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Farm-economics of Genetically Improved Carp Strains in Major Asian Countries and Carp Seed Price Policy Model

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Abstract

The study has conducted the micro level analysis of hatchery operators, fishseed-rearing farmers and carp farmers with respect to their socio-economic characteristics, infrastructural development, husbandry practices and economics returns, based on the survey and on-farm trial data collected by the research partners in six Asian countries, viz. Bangaldesh, China, India, Indonesia, Thailand and Vietnam. The genetically-improved carp strain is economically viable and socially acceptable. The attractive profits to hatchery operators and nursery and carp farmers have created conducive environment for the dissemination of improved carp strain. Price policy models for improved strains have been developed. The premium price for fingerlings and broodstock with improved strain has been assessed. The high price of genetically-improved nuclear seed and broodstock would build self-supportive research and extension systems in the country. A business plan for *Jayanti* rohu has been worked out, as an example for replacement of rohu by *Jayanti* rohu.

Introduction

Experience from tilapia across the Asia has shown that improvement of the stock helps in increasing productivity, income and production of fish (Dey and Gupta, 2000). The WorldFish Centre and its collaborating partners from the Asian countries through their research efforts have made available the genetically-improved carp strains of the selected carp species in Bangladesh, India, Thailand and Vietnam. Genetic improvement of rohu (*Jayanti*) in India, common carp (RAI-1) in Vietnam, silver barb in Bangladesh and Thailand and common carp in China and Indonesia are enough testimonies to advocate that it is possible to improve many economically important traits, such as growth, survival, resistance to diseases, better flesh quality, etc.

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Fry or fingerlings are the most critical inputs for the growth of carp industry and it depends on the capacity of hatchery operators to supply high-quality fry/fingerlings at an affordable price to enable the fish grow-out operators to adopt the improved strains and sustain their operations. The options for improvement in the productivity of fish are either through reducing farm inefficiency, adopting improved strain or both. For the efficient farms, improved stock is one of the options available for increasing the productivity and income. Once the genetically-improved strain is developed and tested for its growth, its dissemination will improve productivity and income of carp farms.

This paper provides the micro level analysis of hatchery operators, fishseed-rearing farmers and carp farmers with respect to their socio-economic characteristics, infrastructural development, husbandry practices and economic returns, based on the survey and on-farm trial data collected by the research partners in six Asian countries (Bangladesh, China, India, Indonesia, Thailand and Vietnam). The improved strain is more profitable than the local strain and the stakeholders can afford to pay a premium price for the improved strain. Attempt has been made to build a model to determine the threshold (premium) price of carp seed with improved strain.

Fish Production System: Structure and Economics

The carp production system can be classified as: (i) hatchery systems for production of spawn/fry/fingerlings, (ii) fish seed rearing systems for production from spawn to fry/fingerlings, and (iii) grow-out systems for the production of table fish. An attractive profit to hatchery operators and nursery and carp farmers is the necessary condition to create favourable adoption and dissemination environment for improved strains. The economics of fish production system at different stages have been examined in the subsequent sections.

Economics of Hatchery Operation

The micro-level analysis concerning infrastructure, hatchery management practices, broodstock source and costs and returns based on the survey data of 56 sample hatchery operators in Bangladesh, 20 in China, 30 in India, 25 in Indonesia, 33 in Thailand, and 35 in Vietnam, has been presented in Tables 1 to 3. Hatcheries are no longer an infant industry. All of them have experience of more than 20 years in the business and a majority of them have also received formal training in hatchery management. Most operators are owner-operators, engaged on full-time basis. They have positive attitude towards genetically-improved strains and are willing to adopt them.

As seen in Table 1, the number of broodstocks, on an average, was maintained between 1327 (in Vietnam) and 3101 (in China) with 2.5 ha (Bangladesh) to 7.0 ha (China) of land. The initial capital investment ranged from US$ 12.4 thousand (Vietnam) to US$ 40 thousand (China) on pond

Table 1. Infrastructure for hatchery and broodstock management in the selected Asian countries

