Genetic Diversity and Selective Breeding of Red Common Carps in China

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Abstract

China has a very rich genetic diversity in common carp (*Cyprinus carpio*) and the red common carp plays an important role in Chinese aquaculture and genetic studies.

Selective breeding, particularly crossbreeding has been applied successfully to red common carps in China, and the products of these efforts have been in commercial use since the 1970s. However, knowledge of the quantitative and molecular genetics of these carps is limited. Studies were therefore undertaken to: (1) understand the genetic diversity and genetic relationship of red common carps in China; (2) understand the inheritance of color phenotype of Oujiang color carp; (3) select stable Oujiang color carp with fast growth rate and ornamental Oujiang color carp comparable with the Koi common carp from Japan; (4) study the culture performance and culture systems suitable for the Oujiang color carp in cages and paddies; (5) extend better quality fish and appropriate culture systems for small scale fish farmers in poor areas.

Introduction

Background

China is one of 12 countries known for its huge biodiversity. There are about 800 species of freshwater fishes in China of which approximately half belong to the Cyprinidae, ie carps. Of these, common carp is the earliest cultivated fish species (probably in the world also). At present the common carp is a principal species in aquaculture and production reached 2.05 million t in 1999 and accounted for 20% of total freshwater fish production in China.

During the long history of its culture, many strains/varieties have evolved and display rich biodiversity and genetic polymorphism. They have played different roles in China's aquaculture industry.

The large diversity in

Fig. 1. Xingguo red common carp.

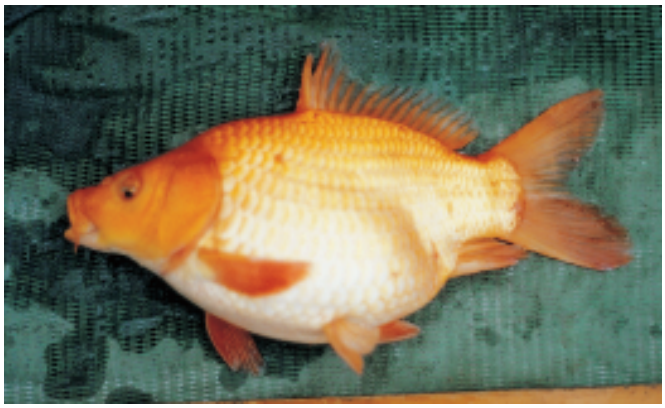

Fig. 2. Purse red common carp.

pigmentation is one of the major characteristics of common carp living in its natural environment and different domesticated environments.

Red common carps, especially Xingguo red common carp (*C. carpio* var. *Singuonensis,* Fig.1*)*, purse red common carp (*C. carpio* var. *Wuyuanensis,* Fig. 2*)*, glass red common carp (*C. carpio* var. *Wananensis,* Fig. 3*)*, generally known as " Jiangxi Three Red Common Carps", were produced by Chinese fish breeders through selection. They are commonly used in hybridization and many genetic studies.

Xingguo red common carp is a regional species of Xingguo county and has more than 1 300 years of culture history. Through 6 generations of selection between 1972-1984, its growth rate improved by 12.7%, with 86.6% completely red color individuals and average body length/depth ratio of 3.38, and a spindle shape (Xingguo red common carp Farm, Biology Department of Jiangxi University 1985).

Purse red common carp is found in Wuyuan county where it is relatively isolated and its culture history might date back 300 years. Selection for body shape and red color was undertaken between 1969 and 1979. In the sixth generation, red individuals formed 89.8% of the population with body length/depth ratio of 2.0-2.3, and purse shape (Agriculture Research Institute of Wuyuan County, Jiangxi Province 1982, unpublished report) .

Glass red common carp originated from four mutant individuals of a farmer's reared population in Wanan county in 1963. Its morphology was very close to the Xingguo red common carp except for its transparent color. After 6 generations' selection between 1973-1983, the body remains transparent and the gut and gills can be seen from the outside in the larval stage. In adult fish, completely red individuals comprised 84% of the population (Wanan Fish Farm, Jiangxi University 1984, unpublished report).

