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THE INTENSIVE CULTURE OF THE ALL-MALE HYBRID OF *Tilapia hornorum* (male) x *T. nilotica* (female) IN NORTHEAST BRAZIL*

by

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Abstract

All male offspring are produced when male Tilapia hornorum is crossed with female T. nilotica. Experiments were carried out to test the culture potential of the Tilapia hybrid in the northeast of Brazil. Highest productions were obtained when the hybrids were stocked at 9 000 to 10 000/ha and were fed agricultural waste products. Maximum calculated production for a twelve-month period was 6 423 kg/ha with feeding and chemical fertilization and stocked at 10 000/ha with an average weight of 60 g. The mixed culture of Tilapia hybrid and mirror carp Cyprinus carpio resulted in no significant increase in total production over Tilapia hybrid cultured alone, although more efficient utilization of feeds resulted in the mixed culture. No significant difference between growth of hybrids and T. nilotica males was calculated. Average growth of hybrids was 281 g over 180 days. Tilapia hybrids proved to be excellent culture fish; they are very resistant to poor quality water and diseases, grow well on a wide range of natural food organismes, organic manures and agricultural waste products and fingerlings are easily produced.

Extracto

Une descendencia de sólo machos resulta cuando se cruzan machos de Tilapia hornorum con hembras de T. nilotica. Se realizaron experimentos en el nordeste brasileño para probar el potencial de cultivo de estos híbridos. Las más altas producciones fueron obtenidas con densidades de 9 000 a 10 000 híbridos/ha, alimentados con productos de desecho agrícola. La máxima producción calculada para un período de doce meses es 6 423 kg/ha con alimentación y fertilización química y a una densidad de 10 000 peces/ha con un peso medio de 60 g. El cultivo mixto de los híbridos con carpa espejo Cyprinus carpio no produjo un aumento significativo en la producción total; aunque se obtuvo una utilización más eficiente del alimento en el cultivo mixto. No se encontró una diferencia significativa entre el crecimiento de los híbridos y los machos de T. nilotica. El crecimiento medio de los híbridos fue 281 g en 180 días. Los híbridos de Tilapia probaron ser unos excelentes peces para cultivo, son muy resistentes a las aguas de baja calidad y a las enfermedades, crecen bien nutriéndose de gran variedad de organismos, desechos agrícolas y fertilizantes orgánicos y los alevines se obtienen fácilmente.

1. INTRODUCTION

Fish of the genus Tilapia are presently found in most tropical areas of the world where water temperatures are sufficient to allow them to reproduce and grow. Tilapias have been cultured in tropical countries for many years with varying degrees of success. Total productions have been reported to range from about 300 to 18 000 kg/ha depending on the species cultured, method of culture, fertility of the water and length of culture period. Most tilapias raised in ponds have proven to be extremely resistant to low concentrations of dissolved oxygen and other adverse environmental conditions, as well as being resistant to parasites and diseases; they also utilize a wide range of natural pond plant and animal organisms as food, and grow rapidly in waters rich in nutrients. Yet, with all these advantages, Tilapia has proven to be a difficult fish to raise successfully because of its ability to reproduce at a rapid rate under most culture conditions. Tilapias start to reproduce within three to six months of age and normally reproduce three to eight times per year. This high rate of reproduction results in overpopulation with a large number of small or stunted individuals. Thus, while total production of tilapias per unit area is often quite high, all too frequently only a small percentage of the fish can be considered of commercial value.

Various methods have been developed to control unwanted reproduction in tilapia cultures, but a majority of these methods have proven to be less than satisfactory. Mixed cultures with a carnivorous species to control tilapia reproduction have been tried with conflicting

results, since the predator species is often not efficient enough. When the predator species was able to control Tilapia spawns, a large percentage of the tilapias reached marketable size, but the total production per area was reduced (Meschkat, 1967; Semakula and Makoro, 1967; Swingle, 1960).

Monosex culture of male tilapias, which grow faster than females, has shown promising results when 100 percent males have been stocked. However, large-scale sexing and stocking of male fish is time-consuming and requires trained workers. Frequently, even with trained labour, small numbers of females are accidently stocked with the males, resulting in unwanted reproduction (Meschkat, 1967; Semakula and Makoro, 1967; Shell, 1968).