Particulars	Bangladesh	China	India	Indonesia	Thailand	Vietnam
Sample of hatcheries	56	20	30	25	33	35
Infrastructure						
Broodstock number	2614	3101	2392	1927	1589	1327
Broodstock ponds (No.)	7	10	5	4	6	2.00
Nursery ponds (No.)	3	6	5	7	7	5
Land (ha)	2.5	7	2.7	3.8	5.9	2.8
Capital ('000 US $)	17.8	40	22.1	37.9	15.4	12.4
Sources of broodstock (% of hatchery)						
Natural	22	16	13	5	2	0
Own hatchery	60	43	62	60	73	75
Government hatchery	8	24	17	30	12	20
Private hatchery	10	16	8	5	13	5
Broodstock management						
Average weight of broodstock (g)	1.95	1.10	2.30	4.14	1.12	2.50
Average age of broodstock (years)	3.52	3.00	3.30	3.09	2.23	2.90
Age of broodstock at first breeding (years)	1.96	2.40	2.40	1.51	1.90	1.4
Frequency of replacement of broodstock, years	3.00	2.90	2.90	1.50	2.50	3.5
Female: male ratio	1.00	0.73	0.38	0.25	0.54	0.5
Number of times broodstock used in a year	2.40	2.00	1.70	4.40	2.20	1.0
Stocking density of broodstock (number/ha)	1222	373	1079	229	950	829.0

Table 2. Cost and return of a hatchery in the selected Asian countries

Country/ hatchery size	Broodstock (No.)	Gross returns (US $)	Variable input cost (US $)	Profit to variable cost (US $)	Rate of return (%)
Bangladesh					
Small	942	10922	4877	6044	123.9
Medium	2125	21154	8184	12969	158.5
Large	4555	49917	16832	33085	196.6
All-hateries	2614	28325	12511	15814	126.4
China					
Small	494	6669	4645	2024	43.6
Large	4840	33036	21125	11910	56.4
All-hateries	3101	22489	14533	7956	54.7
India					
Orissa	430	10915	7608	3306	43.5
West Bengal	2392	27138	12369	14769	119.4
Andhra Pradesh	3423	109703	39810	69892	175.6
All-hateries	2082	80278	30054	50224	167.1
Indonesia					
Government	44.6	7396	1974	5422	274.6
Private	14.2	4270	1506	2764	183.5
Small	5.2	2001	1210	790	65.3
Large	22.5	6028	1848	4179	226.1
All-hateries	19.1	4909	1618	3290	203.3
Thailand					
Small	560	14161	7398	6763	91.4
Large	3934	55168	31919	23249	72.8
All-hateries	1589	26586	14829	11757	79.3

development, building, equipment, vehicle and broodstock. The hatchery operators obtained the initial brood fish from either the government [research station/National Broodstock Centre (NBC)/hatchery] or private hatcheries. At a later stage, there was a trend of rearing brood fish at own hatcheries. About two-thirds hatcheries reported 'own hatchery' as the source of broodstock. They had to eventually face the problem of genetic deterioration due to inbreeding. The management practices varied significantly across countries. For example, the female-male ratio of the brood fish varied from 0.25 in Indonesia to 1.0 in Bangladesh. The number of times brood fish was used in one year ranged from 1.0 (Vietnam) to 4.4 (Indonesia) and changing of their broodstock was after every three years, except in Indonesia where hatchery operators changed their broodstock at most every 1.5 years. Operators were maintaining younger broodstock in Thailand (2.2 years average age), while in other countries, the average age was high (2.9-3.5 years).

The cost and return analysis, presented in Table 2, revealed that hatchery is a lucrative operation and the returns increased with increase in hatchery-size. Taking all hatchery-sizes together, the rate of returns to variable input-cost was highest in Indonesia (203%), followed by India (167%), Bangladesh (126%), Thailand (79.3%) and China (54.7%). Highly profitable activities were exhibited by all sizes of hatchery.

The average variable cost of seed was found substantially lower in Indonesia (US $ 1.52/kg) and Thailand (US $ 1.85/kg) than China (US $ 4.65/kg) and India (US $ 3.54/kg) (Table 3). The seed production cost was found to be much lower than its

Table 3. Average variable cost of fish seed production and its price in the selected Asian countries