"Jiangxi Three Red Common Carps" have been introduced into many provinces of China since the 1970s. Besides use in culture, they are widely used in genetic and breeding studies; many hybrid combinations were produced between these red common carps and local strains of common carp or crucian carp (Table 1). Some of these hybrids have played a significant role in increasing production from carp culture and economic development in local societies (Li et al. 1998)

For several decades, studies on "Jiangxi Three Red Common Carps"

Fig. 3. Glass red common carp.

Fig. 4. Oujiang color common carp.

Table 1. Some hybrids made by crosses with red common carps in China

Hybrid	Parental combination
Feng common carp	Xingguo red common carp(♀); Scatter mirror carp(♂)
He-Yuang common carp	Purse red common carp(♀); Yuangjiang river carp(♂)
Yue common carp	Purse red common carp(♀); Xiangjiang river carp(♂)
Tri-hybridization carp	He-Yuang common carp(♀); Scatter mirror carp(♂)
Lotus common carp	Scatter mirror carp(♀); Xingguo red common carp(♂)
Allogynogenetic crucian carp	Fangzheng crucian carp(♀); Xingguo red common carp(♂)
Cold resistance strain of Purse red common carp	Helongjiang river carp(♀); Purse red common carp(♂)
Jian common carp	Purse red common carp(♀); Yuangjiang river carp(♂)

The listed hybrids have been certified as good varieties for aquaculture by the National Certification Committee on Wild and Bred Aquatic Varieties of China

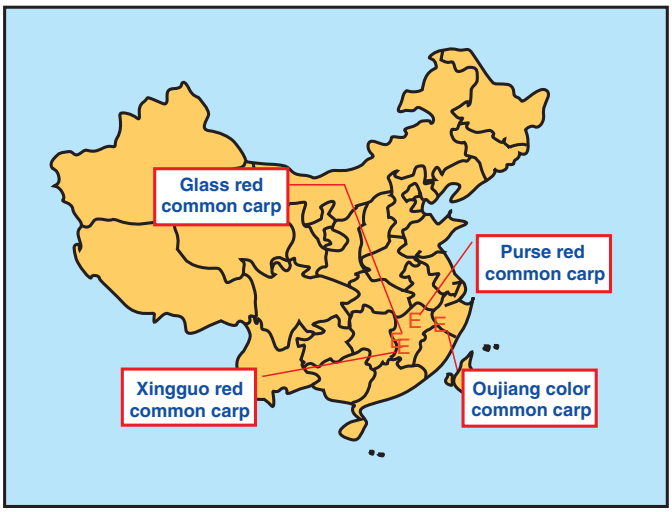

Fig. 5. Geographical distribution of red common carps in China.

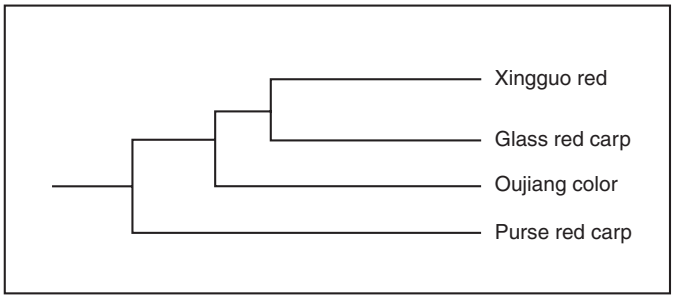

Fig. 6. Phylogenetic tree constructed by UPGMA method of four red carps.

Table 2. Growth rate in various pigmentation types(adult stage) of Oujiang color common carp.

Color type	Initial weight (g)	Final weight (g)	Experiment period (d)	AGR (g/d)	SGR (%/d)
Whole red	34.4±9.2	914.7±267.0	195	4.51	1.68
Red color with big black spots	32.2±10.1	967.6±279.6	195	4.80	1.75
Red color with small black spots	36.0±6.5	904.7±288.5	195	4.46	1.65
Whole white	36.4±8.3	992.7±286.9	195	4.90	1.70
White color with big black spots	37.01±4.5	951.1±330.6	195	4.69	1.67

AGR = absolute growth rate; SGR = specific growth rate

focused mainly on traditional biological characters: morphological, ecological and growth performance. As these studies were conducted separately (Jiang1964; Fu1985; Guo1983; Lin 1985; Yi et al. 1991), with no comparative study, knowledge about their genetic structure and relationship is poor.