Experiments were conducted by Al Daham (1970) in attempts to sterilize Tilapia using chemical sterilants, X-rays and gamma-rays. Preliminary tests gave promising results using chemical sterilants to eliminate reproduction; however, more work is needed to verify the preliminary results and develop pratical methods of treating large numbers of fingerlings.

Experiments conducted at Auburn University, U.S.A. (Pagan, 1970) have shown that T. aurea can be raised in floating cages without unwanted reproduction. Tilapia were unable to reproduce because the eggs and sperm passed through the bottom of the net cage. While cage culture may eliminate unwanted reproduction, Tilapia must be fed a nutritionally balanced, pelleted ration if they are to grow well and in many developing countries the cost of such a ration is prohibitive.

The most promising method of controlling Tilapia reproduction appears to be the hybridization of selected species of Tilapia resulting in hybrids that are 100 percent males. Hickling (1968) in Malacca, Malaya, first succeeded in producing all male hybrids by crossing male T. mossambica[1/] (Zanzibar strain) with female T. mossambica (Java strain). The reverse crossing of these two strains resulted in offspring with the ratio of three males to one female. Hickling noted that the hybrids are fertile and will back-cross with either female parent resulting in offspring with a sex ratio of 50 to 50 males to females. Thus, extreme care must be taken when raising hybrid Tilapia to guard against the accidental introduction of females into the culture ponds.

In West Africa, Lessent (1968), crossed T. nilotica males with T. macrochir females resulting in 75 percent male offspring and 25 percent female offspring. The reverse cross resulted in 100 percent male offspring; however, the cross could only be irregularly produced under natural conditions. Pruginin (1968) in Uganda obtained 100 percent male hybrids by crossing male T. hornorum with female T. nilotica. This cross was produced by stocking 25 to 30 female T. nilotica per 1 000 m^2. Males were stocked in the proportion of two males for every three females. Pruginin also noted that the male hybrids reached sexual maturity in five to six months and could back-cross with the female parents producing fry with the normal 50:50 sex ratio. He concluded that the brood fish should be removed from the spawning ponds before the male hybrid reached sexual maturity and back-crossing could occur. Work done in the U.S.A. by Avault and Shell (1968) resulted in the production 70.6 percent males when male T. nilotica[2/] was stocked with female T. mossambica. The reverse cross of the above two species resulted in 71.6 percent males.

Work done on Tilapia hybridization by Chervinski (1967), in Israel, resulted in the production of 82.6 percent males when male T. nilotica[3/] from Lake Rudolf was crossed with female T. aurea. The reverse cross resulted in the production of 63.5 percent male offspring. Israeli biologists have also successfully crossed male T. aurea with female T. nilotica producing 73.2 percent male offspring.

1/ This subspecies has since been reclassified and is now called Tilapia hornorum zanzibarica
2/ This Tilapia, originally from Israel, has been re-identified as Tilapia aurea
3/ This Tilapia has since been re-identified as Tilapia vulcani

Studies carried out by St. Amant (1966), in southern California, showed that the all-male hybrids of male T. hornorum and female T. mossambica are easily produced in aquaria. Minimum recommended size of aquaria is 20 US gal (7.6 l). The aquaria are checked every 10 days and females carrying eggs are placed in separate aquaria while in the case of females carrying fry, the fry are removed and placed in aquaria. Adequate protection should be provided for the females as agressive males in spawning condition will often kill females not yet in spawning condition in a confined environment. Free swimming larvae and fry should be separated from the parents as it is suspected that the parents are predatory on the young hybrid fry in confined environments. The hybrids were able to tolerate water temperatures of 40°F (4.4°C) for brief periods and 57°F (13.9°C) for extended periods. Upper lethal water temperature was 108°F (42.2°C). Meschkat (1967) gives a good summary of the known Tilapia crosses and their results.