Country/ hatchery size	Average variable cost	Fish seed price	Price-cost ratio
Bangladesh: Spawns (US $/kg)			
Small	9.20	20.61	2.24
Medium	8.01	20.70	2.58
Large	6.92	20.53	2.97
All-hateries	9.10	20.60	2.26
China: Fingerlings (US $/thousand)			
Small	9.41	13.50	1.44
Large	4.32	6.76	1.56
All-hateries	4.65	7.18	1.55
India : Fingerlings (US $/thousand)			
Orissa	7.08	10.16	1.44
West Bengal	3.30	7.23	2.19
Andhra Pradesh	3.99	10.98	2.75
All-hateries	3.54	9.46	2.67
Indonesia: Fingerlings (US $/kg)			
Government	1.39	5.23	3.75
Private	1.58	4.48	2.84
Small	3.06	5.05	1.65
Large	1.19	3.88	3.26
All-hateries	1.52	4.62	3.03
Thailand: Fingerlings (US $ / thousand)			
Small	1.95	3.73	1.91
Large	1.80	3.11	1.73
All-hateries	1.85	3.31	1.79

Table 4. Socio-economic profile of fingerling-rearing farmers in the selected Asian countries

Item	Bangladesh	India	Indonesia
Sample size	30	43	32
Characteristic of seed rearing -farmers and farms			
Age (years)	47	45	47
Education (years)	8	10	9
Experience (years)	22	17	22
Family size, No.	5.42	5.05	5.12
Pond area (ha)	2.58	2.53	2.81
Area under rearing fingerlings (ha)	2.58	2.53	2.81
Sources of spawn (% farmers)			
Own	0	16	0
Private hatchery	100	83.4	80.2
Government hatchery	0	0.5	19.8
Name of species and their shares (%) in total seeds			
Rohu	17.4	33.6	0
Catla	8.3	27.4	0
Mrigal	12.9	24	0
Silver carp	13.3	2.2	0
Grass carp	10.4	4.9	0
Mirror carp	12.4	0	0
Common carp		7.9	100
Silver barb	12.8	0	0
Pangus	7.6	0	0
Kalbasu	1.6	0	0
Big head	2.4	0	0
Black carp	0.9	0	0

market price in all the countries under study. The price-cost ratios were in the range of 1.44 (Orissa, India) to 3.75 (Government hatchery in Indonesia), which indicated that hatchery was a highly lucrative and economically viable enterprise in the Asian countries.

Economics of Fish Seed Rearing

This section provides the micro-level analysis of the characteristics of nursery farms and their profitability in three countries (Bangladesh, India and Indonesia), based on the sample survey of 30 farmers in Bangladesh, 43 farmers in India, and 32 farmers in Indonesia (Table 4). The age of the seed growers was about 45 years, education duration was 8-10 years, and experience was of 17-22 years. The seed growers were experienced farmers and their characteristics did not differ much across the countries under study. The major source of spawn for seed farmers was the private hatcheries, which were meeting more than 80 per cent of their requirements. The Indian major carp (IMC) was the dominating species adopted for seed rearing in India and Bangladesh. A large number of species were being reared in Bangladesh. In Indonesia, only common carp was being reared from spawn to fingerlings.

The average area under a nursery pond was about 2.5 hectares in Bangladesh and India, and 2.8 hectares in Indonesia. The number of crops and rearing periods were just double in Indonesia than Bangladesh and India (Table 5). The input cost for

Table 5. Cost and returns of rearing fingerlings in selected Asian countries

Item	Bangladesh	India	Indonesia
Area under nursery pond (ha/farm)	2.58	2.53	2.81
Number of crops	4	3.5	9.3
Number of months	6	6.6	8.2
Input share in total cost (%)			
Seed	22.7	68.3	34.2
Feed	13.0	12.9	26.2
Fertilizer	7.1	4.3	4.8
Pesticides	1.3	0.8	0.3
Other inputs	13.6	0.7	1.6
Hired labour	10.4	2.7	2.1
Family labour	3.0	0.0	13.1
Other inputs	6.1	10.2	32.9
Total cost (US$/ha)	4076	6460	2719
Total fry/fingerling production ('000/ha)	28.20	1638	4230.69
Average price of fry/fingerlings (US$/1000)	3.07	4.79	1.54
Gross returns (US$/ha/year)	5750.56	7847.84	6592.89
Operational profit (US$/ha)	1674.02	1387.29	3873.39
Cost of production (US$/1000 fry)	2.18	3.94	0.64
Rate of return over total cost (%)	41.06	21.57	142.40

