Chapter 5
Constraints to Increased Yields in Carp Farming: Implications for Future Genetic Research[1]

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5.1. Introduction

The Asian countries, particularly Bangladesh, China, India, Indonesia, Thailand and Vietnam are the largest producers of carps in the world. Various culture technologies and carp strains and varieties have been developed or introduced to these countries. The adoption of carp farming in Asia has greatly improved fish production. However, large difference in production levels exists among farms in each country and between countries, even in China, where carps have been cultured for thousands of years. Several issues related to carp production in Asia are important to the research community:

1. What are the production constraints?
2. What should be the priorities for research?
3. What is the best research strategy according to these priorities?

To meet the urgent need for increased carp production in developing countries of Asia (Delgado et al. 2003; Dey et al. 2004), the problems that affect carp yield must be clearly identified. Planners and policy-makers need information on the relative importance of various problems so that they can design and implement strategies to solve these problems. This chapter has the following specific objectives: (i) to identify the gap between the potential and actual yield (yield gap); (ii) to estimate the contribution of various technical constraints to the yield gap; and (iii) to suggest appropriate research strategies to solve these constraints.

5.2 Conceptual Framework and Survey Methodology

Following previous studies on similar subjects (Widawsky and O'Toole 1990, 1996; Dey et al. 1996; Lin and Shen 1996), the fundamental assumptions of this study are: 1) there exists a yield gap between potential and actual yield or there is a possibility of increasing potential yield; 2) the yield gap is due to a number of constraints; 3) the specific contribution of individual constraints can be estimated and cumulatively account for part, but not all, of the yield gap; and 4) based on the estimated value of yield loss, technical constraints can be ranked in order of importance.

Yield gap analysis has been used in agriculture for many years (IRRI, 1977, 1979; De Datta et al. 1978; Widawsky and O'Toole 1990; Evenson et al. 1996; Dey et al. 1996). Yield gap studies can demonstrate how close farm yields are to the maximal potential yield with the available technology. They can also suggest how to improve production more efficiently through the extension of present available technology or by developing new technologies.

Three definitions of yield gap are found in the literature. Yield gap I is defined as the difference between the yield observed on experimental stations and the best practice yield on farmers' fields. This yield gap probably is largely attributable to inherent differences in the biophysical environments (micro and macro) between the experimental station and typical farmers' fields, which cannot be easily managed

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or eliminated. Production research or changes in socioeconomic conditions can do little to exploit yield gap 1. Yield gap II is defined as the difference between actual and best practice yields on farmers' fields, given a particular technology. Yield gap II is caused by technological constraints (e.g. disease, soil problem, water quality problem, adverse climate/weather, etc.) and/or socioeconomic constraints (e.g. lack of credit, poor knowledge, input unavailability, tradition and attitudes, poor institutions, etc.). It is a measure of the yield that could be gained through technological and policy interventions to overcome constraints. This gap can be overcome if practical, profitable and sustainable means to control constraints are developed. Yield gap III is the difference between the theoretical potential yield and highest experimental yield. It represents the potential increase in biological efficiency, and is attributed to genetic and management improvement conceived but not yet developed or perfected. By definition this yield gap cannot be measured.

In this study the focus is on the technological constraints component of yield gap II. To get information on the yield gap and factors contributing to yield gap II, around 1900 carp farmers in six countries of Asia (Bangladesh, China, India, Indonesia, Thailand and Vietnam) were interviewed. Sampled farmers were asked to report their maximum, minimum and normal (average) yields obtained from particular pond(s)