Surprisingly little has been recorded on the actual culture methods and production of all male Tilapia hybrids. Pruginin (1968) working with the hybrid of male T. hornorum and female T. nilotica in Uganda, reported yields of 800 kg/year when 1 500 hybrids per ha were stocked. When hybrids were stocked at 8 000/ha the growth rate up to 50 g did not differ from that of fry stocked at lower rates. After reaching 50 g, hybrid fry nursed at high densities were then transferred to growing ponds at the density of 1 000–1 500/ha. Under these conditions, daily weight gain of hybrids was 1.5 to 3.0 g per fish and individual fish reached a weight of 200 to 450 g after a period of 100–150 days. Pruginin did not state if feeds or fertilizers were used in these trials. Pruginin also reported that all male hybrids stocked together with T. nilotica had a growth rate 20 percent higher than T. nilotica alone over a 100-day growing period. Hickling (1962) reported that all male hybrids produced at Malacca, Malaya, would reach weights of about 450 g in six months, giving a total production of 1 365 kg/ha, their ponds receiving nothing more than 46 kg of triple superphosphate/ha.

Experimental work carried out in Ivory Coast by Lazard (1973) resulted in the production of 1 396 kg/ha/year of male hybrid Tilapia using triple superphosphate as fertilizer. The male T. hornorum x female T. nilotica hybrids were stocked at 10 000/ha with an average weight of 2 g and after 180 days the hybrids reached an average weight of 98 g. Fertilizer was applied at the rate of 13.5 kg/ha every two weeks.

The current report presents observations and results of a year and a half of experimental work with the all-male tilapia hybrid of male T. hornorum and female T. nilotica (Fig. 1). The research was performed at the Centre for Fish culture Research located in Pentecoste, Ceará, Brazil, which centre is under the direction of the Departamento Nacional de Obras Contra as Secas (DNOCS).

2. METHODS

Experiments were conducted from August 1972 until April 1974 to determine the culture potential of the all-male tilapia hybrid resulting from the cross of male T. hornorum and female T. nilotica. Parent stocks of both species were obtained fron Bouaké, Ivory Coast, through the assistance of the Centre Technique Forestier Tropical.

The experiments were carried out in 355 m^2 earthen ponds with an average depth of 1.2 m. Water is supplied from a large reservoir located about 35 km from the research station and carried to the station by an irrigation canal. Water entering the ponds has a pH of 7.8–8.3, total alkalinity of 140–150 ppm, and total hardness of 100–110 ppm. Rock and gravel filters are used to eliminate wild fish from the water supply for the ponds. In some cases, nylon saran screen socks of 100 meshes/in (100 meshes/2.54 cm) were used to filter the water entering inlet pipes.

All fingerlings were counted and weighed before being randomly stocked into the experimental units in lots of 100–200 fish each. Monthly samples were taken with a 15-m bag seine and at least 10 percent of the fish in the pond were counted, weighed, and in some cases measured so that growth rates and the increases in standing crops could be calculated. At the termination of each experiment, fish were separated into centimetre size groups and

