with potassium permanganate in order to maintain the primary productivity of ponds.

Potassium permanganate may also be used to oxidise the piscicides such as rotenone and antimycin[7]. However, potassium permanganate has been shown to be toxic in itself, with adverse effects observed in some fish at concentrations of 2mg/litre in tap water[17]. The toxicity of potassium permanganate, and its effectiveness as a treatment appeared to be reduced by the presence of organic matter in ponds.

Conclusion

Liming materials may contribute substantially to fish yields by improving conditions for fish, and by enhancing the primary productivity of the pond. Alum is an effective flocculant for reducing clay turbidity. Gypsum is less useful in this regard, but is better suited to raising hardness than lime or alum because of its greater solubility. Potassium permanganate is a useful disinfectant, but may actually be detrimental if added to ponds suffering from oxygen depletion.

References

1. Swingle, H.S. (1957). "Relationship of pH of pond waters to their suitability for fish culture", *Proceedings of the 9th Pacific Science Congress*.
2. Anon. (1998). "Study guide SQQ631 Water Quality Management", Deakin University, Geelong.
3. Boyd, C.E. (1982). "Liming fish ponds", *Journal of Soil and Water Conservation*, vol 37, no 2, pp 86-88.
4. Arce, R. & Boyd , C.E. (1975). "Effects of agricultural limestone on water chemistry, phytoplankton productivity and fish production in soft water ponds", *Transactions of the American Fisheries Society*, vol 104, no2, pp 308-349.
5. Boyd, C.E. & Scarsbrook, E. (1974). "Effects of agricultural limestone on phytoplankton communities of fish ponds", *Arch Hydrobiol*, vol 74, no 8, pp 336-49.
6. Witschi, W. and Ziebell, C. (1979). "Evaluation of pH shock on hatchery-reared rainbow trout", *Progressive Fish-Culturist*, vol 41, pp 3-5.
7. Boyd, C.E. (1990). "*Water quality in ponds for Aquaculture*", Birmingham Publishing Co., Alabama 482 pp.
8. Boyd, C.E. (1984). "Fluids beat granular in fish pond trials", *Solutions*, February.
9. Boyd, C.E. (1971). "Phosphorus dynamics in ponds", *Proceedings of 25th Annual conference of the Southeastern Association of Game and Fish Commissioners*, pp 418-26.
10. Hepher, B. (1962). "Ten years of research in fish ponds fertilization in Israel, I. The effect of fertilization on fish yields", *Bamidgeh*, vol 15, pp 78-92.
11. Pillai, V.K. & Boyd, C.E. (1985). "A simple method for calculating liming rates for fish ponds", *Aquaculture*, vol 46, pp 157-62.
12. Boyd, C.E. (1976). "Liming farm fish ponds", *Leaflet 91, Agricultural Experiment Station*, Auburn University, Alabama, April.
13. Boyd, C.E. (1981). "Fertilisation of warmwater fish ponds", *Journal of Soil and Water Conservation*, vol 36, pp 142-145.
14. Boyd (1979). "Aluminium sulfate (alum) for precipitating clay turbidity from fish ponds", *Transactions of the American Fisheries Society*, vol 108, pp307-13.
15. Mandal, B.K. & Boyd, C.E. (1980). "Reduction of pH in waters with high total alkalinity and low total hardness", *The Progressive Fish-Culturist*, vol 42, no 3, July, pp 183-84.
16. Wu, R. & Boyd, C.E. (1990). "Evaluation of calcium sulfate for use in aquaculture ponds", *The Progressive Fish-Culturist*, vol 52, pp 26-31.
17. Tucker, C.S. and Boyd, C.E. (1977), "Relationships between potassium permanganate treatment and water quality", *Transactions of the American Fisheries Society*, vol 106, pp 481-88.
18. Hepher, B. (1963). "Ten years of research in fish ponds fertilization in Israel, II. Fertilizers dose and frequency of fertilization", *Bamidgeh*, vol 15, pp 78-92.

The utilizations of heterosis in common carp in China

Dong Z.J. and Yuan X.H.

Common carp *Cyprinus carpio* is one of the principal cultured species in China. The production of cultured common carp reached 2.05 million ton in 1999 and accounted for 20% of total freshwater fish production. Since the farming of this fish extends back to ancient times, common carp has a wide distribution in China. As a result of long-term selection (both natural and artificial), common carp populations have acquired a great deal of genetic diversity – there is a great deal of polymorphism in its phenotype and genotype and its genetic structure has high heterozygosity. This heterosis provides the opportunity to improve the productivity of carp through selective breeding.

The utilization of heterosis in selective breeding is an effective way to improve fish quality and increase fish production. Since 1970s, Chinese fisheries scientists have made broad studies on the utilization of heterosis in common carp and achieved significant results. Traits in which crossbreeds express heterosis include improved survival, growth and tolerance to cold and specific diseases. The followings are some hybrids of common carp that have been successfully extended to the practice.

Applications of heterosis in common carp

Feng carp

This hybrid comes from the combination of Xingguo red carp × scattered mirror carp, first developed by staff at the Hubei Institute of Hydrobiology. At the fingerling stage, the growth rate of Feng carp is typically 1.5-1.6 times of that of maternal fish, and at the adult stage, 1.32 times.

Heyuan carp

This crossbreed is obtained from the hybridization between purse red carp × Yuanjiang carp. It has some advantages included a high growth rate, good body shape, high feed conversion rate and a high capture rate.