seed rearing was nearly half in Indonesia (US$ 2720/ha) than that in India (US $ 6460/kg) and Bangladesh (US $ 4076/kg). Spawn constituted a major share in the total cost of seed rearing. It was 22.7 per cent in Bangladesh, 34.2 per cent in Indonesia and 68 per cent in India. The average cost of producing one thousand fingerlings was estimated to be highest in India (US $ 3.94), followed by Bangaldesh (US $ 2.18), and Indonesia (US$ 0.64). It was much below the fingerling price, and resulted in 22 per cent returns to variable cost in India, 41 per cent in Bangladesh and 142 per cent in Indonesia. Due to high profitability and long-duration activity in Indonesia, it was a full time and highly remunerative activity, providing regular cash income round the year, which was necessary to alleviate poverty and hunger in the country. The fish seed price was normally fixed by hatchery operators on 'take it or leave it' basis due to inadequate supply and high demand for quality fry and fingerlings. The hatchery operators could establish markets for their quality seed by following scientific practices.

Economics of Carp Farming

The economics of carp farming based on baseline survey (with traditional carp strains) of carp farmers in all the six countries revealed that carp culture was profitable under 'normal' conditions (Table 6). The return to variable input-cost was about 50 per cent in Bangladesh, India, and Thailand. It was much higher, to the tune of 115 per cent, for rice fish and 248 per cent for VAC system in Vietnam. The return was noticed lower in China and Indonesia (17%), but profit per unit pond area was much higher in these than other countries due to high yield and intensive culture practices. The average cost of production per kilogram of carp fish (breakeven price) was found in the range of US$ 0.21 (Vietnam VAC system) to US$ 0.73 (China), which is much lower than the prevailing carp price. The breakeven price can be further lowered (3.5-34.6%) with the adoption of improved carp strains.

The genetic evaluation and economics of carp system in all its stages of production, viz. hatchery, seed growing and grow-out carp farming have shown that improved strain could realize higher gain than that envisaged before (*also see,* Dey, 2000; Ponzoni *et al.,* 2007). Hatchery operators have a crucial role to play in the expansion of improved seed supply and technology dissemination. The Asian countries have a large number of hatcheries under both public and private sectors, but their size is small and they have

Table 6. Cross-country comparative performance of improved and traditional carp strains under polyculture in selected Asian countries

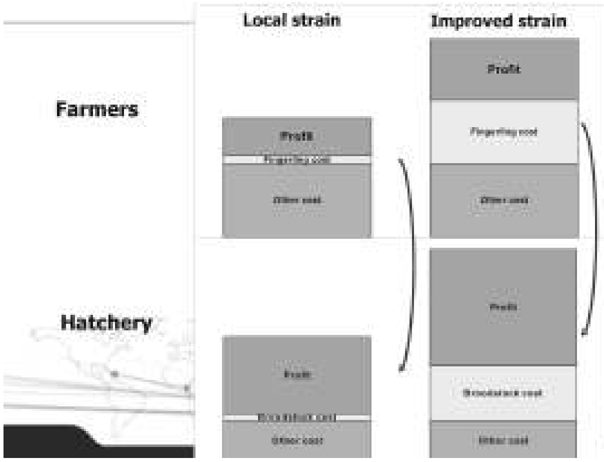
Particulars	Bangladesh Pond	China Pond	India Pond	Indonesia Cage	Thailand Pond	Vietnam VAC	Vietnam Rice-fish
Improved strains							
Sample	20	39	52	25	23	11	8
Yield (kg/ha)	2333	28227	9623	137	2895	5880.6	1983.9
Gross receipt (US$/ha)	1934	24315	6634	117	1483	4305	1452
Variable cost (US$/ha)	1162	16313	3443	95	953	1116	434
Profit over variable cost (US$/ha)	772	8002	3191	23	529	3189	1018
Return to variable cost (%)	66.46	49.05	92.68	23.88	55.50	285.73	234.65
Variable cost (US$/kg)	0.50	0.58	0.36	0.69	0.33	0.19	0.22
Average fish price (US$/kg)	0.83	0.86	0.69	0.86	0.51	0.73	0.73
Local strains							
Sample	20	103	41	35	21	5	5
Yield (kg/ha)	2147	15521	7785	132	2726	4477.6	2677.8
Gross receipt (US$/ha)	1754	13350	5124	110	1392	3214	1922
Variable cost(US$/ha)	1185	11357	3485	94	930	923	895
Profit over variable cost (US$/ha)	569	1993	1640	16	462	2291	1027
Return to variable cost (%)	48.06	17.55	47.05	16.95	49.68	248.32	114.70
Average variable cost (US$/kg of fish)	0.55	0.73	0.45	0.71	0.34	0.21	0.33
Average fish price (US$/kg)	0.82	0.86	0.66	0.83	0.51	0.72	0.72
Changes in improved over local strains (%)							
Yield (kg/ha)	8.66	81.87	23.61	3.55	6.20	31.33	-25.91
Variable cost (US$/kg)	-9.76	-21.0	-20.1	-2.82	-3.45	-7.89	-34.60
Average fish price (US$/kg)	1.46	0.15	4.74	2.94	0.31	2.00	2.00

