

## Cold tolerance of three strains of Nile tilapia, *Oreochromis niloticus*, in China

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### Abstract

Tolerance of three strains (GIFT, Sudan 78, Egypt 88) of Nile tilapia, *Oreochromis niloticus*, to naturally decreasing temperature was evaluated and determined in the Shanghai area. GIFT had been selected for increased body weight. Nile tilapia began to die when the water temperature dropped to 11 °C, and 100% mortality had occurred by 7.4 °C. Low lethal temperature ranged from 11 to 8.4 °C for the GIFT strain, from 9.8 to 7.4 °C for the Sudan 78 strain and from 11 to 7.4 °C for the Egypt 88 strain. The LD<sub>50</sub> for low temperature among the three strains suggested that the GIFT line was less tolerant to low temperature than the other two strains and that there was no difference with respect to temperature tolerance between the Sudan 78 and the Egypt 88 strains. This has important implications for the application of genetically enhanced tilapia in cold climates when developed in warmer regions. © 2002 Elsevier Science B.V. All rights reserved.

**Keywords:** Cold tolerance; Nile tilapia; *Oreochromis niloticus*; Strains

### 1. Introduction

In most of China, the tilapia industry is restricted by low temperatures. Enhancement of tolerance to low temperature of Nile tilapia, *Oreochromis niloticus*, is im-

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portant to prolong its growth period, reduce mortality for overwintering and decrease costs.

Previous research indicates that tilapia has genetic variation for cold tolerance in tilapia. [Khater \(1985\)](#) and [Khater and Smitherman \(1988\)](#) demonstrated that differences existed among the Egypt, Ghana and Ivory Coast strains of Nile tilapia. The further the geographic location from the equator, the more cold tolerance possessed by the strain of Nile tilapia. Apparently, natural selection affects cold tolerance in tilapia.

Selective breeding can alter the cold tolerance of tilapia. [Behrends and Smitherman \(1984\)](#) used introgressive backcrossing to successfully transfer the cold tolerance of blue tilapia, *O. aureus*, to red tilapia. The use of pure blue tilapia or its hybrids could enhance cold tolerance of tilapia in China. However, Nile tilapia are the most commonly grown tilapia in China, probably because of their rapid growth during the warmer part of the seasons. Since Nile tilapia are the most common tilapia in China, study of their cold tolerance is important.

The GIFT line of Nile tilapia is being distributed throughout Asia, therefore, documentation of its performance for important traits such as cold tolerance is needed as a single trait does not measure a genotypes overall aquaculture value. Also, cold tolerance of Nile tilapia developed in a tropical climate then transferred to a temperate climate where Nile tilapia already exists needs evaluation. Cold tolerance has not been previously studied for Nile tilapia in China.

The objective of the current study was to compare the cold tolerance of three strains of Nile tilapia grown in China. One strain was a recent introduction and others were earlier introductions.

## 2. Materials and methods

Three strains, GIFT, Sudan 78 and Egypt 88, of Nile tilapia, *O. niloticus* were tested in this experiment. Fish were maintained at the Genetic Resource Experiment Station (GRE) of Shanghai Fisheries University, Shanghai. Experiments were conducted during the winters of 1994–1995 and 1995–1996.

The first trial was conducted from Oct. 21, 1994 to Jan. 14, 1995. Average weight of fish was GIFT,  $77 \pm 23$  (S.D.) g, Sudan 78,  $89 \pm 27$  g and Egypt 88,  $60 \pm 19$  g, and there were

Table 1  
Cumulative mortality (%) of three strains of Nile tilapia, *O. niloticus*, at different temperatures during 1994–1995

| Temperature (°C) | Genotype                 |                          |                          |
|------------------|--------------------------|--------------------------|--------------------------|
|                  | GIFT                     | Egypt 88                 | Sudan 78                 |
|                  | Cumulative mortality (%) | Cumulative mortality (%) | Cumulative mortality (%) |
| 12               | 0                        | 0                        | 0                        |
| 11               | 15                       | 5                        | 0                        |
| 9.8              | 25                       | 5                        | 10                       |
| 9                | 30                       | 10                       | 10                       |
| 8.6              | 55                       | 30                       | 30                       |
| 8.4              | 100                      | 95                       | 95                       |
| 7.4              | 100                      | 100                      | 100                      |