Besides the "Jiangxi Three Red Common Carp", attention has recently focused on the Oujiang color common carp (Fig. 4), which is found in the Oujiang river basin, in Longquan city, Qingtian county, southern Zhejiang province adjoining Jiangxi province (Fig. 5). Its very gentle and schooling habits make this species adaptable to shallow paddy and high density cage culture systems with resultant high productions. This fish is characterized by a variety of body colors, such as completely red, red with scattered black spots, completely white and white with scattered black spots. The culture of Oujiang color common carp can be traced back 1 200 years in several counties in the southern part of Zhejiang Province, but no scientific studies were undertaken until 2000.

Although the red common carps have played and continue to play an important role in carp culture in China, their genetic diversity, especially at molecular level, is very poorly understood, and the genetic mechanisms in crossbreeding are not clear. There would be a theoretical value in body-color inheritance of the fish and practical feasibility in selection of ornamental carp if the studies on exploitation and utility on Oujiang color common carp could be carried out.

Primary study and results

Genetic relationship of four red common carps

The study undertaken covers aspects of morphology, biochemistry and molecular genetics. The molecular genetics study focused on aspects such as mtDNA RFLP analysis, and genomic microsatellite DNA analysis.

In year 2000, Random Amplified Polymorphic DNA (RAPD) analysis was carried out to examine the genetic structures and phylogenetic relationships of four red carps (Fig. 6).

A study of differences in morphology, and isoenzymes was also conducted in early 2001.

Selective Breeding

Selective breeding was undertaken in Oujiang color carp with the objectives of: (1) producing a stable fish strain with improved growth rate and yield capacity; (2) producing ornamental common carp with different pigmentation patterns.

Growth-color pattern relationship evaluation

In year 2000, evaluation of growth performance of five pigmentation types of Oujiang color carp was undertaken in concrete ponds at juvenile stage and in reservoir cages at adult stage. At the juvenile stage, 60 individuals of each body color type were communally stocked in 4 concrete ponds for 6 months, the absolute growth rate (AGR) ranged from 0.55-0.81g/d and specific growth rate (SGR) ranged from 2.52-2.80%/d in various pigmen-tation types. At the adult stage, 20 cages (2x2x1m) were used under monostocking and communal stocking, and density effects on growth rate were evaluated. Table 2 presents the results of the communal stocking trial, in which four cages were used. Each cage was stocked with 400 fish comprising the five pigmentation types; each pigmentation type comprising 80 individuals. The AGR ranged from 4.51-4.90 g/d and the SGR ranged from 1.65-1.75%/d (Cheng et al. 2001).

There was no significant difference in growth among the five pigmentation patterns.

Study on color inheritance

In year 2000, nearly 10 000 fishes of Oujiang color common carp were collected from many private farmers, five typical pigmentation patterns were selected and established as the foundation population. Fifteen mating pairs (female and male with the same color) were spawned in earthen ponds (10-20 m^2). Their offspring were raised in different tanks (50 m^2). Their pigmentation patterns were estimated when their lengths reached 15-20 cm and when there was stable pigmentation. The preliminary results are presented in Table 3. The pairs of completely red and completely white color pattern produced almost 100% completely red and completely white offspring, and the other three color patterns produced a rather high rate (over 70%) of same color type offspring as parents. These results indicated the existence of strong genetic inheritance in pigmentation pattern.

Table 3. Color phenotype in F1 generations from various pigmentation types parents in Oujiang color common carp.