Note: Results of Indonesia are under monoculture

limited infrastructural facilities and capital investment. However, they have the necessary education, adequate training and experience, and willingness to adopt new technologies. If a hatchery is to meet the specified standards for the production of quality seed, then it needs more capital and land to maintain the progeny of broodstock and rear the spawn at least for 30 days, to the size of fry/fingerlings. The hatchery with improved carp strain needs more land and capital, as for example Sri Ram Hatcheries in India specializing in *Jayanti* rohu use about 82 hectares of land (13 ha owned land and 68 ha leased land with land rent of US $ 1098/ha) and has taken credit of US $ 58 thousand from a bank. If our policy option is that small hatcheries should co-exist, then these must be encouraged to produce spawns only by using the genetically-improved brood fish and promote contract farming for rearing spawns to fry/fingerlings. This will help maintain the quality of fingerlings and check inbreeding. However, there is a need to develop guidelines for the seed certification system to ensure production and supply of quality seed. In this context; contract farming is seen as one of the alternative modes to secure the desired quality, quantity, location and timing specifications (Woodend, 2003; Silva, 2005). It will reduce marketing risks and enhance management skills through technical assistance. The uncertainty about sale price will also be reduced.

Self-Sustainability of Genetic Improvement Program

Broodstocks and fry/fingerlings are crucial inputs for the carp industry. But, a new genetically-improved strain has been evolved with large research investments. Therefore, the improved carp brood is expected to be more expensive than the existing strains of carp. As both the strains have similar rearing costs to the age of first breeding, the average cost of spawn/fry/fingerlings due to higher cost on nuclear



Box 1: Conceptual framework for fish seed price policy of improved and local strains

seed must be higher for the genetically-improved strain than the local strains. The improved strains are more profitable than the existing strains of carp at the grow-out farm level and can afford to pay a higher price of fingerlings to hatchery. This would increase the profitability of a hatchery which can afford to pay a higher price for genetically-improved broodstock/nuclear seeds to BSC/nuclear unit (Box 1). The higher price of broodstock and nuclear seeds would lead to self-supportive resource generation for research and extension system.

Due to high productivity and profitability of the improved strain at the farm level, a premium price can be assigned to the genetically-improved fingerling/spawn/broodstock. We need to workout the potential price of improved fish seed at various levels of carp system with the assumptions that price must be sufficiently high, not only to counteract the rising costs but also to give additional profit margin to attract adoption of the improved strain by replacing the local strains.

An arithmetic formulation was developed to determine the threshold price of improved strains at the levels of farmers and hatcheries under a set of assumptions.

Price Determination Model for Fingerlings with Improved Strain

The income to carp farm with local strain can be represented by Equation (1):

$$I_0 = Y_0P_0 - C_0 - S_o p_0 \qquad \ldots(1)$$

where,

I_0 is the net income per hectare to grow-out carp farmer with local strain,

Y_0 is the carp yield per hectare with local strain,

P_0 is the price of carp fish with local strain,

C_0 is the rearing cost from fingerlings to grow-out fish, excluding fingerling cost with local strains,

S_0 is the stocking density (number of fingerlings per hectare) with local strain, and

p_0 is the price of fingerlings with local strain.

The income to carp farm with improved strain can be represented by Equation (2):

$$I_1 = Y_1P_1 - C_1 - S_1p_1 \qquad \ldots(2)$$

where,

I_1 is the net income per hectare to grow-out carp farmer with improved strain,

Y_1 is the carp yield per hectare with improved strain,

P_1 is the price of carp fish with improved strain,

C_1 is the rearing cost from fingerlings to grow-out fish, excluding fingerling cost with improved strain,

S_1 is the stocking density with improved strain, and

p_1 is the price of fingerling with improved strain.