Table 5.1. Yield gap II in carp culture by intensity level

Intensity Level[a]	Bangladesh	China	India	Indonesia[b]	Thailand	Northern Vietnam
"Low" intensity						
No. of farms	295	122	96	39	95	27
Potential (max) farm yield (mt/ha)	6.31	21.39	6.79	89.10	9.50	6.97
Average (actual) farm yield (mt/ha)	3.06	6.77	2.80	48.17	3.60	3.47
Yield gap II (mt/ha)	3.25	14.62	3.99	44.30	5.90	3.50
Yield gap II as % of max farm yield	54.88	68.36	58.76	49.72	62.11	50.19
"Medium" intensity						
No. of farms	146	155	232	71	105	56
Potential (max) farm yield (mt/ha)	6.69	28.95	14.62	96.10	10.60	10.11
Average (actual) farm yield (mt/ha)	3.23	11.69	3.20	57.40	3.70	3.53
Yield gap II (mt/ha)	3.46	17.26	11.42	38.70	6.90	6.58
Yield gap II as % of max farm yield	51.77	59.63	78.11	40.27	65.09	65.08
"High" intensity						
No. of farms	99	157	81	31	48	28
Potential (max) farm yield (mt/ha)	8.45	40.77	16.89	280.50	11.30	12.16
Average (actual) farm yield (mt/ha)	3.91	16.61	3.78	200.70	4.40	4.05
Yield gap II (mt/ha)	4.54	24.16	13.11	79.80	6.00	8.11
Yield gap II as % of max farm yield	53.76	59.26	77.62	28.45	53.09	66.69
Overall[b]						
No. of farms	540	434	409		248	111
Potential (max) farm yield (mt/ha)	7.13	27.18	14.94		10.58	10.38
Average (actual) farm yield (mt/ha)	3.26	12.08	3.20		3.78	3.65
Yield gap II (mt/ha)	3.87	15.10	11.74		6.80	6.73
Yield gap II as % to max farm yield	54.30	55.56	78.58		64.27	64.84

[a] Although most of the fish farms surveyed are semi-intensive in nature (except for some intensive pond culture in China and some intensive cage culture in Indonesia), the sample farmers were grouped into three intensity levels ("low", "medium" and "high") to see whether the yield gap varies with the changes in the intensity level. For all countries except Indonesia, the culture system/environment is pond polyculture under all intensity levels. For Indonesia, it is running water, floating cage and double floating cage for "low", "medium" and "high" intensity levels, respectively.

[b] Given the fact that the Indonesian sample from three culture systems /environments (i.e., running water, floating cage and double floating cage) represent three different levels of input intensity (low, medium and high); we have not done any analysis for the overall sample.

Source: Field surveys conducted by the authors..

during the last 10 years. Yield gap II was calculated as the difference between the maximum farm-level yield and the average actual farm-level yield. The adoption of a single maximum yield from the sample is not wise as it may be an outlier and hence may exaggerate the magnitude of the yield gap. To overcome this potential problem, the average of the top 5 per cent of the total sample was used as the maximal farm level yield.

A total of 1 883 fish farmers, who are knowledgeable about various technical details of fish farming, were interviewed in six countries[8] using a pre-designed questionnaire to collect information on yield gaps and yield losses by technical constraints. The interviews were conducted by experts who are also knowledgeable about local fish farming conditions, sometimes in the presence of one or more local fisheries/aquaculture workers. The survey covered pond polyculture in Bangladesh, China, India, Thailand and Vietnam, and monoculture of *C. carpio* in a running water system and cages in Indonesia.

5.3 Technical Constraints to Carp Production in Asia

Yield gap analysis

The overall average yield gap II in carp culture of the six countries examined is more than 50 per cent of the potential yield (Table 5.1). This yield gap is considerably larger than the country specific rice yield gaps estimated by the International Rice Research Institute (IRRI) and its partners in the early 1990s (Evenson et al. 1996). This may be due to the fact that, compared with rice cultivation, carp culture is carried out in a more complex environment. That is, farm fish production is more influenced by the environmental conditions than is rice cultivation.

Comparisons among the different countries indicate that on average Indonesia has the smallest yield gap for carp culture. In contrast, countries with considerable environmental variation and a diversity of culture systems, such as Bangladesh, China, India and Thailand, have relatively higher yield gaps. The average ratio of the yield gap to the potential yield is between 54 and 79 per cent in all countries, except Indonesia. Although most of the fish farms surveyed were semi-intensive in nature (except for some intensive pond culture in China and some intensive cage culture in Indonesia), the sample farmers were divided into three intensity levels ("low", "medium" and "high" to see whether the yield gap varies with the changes in the intensity level. In general, the yield gap is higher in higher intensity farms, as is the average yield.

Yield loss analysis

To explain the yield gap II in present carp culture in the six different countries, yield loss analysis was undertaken. It was expected that the yield loss analysis by technical constraints would provide insights into identifying priority areas for further genetic research to improve production. Two kinds of technical constraints, abiotic (e.g. water, soil, temperature, etc.) and biotic (e.g. disease) were identified by biologists and included in the study. The financial loss caused by different factors (constraints) was estimated, based on the producer survey data. The results of this analysis are in Table 5.2. The outcome of the Indonesian study could not be incorporated into this analysis because data collection differed from that in other countries.