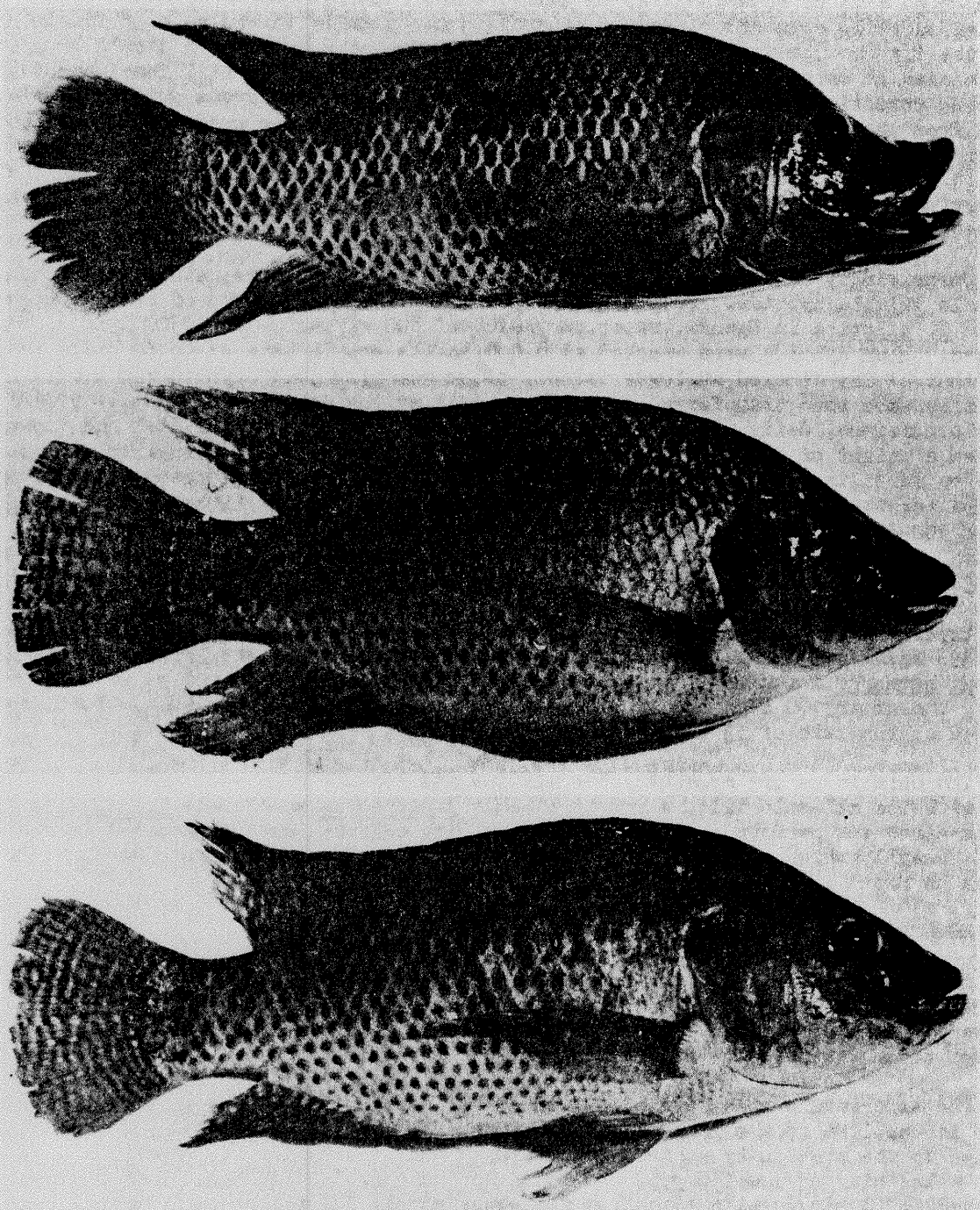

Fig. 1. From top to bottom: male Tilapia hornorum, Tilapia hybrid, female Tilapia nilotica.

weighed. In all experiments, fish were fed agricultural waste products at 3 percent of the standing crop of fish in the ponds, six days a week. The ration was fed as a moist feed ball placed in a feeding tray located in the shallow end of each pond. The feeding rate was changed monthly on the basis of growth as indicated in monthly seine samples. Dissolved oxygen readings and water temperatures were taken using a YSI portable oxygen meter. Analysis for pH was performed colorimetrically.

3. RESULTS

3.1 Comparison of a control, organic fertilizer, and feeding at two levels of stocking

A factorial experimental design included three treatments, each replicated three times at two different levels of stocking. Fingerlings were stocked in 9 ponds at 5 600/ha and in the remaining 9 ponds at 8 960/ha. All ponds within a treatment were treated equally. Ponds receiving organic manure were fertilized once a week with 30 kg (840 kg/ha) of cattle manure. Ponds receiving feeds were fed a ration composed of 50 percent wheat chaff and 50 percent castor bean meal. The ration contained approximately 25 percent protein. Ponds with the same level of stocking were fed equally, receiving 1/2 of the daily allotment in the early morning and the remaining portion in the late afternoon. Maximum rate of feeding was 50.6 kg/ha/day for a one-month period in ponds stocked at 8 960 fish per hectare.

Analysis of variance resulted in a significant difference (0.5 level) in total fish production between the two levels of stocking and a highly significant difference (0.01 level) between treatments. Thus, higher fish productions were obtained with a higher rate of stocking and with the use of feeds. Statistical analysis indicated a significant (0.5 level) interaction between treatments and levels of stocking. A summary of the results of this experiment are found in Table I.