Assuming λ_1 to be the yield gain with improved strain over the old strain and λ_2 to be the gain in price due to the bigger size of improved strain of fish, we have

$$Y_1 = Y_0\,(1+ \lambda_1) \qquad \ldots(3)$$

$$P_1 = P_0\,(1+ \lambda_2) \qquad \ldots(4)$$

By substituting Equation (3) and Equation (4) into Equation (2), the income Equation (2) can be written as:

$$I_1 = Y_0\,(1+ \lambda_1)\,P_0\,(1+ \lambda_2) - C_1 - S_1p_1 \qquad \ldots(5)$$

Assuming θ to be the income growth over local strain, as necessary to create adoption environment for the improved strain among carp farmers, thus, one gets

$$I_1 = I_0\,(1+ \theta) \qquad \ldots(6)$$

Substitute Equation (5) and Equation (1) into Equation (6) and solve for fingerling price (p_1) with improved strain, say p*, i.e.

$$p^* = [Y_0 P_O (\lambda_1 + \lambda_2 + \lambda_1 \lambda_2 - \theta) - C_1 + C_0 (1+\theta) + S_0 p_0 (1+\theta)] / S_1 \quad \ldots(7)$$

The p* is the maximum potential price of fingerlings with improved strain, which the carp farmers can pay to the seed supplier.

Price Determination Model for Spawn with Improved Strains

The income to a nursery farm (rearing from spawn to fingerling) with local strain can be represented by Equation (8):

$$I_0 = Y_0 P_0 - C_0 - S_o p_0 \quad \ldots(8)$$

where,

I_0 is the net income per hectare to a nursery farmer with local strain,

Y_0 is the number of fingerlings harvested per hectare with local strain,

P_0 is the price of fingerlings with local strain,

C_0 is the cost of rearing from spawn to fingerling, except spawn cost with local strain,

S_0 is the stocking density of spawn (kg/ha) with local strain, and

p_0 is the spawn price per kg with local strain.

The income to a nursery farm with improved strain can be represented by Equation (9):

$$I_1 = Y_1 p^* - C_1 - S_1 p_1 \quad \ldots(9)$$

where,

I_1 is the net income per hectare to a nursery farmer with improved strain,

Y_1 is the number of fingerlings harvested per hectare with improved strain,

p* is the price of fingerlings with improved strain computed from Equation (7),

C_1 is the cost of rearing from spawn to fingerling, except spawn cost, with improved strain,

S_1 is the stocking density of spawn (kg/ha) with improved strain, and

p_1 is the price of spawn per kg with improved strain.

Assuming θ to be income growth over the local strain, as necessary to create adoption environment for improved strain among nursery farmers, we get

$$I_1 = I_0 (1+\theta) \quad \ldots(10)$$

Substituting Equation (8) and Equation (9) in Equation (10) and solving for spawn price (p_1) with improved strain, say p**, we get

$$p^{**} = [Y_1 p^* - C_1 - (1+\theta)(Y_0 P_0 - C_0 - S_o p_0)] / S_1 \quad \ldots(11)$$

The p** is the maximum potential price of spawn with improved strains, which a nursery can pay to the hatchery.

Price Determination Model for Broodstock with Improved Strain

The income to a hatchery with local strains can be represented by Equation (12):

$$I_0 = Y_0 p_0 - C_0 - (BP_0 / T_0) \quad \ldots(12)$$

where,

I_0 is the annual net income per broodstock to hatchery with local strain,

Y_0 is the annual production of spawn per broodstock with local strain,

p_0 is the price of spawn with local strain,

C_0 is the input cost per Broodstock, except broodstock cost, with local strain,

BP_0 is the broodstock price with local strain, and

T_0 is the time in years, the local strain of broodstock has been in use.

The income to a hatchery with improved strain can be represented by Equation (13):

$$I_1 = Y_1 p^{**} - C_1 - (BP_1 / T_1) \quad \ldots(13)$$

where,

I_1 is the annual net income to hatchery per broodstock with improved strain,

Y_1 is the annual production of spawn per broodstock with improved strain,

C_1 is the input cost per broodstock, except broodstock cost, with improved strain,

p** is the price of spawn with improved strain, computed from Equation (11),

BP_1 is the broodstock price with improved strain, and

T_1 is the time in years, improved strain broodstock has been in use.