The reported total annual financial loss caused by various biotic and abiotic factors ranged from US$243/year/ha (Bangladesh) to US$1 691/year/ha (China). Financial loss as a percentage of the total yield was highest in northern Vietnam and Thailand (53 and 54 per cent, respectively) and lowest in Bangladesh (14 per cent). Such wide differences mainly result from factors included in the study by different countries or institutions. Given the fact that the average yield gap II is about 65 per cent of the potential yield (i.e. yield gap is about 185 per cent of the average yield) (Table 5.1), the result of the yield loss explained only a small portion of the gap II. As hypothesized earlier, technical constraints account for only a part of the total yield gap II. Yield loss estimated under this study did not include an analysis of the socioeconomic factors. Many of the small-scale fish farmers in Asia are risk averse, i.e. they are not prepared to take the financial risks involved in intensification.

The study revealed that water quantity and quality (specifically, high turbidity and low dissolved oxygen) and diseases (bacterial and viral) are factors contributing most to yield loss. Soil problems and extreme temperatures also

[8] The number of farmers interviewed in each of the countries are given in Table 5.2.

contribute to the total yield loss among farmers in Thailand. Among the important factors contributing to the total yield loss, low dissolved oxygen and disease are related to both the fish and farm management. The results presented in Table 5.2 indicates that the losses per hectare due to low DO and diseases are higher in countries with a more intensive production system (e.g. China). Improved farm management can reduce the likelihood of low dissolved oxygen and outbreaks of disease. However, it is not possible to avoid losses from these factors in today's carp culture practices, especially with the tendency to increase the farming intensity level. Therefore,

Table 5.2. Yield loss (US$/year/ha) caused by various factors in five participating countries

Factor	Bangladesh	China	India	Thailand	Northern Vietnam	Average
Water quality	170.98	776.48	269.86	139.17	470.07	365.31
High turbidity	109.28	-	-	26.68	-	27.19
Plankton bloom	21.17	77.48	5.50	21.11	-	25.05
Filamentous algae/weeds	4.52	-	-	68.53	-	14.61
Low Dissolved Oxygen	36.01	442.48	264.36	22.85	470.07	247.15
Pollution	-	256.52	-	-	-	51.30
Water	55.74	-	211.51	341.81	378.35	197.48
Shortage of water	8.48	-	211.51	89.88	378.35	137.64
Flooding	47.26	-	-	251.93	-	59.84
Soil Problem	8.42	-	-	184.51	-	38.59
Acidity	-	-	-	108.54	-	21.71
Sedimentation	-	-	-	5.48	-	1.10
Seepage	8.42	-	-	70.49	-	15.78
Disease	8.11	625.06	247.71	128.71	354.15	272.75
Virus	2.58	253.09	-	61.91	-	63.52
Bacteria	5.53	258.58	247.71	66.80	-	115.72
Parasite	-	113.39	-	-	-	22.68
Temperature	-	84.90	-	123.85	15.29	44.81
High	-	47.21	-	28.72	-	15.19
Low	-	30.37	-	95.13	15.29	28.16
Abnormal fluctuation	-	7.32	-	-	-	1.46
Others	-	119.79	-	189.78	48.41	71.60
Reduced growth	-	61.33	-	-	-	12.27
Easily affected by disease	-	58.46	-	-	-	11.69
Others	-	-	-	-	-	-
Total loss (US$/ha)	243.24	1 691.13	729.08	1 231.68	1 281.56	1 035.34
Average gross output (US$/ha)	1 715.12	10 797.11	2 124.53	2 343.42	2 374.07	3 870.85
Loss % of the yield	14.18	15.66	34.32	52.56	53.98	34.14