Parents color	Color pattern in F1(%)				
	Offspring color	In mating combination 1	In mating combination 2	In mating combination 3	Mean rate
Whole red	Whole red	99.11	99.76	Occasionally died	99.44
	Red color with big black spots	0.89	0.24		0.56
Red color with big black spots	Whole red	4.45	23.53	37.28	21.75
	Red color with big black spots	95.55	76.47	62.72	78.25
Red color with small black spots	Whole red	24.52	11.22	10.46	15.40
	Red color with big black spots	0	27.55	11.72	13.09
	Red color with small black spots	75.48	61.23	77.82	71.51
Whole white	Whole white	99.21	100	100	99.74
	White color with big black spots	0.79	0	0	0.26
White color with big black spots	Whole white	26.41	4.26	20.98	17.22
	White color with big black spots	73.59	95.74	80.12	82.78

Fig. 7. Fish paddies on the mountain areas of Oujiang River basin.

Fig. 8. Harvesting red carp in paddy terraces.

Fig. 9. Bringing fish home.

Planned study

Studies will be undertaken to:
(1) select ornamental Oujiang color carp with various stable color patterns;
(2) demonstrate and expand the population of Oujiang color carp suitable for paddies and cage systems.

Selection

In year 2001, selection will be undertaken to look for traits such as the dominant gene in body colour and fast growth rate.

Quantitative genetics study

Quantitative genetics plays a critical role in selective and cross breeding, but it is rather weak in China. There are only a few reports [Zhang(1981) reported on a preliminary estimation of heritability of common carp]. The red common carps, especially Xingguo red common carp and purse red common carp, have produced many hybrid combinations, but information on their genetic contribution to heterosis is very limited.

A diallel cross experiment is planned to evaluate the genetic factors in variations of growth and morphological parameters including body shape. Mixed linear models will be employed. The study will focus on:

(1) General genetic effects analysis

According to the mixed linear model, total genetic effects could be divided into additive effect, dominance effect, additive x additive effect and additive x dominance effect etc, and each effect would be evaluated separately. The results will be very useful for further selective breeding.

(2) Genetic-environment interaction effects analysis

Quantitative traits of fishes are dominated by genetic effects and environmental conditions such as nutrition, water quality and management. Through the analysis of genotype-environment interaction effects of red common carps and their hybrids reared in different conditions, the genetic effects, environmental effects and genotype-environment interaction effects on growth performance could be estimated.

Demonstration and extension

Oujiang Red common carp is cultured traditionally in the mountainous area (Figure 7-9) of Zhejiang province, where transportation is poor, the availability of seafood rare, and purchasing power low. The farmers culture red carp in their yard ponds or paddies as source of protein and for occasions of celebration. Home made smoked red carp is a famous local product originated from the Oujiang river basin. Because of population isolation and poor environmental conditions, the breeding population is small, and under serious threat of inbreeding. In some places, the red carp matures at 100-150 g during its second year, and the harvest size is rather small and varied.

Through genetic breeding, we believe that the Oujiang red common carp can retain its genetic advantages (such as tough habits) and improved growth rate, etc. A genetically improved strain of red carp will meet the demand of small-scale private farming.

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Meeting on Biodiversity Education and Public Awareness

Education and public awareness are essential to reverse the loss of biological diversity. The Convention on Biological Diversity (CBD) and United Nations Educational, Scientific and Cultural Organization (UNESCO) Consultative working group of experts, charged with developing and testing a global initiative on biological diversity education and public awareness, as a follow-up of decision adopted at the Fifth Conference of the Parties of the Convention on Biological Diversity, held a meeting from 5-7 November 2001 in Bilbao, Spain. The aims of the global initiative included creating dynamics or awareness leading to participation and action in the conservation, sustainable use and equitable sharing of benefits of biological diversity; and providing an overall strategy for the implementation of national and international solutions to specific issues in the area of biodiversity education and public awareness.

