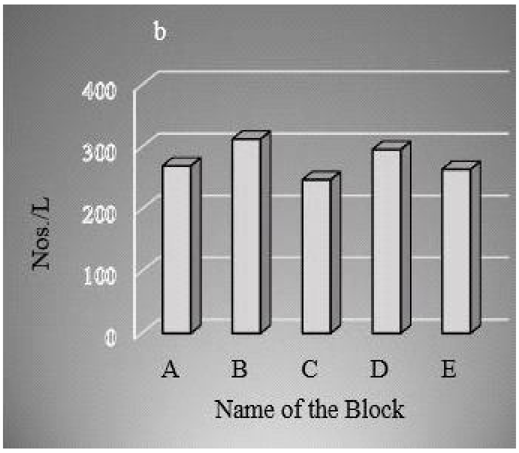


Fig. 10. Mean concentration of phytoplankton (a) and zooplankton (b) in different Blocks. Indus (A), Patrasayer (B), Taldangra (C), Onda (D), Indpur (E)

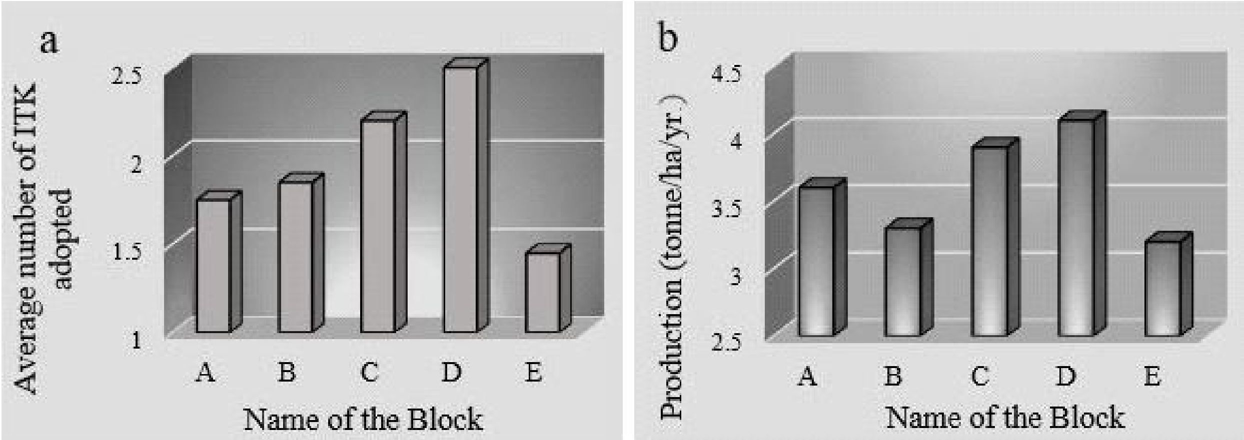


Fig. 11. Average ITK adoption (a) and average annual yield (b) in different Blocks of Bankura district. Indus (A), Patrasayer (B), Taldangra (C), Onda (D), Indpur (E)

(Fig. 11a). Also, the highest average annual fish production was recorded in Onda Block (4.1 tonne/ha/yr) (Fig. 11b). Average number of ITK adoption by the individual farmer was lowest (1.45 nos./farmer) in Indpur Block (Fig. 11a) with lowest average annual fish production of 3.2 tonne/ha/yr (Fig. 11b).

DISCUSSION

From the results of the study, it was apparent that the ITKs in practice by the surveyed farmers were time-tested for long and yielded benefits upon their adoption. The results also indicated more reliability of the farmers on their own experience next to the bonafide of their ancestors as fish farmers in the adoption process of locally practiced ITKs. Moreover, the farmers in the selected Blocks of Bankura district were primarily concerned with the application of ITKs in fish health management and disease control, primarily in the hatchery and seed production management. Such maneuvering of the culture environment through the application of natural inputs resulted in achieving better performance in fish seed production as reported by the respondents. Therefore, they continued with such approaches. Moreover, in the adoption process of input-based ITKs, ease of application matters, as application of any input directly in the culture pond is easier compared either with feed or as topical application to the fish in disease management.

Adoption of ITKs directly from the ancestral lineage was found to be highest in Onda Block and lowest in Indpur Block. Adoption/ development of ITKs through the farmers themselves was recorded highest in Indus Block, which indicated that among different Blocks under the present study in Bankura district, farmers of Indus Block were more innovative. Lack of proper documentation of ITKs, limitations of ITKs to solve a problem under any situation, the unwillingness of the experienced elderly farmers to pass on the knowledge to others and lack of sufficient resources are the major problem regarding the adoption of ITKs in Bankura, such problem in Assam was also reported by Devi *et al*. (2014).