Table 2

Cumulative mortality (%) of three strains of Nile tilapia, *O. niloticus*, at different temperatures during 1995–1996

| Temperature (°C) | Genotype                 |                          |                          |
|------------------|--------------------------|--------------------------|--------------------------|
|                  | GIFT                     | Egypt 88                 | Sudan 78                 |
|                  | Cumulative mortality (%) | Cumulative mortality (%) | Cumulative mortality (%) |
| 11               | 0                        | 0                        | 0                        |
| 10.5             | 8                        | 0                        | 0                        |
| 10.2             | 10                       | 0                        | 0                        |
| 10.1             | 13                       | 0                        | 0                        |
| 10.0             | 22                       | 0                        | 0                        |
| 9.6              | 30                       | 2                        | 0                        |
| 9.1              | 38                       | 2                        | 0                        |
| 8.8              | 78                       | 7                        | 17                       |
| 8.6              | 82                       | 8                        | 23                       |
| 8.4              | 100                      | 100                      | 100                      |

20 fish of each strain. Two replicate recirculating aquariums of 0.25 m<sup>3</sup> were used. Ten fish of each of the three strains were communally stocked in each aquarium after fin clipping. A second trial was conducted from Oct. 15, 1995 to Jan. 6, 1996. For the second winter of experimentation, the number of replicate fish was increased to 60, average weight was GIFT, 80 ± 25 g, Sudan 78, 98 ± 17 g and Egypt 88, 120 ± 24 g, and the fish were communally stocked in a large aquarium of 18 m<sup>3</sup> (not recirculating), fin clipped as before. Fish number was increased the second year because larger facilities were available.

Experiments were conducted indoors. Temperature decreased naturally at a rate of less than 1 °C per 24 h and did not fluctuate more than 1 °C day and night. Water temperature

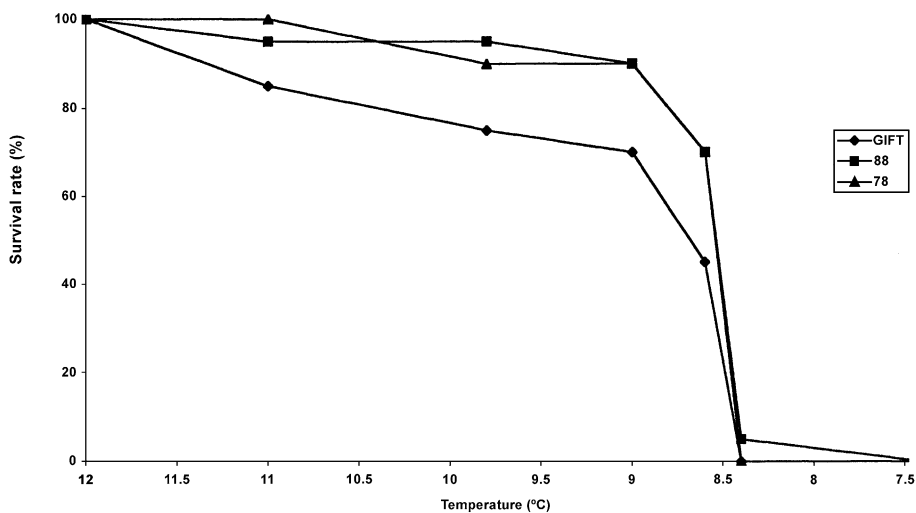


Fig. 1. Survival rates (%) of three strains of Nile tilapia under different temperatures, first trial, 1994–1995. 88 = Egypt 88; 78 = Sudan 78.