Assuming θ to be the income growth over local strain as necessary to adopt the improved strain at hatchery, we get

$$I_1 = I_0 (1+ \theta) \qquad \ldots(14)$$

By substituting Equation (12) and Equation (13) into Equation (14) and solving for broodstock price (BP_1) with improved strain say BP*, we get

$$BP^* = [Y1\ p^{**} - C_1 - (1+\theta)(Y_0 P_0 - C_0 - BP_0/T_0] / T_1 \qquad \ldots(15)$$

The BP* is the maximum potential (threshold) price of broodstock with improved strain.

An Illustration

The threshold price of fingerlings and broodstock with improved strain, given in Table 7, revealed that seed prices were positively responsive to productivity gain and the threshold price for improved fingerlings was 2.7 to 9.2-times higher than of the local strains. In India, farmers can afford to pay a higher price for *Jayanti* rohu as compared to that for silver barb in Bangladesh and Thailand. The fingerling price has inverse relation to the seed share in total variable cost. As the share of fingerlings/broodstock cost increases, the threshold price of fish seed increases. It has policy implication that the resource-rich farmers can afford a much higher price for improved strain as compared to that by resource-poor farmers. Thus, while implementing the price policy of seed, the interests of poor households must be protected. The resource-poor households are in major number in the Asian countries, the 'incentive' policies with poor bias would help in disseminating the improved strain to a large domain. Results of Table 7 also reveal that the higher price would increase the profitability of hatchery which can afford to pay 2.9 to 8.3-times higher price for improved brood to the nucleus unit or NBC. This process will generate enough resources, leading to evolution of a self-supportive research and extension system in a country.

Business Plan

The strategies will not yield the desired results until infrastructural facilities and institutions for dissemination channels are built. The business plan for *Jayanti* rohu has been worked out, as an example, keeping the target of five years for 10 per cent replacement of the rohu by *Jayanti* rohu, covering large geographical areas of Indian states. Production of improved strain would be 0.1 million tonnes and with expected benefits, will provide US $ 30 million every year. It requires interventions at the nucleus level, seed production level (multiplier unit), seed and grow-out market, and policy levels. There is a need to strengthen nucleus, multiplier units, addition of multiplier units in other parts of India, second nucleus to safeguard the *Jayanti* strain, strengthening of private-public partnership, development of seed market, development of specialized outlets for the improved strain in seed markets, and development

Table 7. Economic potential price of fingerlings and broodstock in selected countries

Country	Increase in productivity due to improved strain, %	Fingerling price (US$ / thousand)			Broodstock price (US $ / brood)		
		Local strains	Improved strains	Price ratio (IS to TS)	Local strains	Improved strains	Price ratio (IS to TS)
Bangladesh (13.7)	35.4	3.1	8.3	2.7	2.6	7.8	2.9
India (8.3)	58.1	4.8	44.2	9.2	3.5	29.1	8.3
Thailand (10.2)	29.8	4.0	9.5	2.4	3.0	11.7	3.9

Source of data: Survey Carp 2

Figures within the parentheses are the shares of fingerlings in total variable cost of fish production.

of protocol and guidance for the culture of *Jayanti* rohu.

At the nucleus level, the existing capacity of the nucleus centre is to be fully utilized and it requires further improvement in infrastructure to sustain supply of the nucleus seed. For additional manpower, space and funds are needed. A regional base of five multiplier units needs to be developed. These multiplier units will be the National Broodstock Centres (NBC) and will supply broodstocks and fingerlings to hatchery and farmers, respectively. In addition, the extension system will be strengthened for creating awareness, conducting demonstrations, preparing and distributing publication materials and conducting training, visits and farmers meet. The nucleus unit at CIFA will supply 4000 nucleus brooder per multiplier unit. Each multiplier unit will have the capacity of producing 200 million seeds per year. It will require resources to build additional infrastructure and operational cost. The needed resources have been computed and are given in Table 8.