Among the Blocks under the present study of Bankura district, farmers of the Onda Block were more progressive in adopting ITKs that have yielded better productivity, and the rate remained much higher than the national productivity level of 3.2 tonnes/ha in inland freshwater of India. Though it was opposite in the case of Indpur Block, productivity remained at par with the national average. The results indicated that most of the farmers were keen on adoption of ITKs against a substantial portion (23%), who certainly have some limitations in the adoption process, might be out of lack of motivation, non-availability of input materials in the locality of their operation, farm size limitation and others. Number of single ITK users was recorded highest in Indus Block. Number of multiple ITK users was highest in Taldangra Block. Non-users of ITK were highest in Indpur Block, that might have reflected in the lowest productivity of this Block. The fitted relationship between average number of ITK adopted and average annual yield has been established as ($y = 0.8722x+1.9192$; $R^2 = 0.8603$) (Fig. 12). Therefore, it was imperative that the ITKs adopted by the farmers of their own were effective in the production process that translated into higher productivity. Moreover, the fitted relationship between number of ITK adopted and average fish farming experience of the farmers in Bankura district has been established as $y = 0.5869x+1.6827$; $R^2 = 0.751$ (Fig. 13a). As most of the ITKs were evolved through the ages, based upon the experiences of the farmers working with low cost locally

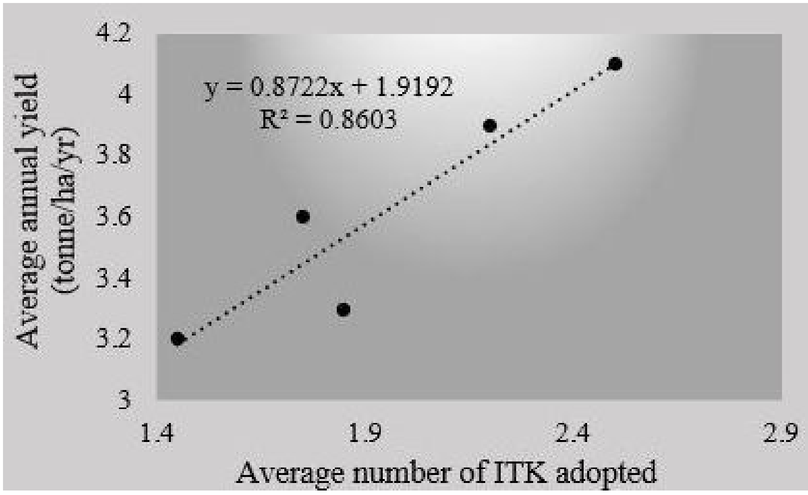


Fig. 12. Fitted relationship between average number of ITK adopted and average annual yield under the district Bankura