Yue carp

These are the first generation offspring (F1) of the hybridization combination of purse red carp × Xiangjiang carp. Their growth rate is 50-100% more than the paternal fish and 25-50% than the maternal fish. Field trials have shown that they can reach market size after 200 days culture in the Hunan area (central China).

Triple-hybrid carp

The maternal and paternal fish of this hybrid is Heyuan carp and scattered mirror carp, respectively. The growth increment of the hybrid is 15% and 50% greater than the maternal and paternal fish, respectively.

Lotus carp

This was first obtained by crossing scattered mirror carp and Xingguo red carp, first conducted in 1975. This carp may reach 6kg after the first year of cultivation.

Jian carp

The varieties of carp we mentioned before are all hybrids. The traits of the offspring of the hybrid carps will be segregated. So new hybrids should be made every year and at least two varieties of parental fish must be conserved in order to obtain the hybrid carps. This can be inconvenient in practice. Jian carp is the first variety of common carp that was produced by artificial breeding in China. The technique applied in its breeding procedure includes hybridization, family selection and gynogenesis. Jian carp has several advantageous characteristics, for example, a high growth rate and fine body shape. The growth advantage of Jian carp is significant. The body weight increment outperforms purse red carp, Yuanjiang carp and Heyuan carp by a factor of 141-250 %, 80-96 % and 40-42 %, respectively. The gross production of this carp may be more than 30% greater than other varieties of common carp.

Molecular studies on the mechanism of heterosis

It takes several years for fish to reach maturity and selecting heterotic crossbreeds from hybrid combinations often takes a lot of selection work, time and effort. Therefore, a study looking for a stable and practical index to predict heterosis is a highly desirable aid for fish breeding. Fisheries scientists in China also have tried to study the mechanism and prediction of heterosis at a molecular level. Random amplified polymorphic DNA (RAPD) technique was applied to analyze the genetic relationship within and between Feng carp and the parental fish. The genetic distance between parental fish and genetic similarity indices between Feng carp and parental carps were calculated. The results showed that the genetic distance between Xingguo red carp and scattered mirror carp was farthest in the experimental fish. The genetic similarity indices between Feng carp and two parental fish were almost same, which indicated that Feng carp inherited equal genetic material from maternal and paternal fish. The same technique was also used to examine the heterozygosity of Jian carp. The result revealed that Jian carp has a higher ratio of polymorphic loci and higher average allelic heterozygosity compared to other carp populations. The advantageous traits of Jian carp may come from the greater heterozygosity of these fish.

Suggestions on the utilization of heterosis

The major factors influencing heterosis include the genetic relationship and the purity of the parents. We know that within a certain range, hybrids generated by varieties with a farther 'genetic distance' (ie. that are less closely related) have a greater heterosis. So in practice, we should use varieties with a farther genetic distance as the parental stock to generate hybrids with high heterosis and superior characteristics. But how can we know which varieties have a greater genetic distance? Molecular biological methods are highly accurate but are not available to farmers. Fortunately, there are some general guidelines that farmers can use to select broodstock varieties with a greater genetic distance:

1. Varieties whose native habitats lie in widely separated geographic regions usually have a greater genetic distance and can be used as parents to produce heterotic hybrids. For example, the crossbreeds of purse red carp (native habitat in Jiangxi, mid-east of China) and Yuanjiang carp (native habitat in Yunan, southwest of China) have a high heterosis.

2. Varieties with greater differences in morphology/body shape or physiology can be used as parental stock to produce crossbreeds of high heterosis. Evidence of this comes from Feng carp and lotus carp whose parental fish are Xingguo red carp (red color and all scales) and scattered mirror carp (caesious color and scattered scales).

3. Another factor influencing heterosis is the genetic purity of the parental fish. Usually, more pure the parent fish are, higher the heterosis of their crossbreeds. It is necessary to select broodstock every year in order to get the hybrids with higher heterosis.

For more information contact Prof. Dong Zaijie, Freshwater Fisheries Research Centre of Chinese Academy of Fisheries Sciences, Wuxi, 214081, China. Email: dongzj@bigfoot.com.

Progress of fish gene technology research in China

Zhang Yue and Zhu Xinping
Pearl River Fisheries Research Institute, Guangzhou, 510380, P.R. China

Research on the genetic modification of fish (transgenic and nuclear transplantation) has been undertaken in China for over two decades, since the first successful human growth hormone gene transfer in goldfish[1]. To date, most research in this area has focused on improving the growth rate of species or other useful traits such as cold-tolerance and resistance to disease. Most of the Chinese research can be categorized into three main groups: 1) Growth hormone gene transformation, 2) anti-freeze protein gene transformation, or 3) disease-resistance gene transformation.

To date, the Chinese researchers have engineered more than 20 species of fishes. Some of these are cloned[2]. However, the first engineered fish to enter commercial production is likely to be a carp developed by the Zhu research group. In this fish the carp beta-actin promoter and grass carp growth hormone have been fused using a combining of gene cloning with nuclear transplantation.

Progress of studies on engineering fish

Growth hormone gene transformation

In the Wuhan Hydrobiology Institute, researchers have conceived and developed an "all fish" growth hormone model. They have cloned and sequenced the grass carp and common carp carbonic anhydrase (CA) gene and growth hormone gene. The grass carp CA gene (beta-actin) promoter has been linked to a grass carp growth hormone cDNA to form a high efficiency expression vector called pCAZ. Using the CAT gene as a reporter gene, a pCA grass carp growth hormone recombinant was microinjected