The budgetary requirements for developing infrastructure for *Jayanti* rohu dissemination will be US $ 100 million. In this, 53.2 per cent will be shared by public (government) sources, 20.3 per cent by private stakeholders through private-public partnership, and 26.6 per cent will be from international donor institutions like ADB, World Bank, and other international institutions. Almost US $ 20 million are needed for developing the NBC and US $ 12.5 million for seed market development. The research support at CIFA needs US $ 0.3 million. The genetically-improved nuclear seed can be charged at the rate of US $ 29.1/brood against US $ 3.5/brood for the local strain (Table 9). Thus, the research institute can generate US $ 0.51 million by selling 20 thousand nucleus brooders to five multiplier units. This amount is more than the projected budgetary requirements of CIFA. Once the policy for charging the economic potential price of improved strain is adopted, the research system would become self-resource supportive.

Conclusions and Policy Implications

The micro-level analysis has shown that the genetically-improved carp strain is economically viable and socially acceptable in all the countries under study for its adoption at various stages (viz. hatchery, seed-rearing farm and fish grow-out farm). The success of research for carp genetics and its economic evaluation have induced catalytic effects on policymakers to build strategies and institutions for the dissemination of improved carp strain on a large scale to benefit the resource-poor farmers in the Asian countries. Small hatcheries co-exist and concentrate on spawn production along with promoting contract farming for rearing of spawn to fry/fingerlings.

The price policy analysis of seed based on a small sample has provided the direction of price movement of improved strain and has tested the hypothesis that the threshold prices of improved strains are high but affordable for the stakeholders. A rational price policy will be able to generate enough resources to make

Table 8. Budgetary requirements for dissemination of Jayanti rohu in India

(in million US $)

Items	Total fund	Outsources		
		Public	Private	Donor
Research support	0.3	0.1	0.0	0.1
Nucleus level	3.7	3.1	0.0	0.6
Multiplier units	3.9	0.0	3.9	0.0
Extension and dissemination	1.5	0.8	0.0	0.7
National Broodstock Centre (NBC)	20.0	15.0	0.0	5.0
Enforcement for certification and quality control	2.5	2.5	0.0	0.0
Seed market development	12.5	2.5	5.0	5.0
Seed transportation	0.8	0.0	0.3	0.5
Total	45.1	24.0	9.1	12.0
Percentage	100.0	53.2	20.3	26.6

Table 9. Economic valuation of *Jayanti* rohu and resource generation in India

Item	Rohu	*Jayanti* rohu
Potential price of fingerlings (US$/thousand)	4.8	44.2
Potential price of broodstock (US $/brood)	3.5	29.1
Value addion to improved rohu strain (US $)		25.6
Sale of *Jayanti* broodstok nucleus (numbers)		20,000 to five NBCs
Total royalty to research institute (nucleus unit)		US $ 512000
Research support estimated for 10 per cent adoption (Table 8)		US $ 300000

the research and extension system self-supportive. The example of India has shown that once the policy for charging the economic potential price of improved strain is adopted, the research system would be self-sustainable in genetic improvement program. Before its introduction into policy planning, a comprehensive survey and systematic data collection on hatcheries management and rearing of fish at various stages (from nucleus seed to brood, spawn to fingerlings, and fingerlings to grow-out fish) are needed by category and size of hatcheries, nurseries, farms and markets under different agro-ecological locations. Based on the comprehensive data, price policy for improved strains can be built, tested and implemented.

It is necessary to generate awareness about the improved carp strain technology and to develop business plans for its higher adoption/ dissemination and self-supportive resource generation. The feasibility studies should be conducted for developing NBCs at different geographic locations. Seed demand should be assessed and multiplication centres across the countries should be increased to match the demand.

Research institutes must act as the nucleus unit to maintain germplasm and produce nucleus seeds. NBCs need be established at few convenient geographical locations with major responsibilities of production and sale of broodstock, development of country-specific standards for hatchery management and quality seed production on one hand, and conducting training and capacity building of hatchery operators, on the other. The agency for implementing accreditation of hatchery should be empowered with the responsibility of its registration and regular inspection for fish seed certification, quality assurance and price regulation of the improved strain for an affordable price. The public-private partnerships in establishing NBCs and model hatchery should be strengthened. There is a huge potential in contract farming for rearing spawn to fry/fingerlings. It will overcome the constraint of supply of quality seeds with improved strains. The seed markets should be developed and should have specialized outlets for improved strains of carp. Awareness generation about the improved carp strain technology has been suggested.

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