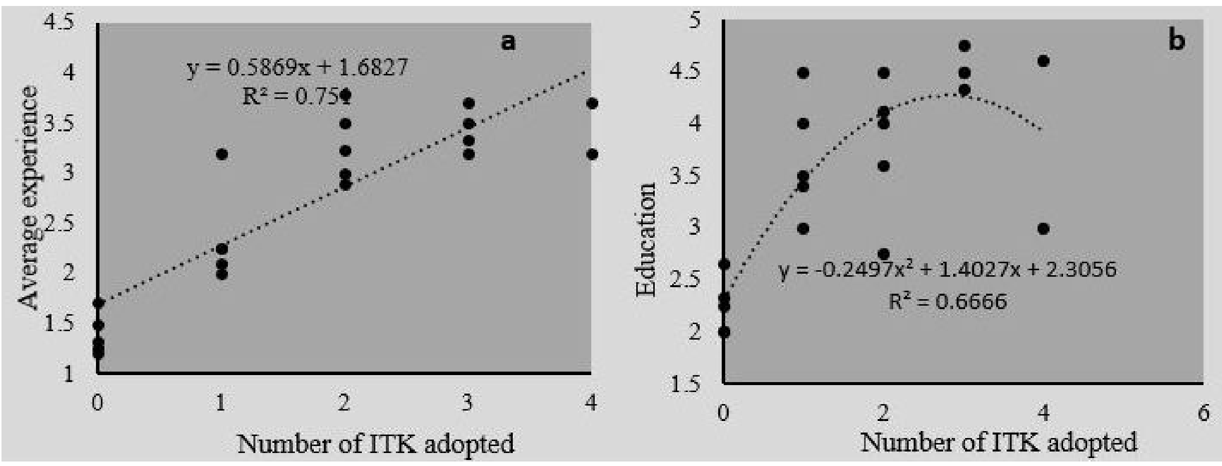


Fig. 13. Fitted relationship between number of ITK adopted and average experience of the farmer (a), and level of education of the farmer (b) under Bankura district, (a: average experience score fitted in 4-point scale where 1 = up to 5 years, 2 = 6-10 years, 3 = 11-15 years and 4 = >15 years: b: education score fitted in 5-point scale where 1 = Illiterate, 2 = Primary, 3 = Secondary, 4 = Higher secondary and 5 = Graduate)

available inputs, such relationship was strongly justified. However, number of ITKs adopted and level of education of the farmers has been established as y = $-0.2497x^2+1.4027x+2.3056$; $R^2 = 0.6666$ (Fig. 13b). Such relationship was not direct beyond educational score of 4.25 that indicated that adoption of ITKs though was correlated with educational status of the farmers; it was not an absolute determinant in the adoption process.

The use of yellow soil/laterite soil was done, because addition of yellow soil /red soil/ laterite soil coagulates the suspended organic matters, removes pollutants, absorbs carbon dioxide and ammonia from the medium, consequently increases the survivability of fry, also facilitates better environment during seed transportation (Das and Mondal, 2005). Use of '*haritaki*' (*Terminalia chebula*) in hatchery operation is also founded with scientific rationale as '*haritaki*' contains tannic acid, gallic acid, antioxidant, anti-inflammatory and analgesic agent. Due to the application of this mixture, the outer membrane of the fertilized egg becomes hardened because of tannin and prevents immature hatching (Das *et al*., 2012a; Afshari *et al*., 2016). The use of neem (*Azadirachta indica*) derivatives has strong rationality, as neem is recognized as a medicinal plant well known for its antibacterial, antimalarial, antiviral, and antifungal properties. There is a growing tendency to apply various parts of neem as such or its extracts in aquaculture, particularly for remedial measures in case of disease (Das *et al*., 2002) or for the purpose of amelioration (Das *et al*., 2012b; Kumar *et al*., 2018). Use of turmeric (*Curcuma longa* L.) was observed; the scientific standpoint is that turmeric has antioxidant, immunomodulatory, anti-inflammatory and tumor cell suppression effects (Kocaadam and Şanlier, 2017; Pereira *et al*., 2021). The use of organic juice by the farmers were scientifically validated because it was previously reported as effective in reducing the cost of production of omnivorous carp like *Cyprinus carpio*, L., as feed conversion efficiency was enhanced compared to control (Dinda *et al*., 2020). The use of liquid mixture of chickpeas, mustard oil and molasses was observed for the growth promotion of fry. Previous studies state that pea protein concentrate showed to be a promising new protein ingredient for salmonids and could replace 20% of high-quality fish meal protein in the feed without any adverse effect on growth performance (Overland *et al*., 2009). As the banana stem binds dissolved and suspended particles in the water column and thus clears water by coagulating the physical particles (Hoque *et al*., 2018), the application of this natural input appeared scientifically sound. Use of black *carp*, *Mylopharyngodon piceus* in carp culture pond to control snail was justified as previous studies have shown that the black carp is primarily molluscivorous (Phan *et al*., 2010; Hung *et al*., 2013).

The study conclusively proved that the natural input-based ITKs by the farmers in the selected Blocks of the Bankura district were significant in increasing the productivity in seed production and table fish production well. All the ITKs documented in this study were inherent with scientific rationale and should be preserved, propagated and percolated through the generations. Government and other organizations have to increase extension support to promote farmers' innovations and to protect Indigenous Technical Knowledge those appeared justified with inherent scientific rationale. Conservation of all medicinal plants, specially *Semecarpus anacardium,* is also recommended as this valuable plant is rarely available, and farmers' perception was also excellent about the result of using this in carp culture pond to remove filamentous algae.

Conflict of interest: Authors have no conflict of interest in this study.

Author's contribution: RD: Collected data, analyzed samples and data, and prepared the manuscript; SKD: Conceptualized the problem, critically evaluated the results and finalized the write-up of the manuscript.

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