For more information, contact: Mr. Hamdallah Zedan, Executive Secretary; Secretariat of the Convention on Biological Diversity; Tel: 514 288 2220; Fax: 514 288 6588;
E-mail: secretariat@biodiv.org; web: http://www.biodiv.org

Biosafety Workshop in Africa

Africa is considered the world's repository of diverse freshwater fish fauna, especially tilapias. However, many freshwater species in African waters are already on the verge of extinction due to introduction of exotics, over fishing and habitat degradation. Declining catches from the wild coupled with increasing population has led farmers to embark on fish farming. Some African countries have initiated genetic improvement programs to develop high yielding strains and introduced exotic species for aquaculture. However, the improved strains that result from their research and the exotics are likely to find their way to other countries in the region, escape into the wild where they may have negative influence on the native populations. Keeping in view the need for increased production to meet the needs of the African population, it is also essential to protect the aquatic environment and conserve the biodiversity. A number of issues need to be addressed if the full benefits of genetic improvement programs are to be realized in the region.

In this context, an 'Expert Consultation on Biosafety and Environmental Impact of Genetic Enhancement and Introduction of Improved Strains and Exotics in Africa' is being organized by ICLARM-The World Fish Center, in collaboration with the Technical Center for Agriculture and Rural Cooperation (CTA), Food and Agriculture Organization of the United Nations (FAO) and World Conservation Union (IUCN). The meeting will be held in Nairobi, Kenya on 20-23 February 2002 and this will focus on: (i) evaluating the potential benefits and risks of genetic enhancement and introduction of improved germplasm; (ii) developing guidelines for regulating translocation, quarantine and dissemination of improved strains; (iii) promoting greater awareness among policy makers of the need for conservation and management of aquatic genetic resources; and (iv) promoting consultation among African agencies and coordinating in genetics research for aquatic species and dissemination of improved germplasm.

The workshop is expected to be attended by fisheries officials from African countries, fish breeders, geneticists and invited resource persons familiar with the environmental impacts of genetically modified organisms and biodiversity conservation.

A Manual on Induced Breeding and Seed Production of Bighead Carp

The bighead carp, *Aristicthys nobilis* has become a popular fish for freshwater aquaculture in the Philippines and in many parts of Asia because of its fast growth and high survival. The Southeast Asian Fisheries Development Center Aquaculture Department (SEAFDEC AQD), an Associate Member of INGA, has been conducting extensive research on this species since 1979. The significant findings of SEAFDEC AQD's research on culture, breeding, gonad maturation and rematuration of bighead carp in floating net cages have accelerated the development of bighead carp culture in the Philippines. The technology developed through the years by SEAFDEC AQD and its partners for this commodity is summarized in a manual entitled 'Induced Breeding and Seed Production of Bighead carp *Aristichthys nobilis* (Richardson)', by A.C. Gonzal, C.B. Santiago, A.C. Fermin, and E.V. Aralar. Published in July 2001, the manual is expected to benefit aquaculturists who may want to go into production of bighead carp, as well as extension workers, technicians, teachers and students in the field of aquaculture.

For more information, contact: Training and Information Division, SEAFDEC Aquaculture Department, Tigbauan, Iloilo 5021, Philippines; Fax: (63-33) 335 1008, 336 2891; E-mail: tid@i-iloilo.com.ph/bfs; aqd@i-iloilo.com.ph; devcom@aqd.seafdec.org.ph

INGA Expands Membership

Deakin University, Australia has recently been admitted as an Associate Member of the International Network on Genetics in Aquaculture. With their expertise in molecular genetics, they will be able to contribute to achieving the objectives of the network. To date, INGA has 13 developing countries as Members, 10 advanced scientific institutions and two regional/ international organizations as Associate Members.

Germplasm Transfer

The Rajadanu strain of common carp (*Cyprinus caprio*) has been transferred from Indonesia to India. This strain will be evaluated, along with the other two common carp strains received from Hungary (Sarwas P3 and wild strain) and three strains received from Vietnam (common carp1; selected Vietnamese2; Vietnamese local), and initiate suitable breeding program for increased growth and late maturity.

Arrangements are also being made by the Government of India for transfer of wild germplasm of rohu (*Labeo rohita*) to Vietnam. The fish for Vietnam will be used for strain evaluation and subsequent genetic improvement.

Requests are being received from private sector organizations in a number of countries for GIFT Nile tilapia.