Source: Field surveys conducted by the authors

Table 5. 3. Percentage of each factor of the total yield loss

Factor	Bangladesh	China	India	Thailand	Northern Vietnam	Average
Water quality	70.29	45.91	37.01	11.30	36.68	40.24
High turbidity	44.92	0.00	0.00	2.17	0.00	9.42
Plankton bloom	8.70	4.58	0.75	1.71	0.00	3.15
Fila. Algae/weed	1.86	0.00	0.00	5.56	0.00	1.48
Low Dissolved Oxygen	14.80	26.16	36.26	1.86	36.68	23.15
Pollution	0.00	15.17	0.00	0.00	0.00	3.03
Water quantity	22.91	0.00	29.01	27.75	29.52	21.84
Shortage of water	3.49	0.00	29.01	7.30	29.52	13.86
Flooding	19.43	0.00	0.00	20.45	0.00	7.98
Soil Problem	3.46	0.00	0.00	14.98	0.00	3.69
Acidity	0.00	0.00	0.00	8.81	0.00	1.76
Sedimentation	0.00	0.00	0.00	0.44	0.00	0.09
Seepage	3.46	0.00	0.00	5.72	0.00	1.84
Disease	3.33	36.96	33.98	10.45	27.63	22.47
Virus	1.06	14.97	0.00	5.03	0.00	4.21
Bacteria	2.27	15.29	33.98	5.42	0.00	11.39
Parasite	0.00	6.70	0.00	0.00	0.00	1.34
Temperature	0.00	5.02	0.00	10.06	1.19	3.25
High	0.00	2.79	0.00	2.33	0.00	1.02
Low	0.00	1.80	0.00	7.72	1.19	2.14
Abnormal fluctuation	0.00	0.43	0.00	0.00	0.00	0.09
Others	0.00	7.08	0.00	15.41	3.78	5.25
Reduced growth	0.00	3.63	0.00	0.00	0.00	0.73
Easily affected by disease	0.00	3.46	0.00	0.00	0.00	0.69
Total Loss	100.00	100.00	100.00	100.00	100.00	100.00

Source: Field surveys conducted by the authors

geneticists and other scientists may look into the possibilities of initiating research to develop strains of fish that are resistant to disease and tolerant to low dissolved oxygen (DO). Apart from tolerance to low dissolved oxygen and resistance to disease, other problems such as intolerance to extreme temperatures may also be solved through genetic research. A closer examination of these data, however, shows that genetic gains may be able to reduce the total loss by only 18 per cent. On the other hand, 80 per cent of the total loss can be reduced by better management and other types of research (Table 5.4). Genetic research can also reduce yield gap III by increasing the highest potential yield (i.e. by pushing the yield frontier further). It is, however, important to note that there is a biological and ecological limit to which yield can be increased.

5.4 Conclusion

This chapter represents a first step towards identifying priorities for genetic research in Asia through economic analysis. The present yield gap and yield losses caused by various factors identified provide guidance to develop a strategy to further improve the production of carp culture in Asia and the world. Important traits that could be improved through genetic methods to increase the production quantity and output quality have been identified.

It is, however, important to note that the data presented in this chapter on yield loss are measures of demand for yield increasing research. For identifying genetic research priorities, the supply side of the research (i.e. research discovery

Table 5.4. Percentage of each factor of the total yield loss classified by potential solutions

Factor	Bangladesh	China	India	Thailand	Northern Vietnam
Genetic research	18.14	71.75	70.24	35.15	65.90
Disease (total)	3.33	38.91	33.98	11.62	27.80
Virus	1.06	15.76	-	5.59	-
Bacteria	2.27	16.10	33.98	6.03	-
Parasite	-	7.06	-	-	-
Soil Problem	-	-	-	10.29	-
Acidity	-	-	-	9.80	-
Sedimentation	-	-	-	0.49	-
Water quality	14.80	27.55	36.26	2.06	36.90
Low Dissolved Oxygen	14.80	27.55	36.26	2.06	36.90
Temperature	-	5.29	-	11.18	1.20
High	-	2.94	-	2.59	-
Low	-	1.89	-	8.59	1.20
Abnormal fluctuation	-	0.46	-	-	-
Other form of research	1.86	-	-	23.32	-
Filamentous algae/weeds	1.86	-	-	6.19	-
Others (predators)	-	-	-	17.13	-
Management	80.00	20.79	29.76	41.53	33.50
Water quality	53.63	4.82	0.75	4.31	-
High turbidity	44.92	-	-	2.41	-
Plankton bloom	8.70	4.82	0.75	1.91	-
Water quantity	26.38	15.97	29.01	37.22	29.70
Shortage of water	3.49	-	29.01	8.11	29.70
Flooding	19.43	-	-	22.74	-
Pollution	-	15.97	-	-	-
Seepage	3.46	-	-	6.36	-
Others	-	-	-	-	3.80

Source: Field surveys conducted by the authors.

process) would also need to be considered. Some problems are more difficult than others for research to address - they require more time or money to investigate, or have been less explored previously and there may be greater uncertainty associated with conducting research on them. For example, it is currently more feasible to develop disease resistant fish strains than to develop strains tolerant to low DO. There is a need to collect additional information on the likelihood, possible time length and cost of solving the constraints identified.

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