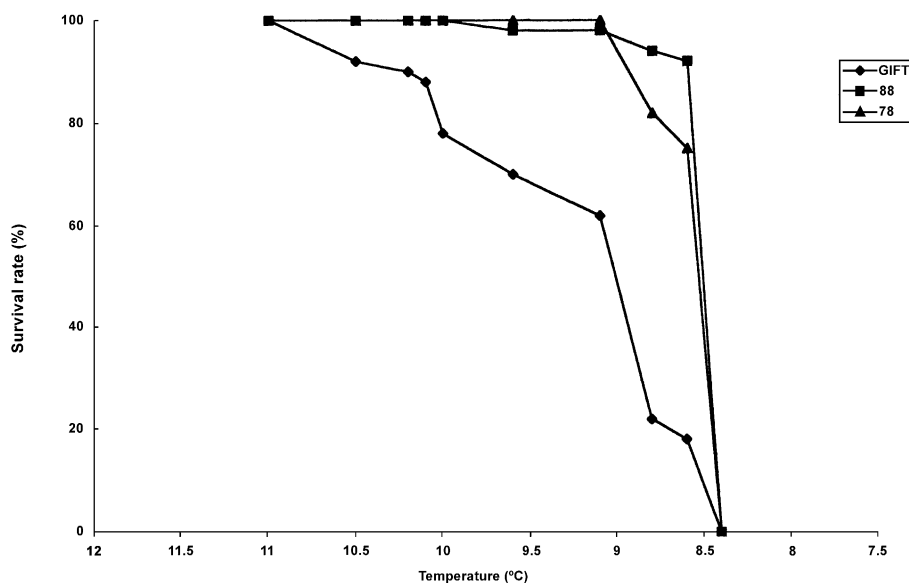


Fig. 2. Survival rates (%) of three strains of tilapias under different temperature, second trial, 1995–1996. 88 = Egypt 88; 78 = Sudan 78.

was measured three times per day and the behaviour of the fish was observed. Fish were fed ad libitum. Food residue and excrement were siphoned out to maintain water quality.

Water quality characteristics were dissolved oxygen, 13–15 mg/l; pH, 6.88–7.08; alkalinity, 77.0–100.4 mg;  $\text{CaCO}_3/\text{l}$  (pH = 5); ammonia, 0.33–0.75 mg/l; nitrate, 0.56–4.90 mg/l; nitrite, 0.01–0.02 mg/l; active phosphate, 0.01–0.17 mg/l.

Mortalities of Nile tilapia to different temperatures were calculated. The  $\text{LD}_{50}$  for lower lethal temperature of each strain was calculated by the graphic method. The means for the 2 years for the different strains were compared by  $\chi^2$  test (Du, 1985):

$$\chi^2 = \sum_{i=1}^n (X_{i1} - X_{i2})^2 / X_{i2}$$

When comparing results for the 2 years, the  $i$  means of  $i$  strain,  $X_{i1}$  and  $X_{i2}$ , refer to the  $\text{LD}_{50}$  for low lethal temperature of  $i$  strain for each year, respectively. When comparing the results of different strains in the  $i$  mean experiment year, while  $X_{i1}$  and  $X_{i2}$  refer to the  $\text{LD}_{50}$  for low lethal temperature of two strains in the same year.

Table 3

The lowest lethal temperature of 50% individuals ( $\text{LD}_{50}$ ) for three strains of Nile tilapia, *O. niloticus*

| Strain            | $\text{LD}_{50}$ |           |
|-------------------|------------------|-----------|
|                   | 1994–1995        | 1995–1996 |
| GIFT <sup>a</sup> | 8.8              | 9.0       |
| Egypt 88          | 8.2              | 8.2       |
| Sudan 78          | 8.2              | 8.5       |

<sup>a</sup> GIFT significantly higher ( $\chi^2$ ,  $P < 0.05$ ).

### 3. Results

#### 3.1. Mortality under different temperatures

The first trial in 1994–1995 had duration of 85 days, while the duration for the second trial of 1995–1996 was 83 days. The GIFT and Egypt 88 strains began to die at 11 °C, and the Sudan 78 strain at 9.8 °C. GIFT strain experienced total mortality at 8.4 °C, and this parameter was 7.4 °C for Egypt 88 and Sudan 78 strains (Tables 1 and 2; Figs. 1 and 2). These data indicate that lower lethal temperature of GIFT strain was higher ( $P < 0.05$ ) than the other two strains. The results for cold tolerance for the 2 years were virtually identical even though the rankings of the sizes of the fish for the 2 years were different.

#### 3.2. Low lethal temperature

The lowest lethal temperature for 50% of the individuals of three strains is listed in Table 3. The LD<sub>50</sub> of the GIFT line was higher ( $P < 0.05$ ) than that of Sudan 78 and Egypt 88. The lethal temperature for Sudan 78 and Egypt 88 was not significantly different ( $P > 0.05$ ). The low lethal temperature of GIFT was significantly higher than that of Sudan 78 and Egypt 88. These results were coincident with results of mortality.

### 4. Discussion

The two trials revealed that GIFT line had the worst cold tolerance of these three strains, while Sudan 78 strain had the best. The GIFT line originated from the mixing of eight strains, Egypt, Kenya, Senegal, Ghana; all wild strains from Africa; and four domestic strains from the Philippines, Israel, Thailand, Singapore and Taiwan, all of which have origins in Egypt and Ghana but Thailand is believed to be of only Egyptian origin (Eknath et al., 1993; Bentsen et al., 1998). One explanation for the poor cold tolerance of the GIFT line is that it was selected in a tropical country, had not previously been exposed to the selective pressures of low temperature and had not been in China long. The Sudan 78 strain had been introduced into China for several years, has been subjected to cold temperature and some selection response for cold temperature tolerance may have taken place. Alternatively, some of the founder strains of GIFT may have had poor cold tolerance, particularly Ghana (Khater and Smitherman, 1988). A third explanation is that GIFT may be contaminated with *O. mossambicus*, a species with poor cold tolerance alleles (Macaranas et al., 1986; Abdelhamed, 1988), whereas Chinese strains may be contaminated with *O. aureus*, a more cold tolerant species, alleles. Of course, a combination of the above factors could account for the strain differences seen in this study.

Wan (1981) reported that the low lethal temperature of Sudan 78 strain was 10–12 °C in China, higher than our results (7.4–9.6 °C), which was observed after 15 more years of potential selection pressure. Li (1985) and Fang et al. (1988) reported that Sudan 78 strain can live in 7.0 °C water for a short time in cold areas of north China. These preliminary observations may indicate that selection for low temperature tolerance in Nile tilapia is possible.

When Egypt 88 strain was introduced into China, its cold tolerance was better than Sudan 78 (Fang et al., 1988). Egypt 88 could tolerate temperatures 1–2 °C lower than Sudan 78. However, there was no significant difference in LD<sub>50</sub> between Egypt 88 and Sudan 78 in the current experiments. It has been observed that Egypt 88 strain was more active (more alert, less sluggish and had more feeding activity) than GIFT and Sudan 78 strain on farms at low temperatures. Possibly, both strains are reaching biological limits for tilapia cold tolerance, which would explain the difference in results after a period of 10 years. The difference of cold tolerance of these two strains needs more detailed studies.

Our experimental results indicate that tilapia can adjust to gradual decreases in temperature. When the temperature is maintained above 12 °C, the fish experience no irreversible harm, such as losing equilibrium, cessation of respiration, cessation of food consumption. During winter, tilapia is more easily infected by disease. For example, the water temperature of overwintering tanks of Nile tilapia in a tilapia farm of Zhejiang province usually winters the fish at 14 °C, and only 20% to 30% of the fish survive. The suggested water temperature for Nile tilapia overwintering should be above 16 °C, which can assure the fish have normal activity and high survival rate.

Our data and that of Khater (1985) suggest that genetic variation for cold tolerance exists in Nile tilapia. Heritabilities should be determined in these strains, particularly for GIFT, for this trait to predict the potential genetic gains that might be possible for selection for cold tolerance.

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