3.2 Comparison of food plus organic fertilizer, chemical fertilizer, and organic fertilizer at one level of stocking

A second experiment was performed to give added information on the production of tilapia hybrids using different methods of culture over a one-year period. A completely random design was used with three treatments, each treatment replicated twice. All ponds were stocked with 8 960 fingerlings per hectare. The two ponds receiving organic fertilizer only were fertilized with cow manure at the rate of 1 400 kg/ha/week. The two ponds treated with chemical fertilizer received 28 kg/ha/bi-weekly of triple superphosphate and an equal amount of ammonium sulphate. The fertilizer was applied by placing the fertilizers together in a floating, perforated plastic pail. The remaining two ponds were fertilized with 1 400 kg/ha/week of cow manure for nine months after which fertilization was suspended, because water fertility was maintained at a high level by feeding alone. This treatment also received a ration of 50 percent wheat chaff and 50 percent castor bean meal which was fed in the early morning and late afternoon. The four ponds receiving organic manure were fertilized twice with 2 100 kg/ha two weeks before the start of the experiment to ensure adequate pond fertilities when Tilapia hybrids were introduced. The two units receiving chemical fertilizer were fertilized with 140 kg/ha of triple superphosphate and 112 kg/ha of ammonium sulphate applied in two doses over a two-week period before introduction of fish.

A summary of the results of the experiment is given in Table II. Statistical analysis resulted in a highly significant difference (0.01 level) between treatments. Total production with feeding and fertilizer was 163 percent and 264 percent more than with chemical and organic fertilizer respectively. Maximum daily feeding rate was 122.4 kg/ha which was sustained for a two-month period without any fish mortality.

3.3 Mixed culture of Tilapia hybrids and mirror carp

The hypothesis that larger fish productions could be obtained by raising tilapia hybrids and mirror carp (Cyprinus carpio) together than by raising either species alone was then tested. An experiment was initiated which utilized a random design, three treatments

Table I

Summary of results of male hybrid Tilapia experiment stocked at two levels with three treatments

Stocking Levels	5 600			8 960		
Treatments[1]	Control	Organic Fertilizer	Feed	Control	Organic Fertilizer	Feed
Total production kg/pond	11.8	28.7	35.0	9.9	36.3	63.5
Total production kg/ha	330.0	804.0	980.0	277.0	1 016.0	1 778.0
Net production kg/pond	10.3	27.3	33.6	6.4	33.1	60.0
Net production kg/ha	288.0	764.0	941.0	179.0	927.0	1 680.0
Av. wt. of fish at stocking, g	7.4	7.4	7.1	8.0	7.3	7.2
Av. wt. of fish at harvest, g	58.0	166.0	185.0	36.0	148.0	229.0
Percent survival	83.3	86.5	94.0	87.3	90.1	86.4
Fertilizer applied kg/pond	--	990.0	--	--	990.0	--
Fertilizer applied kg/ha	--	27 720.0	--	--	27 720.0	--
Feed fed kg/pond	--	--	91.3	--	--	163.5
Feed fed kg/ha	--	--	2 556.0	--	--	4 578.0
Feed conversion	--	--	2.7:1	--	--	2.7:1
Days of experiment	253.0	253.0	253.0	253.0	253.0	253.0
Growth - g/day	0.2	0.6	0.7	0.1	0.6	0.9

[1] Treatment results are the averages of three replicates.

Table II

Summary of results of Tilapia hybrid experiment at one level of stocking with three treatments

Treatments	Organic Manure (cow)			Chemical Fertilizer			Organic Manure + Feeding		
Ponds	22	24	Av.	21	26	Av.	23	25	Av.
Stocking rate, ha	8 960.0	8 960.0		8 960.0	8 960.0		8 960.0	8 960.0	
Av. weight at stocking, g	20.0	21.0	21.5	22.0	22.0	22.0	20.0	20.0	20.0
Av. weight at harvest, g	164.0	144.0	154.0	226.0	203.0	215.0	616.0	514.0	565.0
Total production									
kg/pond	52.2	43.6	47.9	68.4	64.3	66.3	187.8	161.0	174.4
kg/ha	1 462.0	1 221.0	1 341.0	1 915.0	1 800.0	1 856.0	5 258.0	4 508.0	4 883.0
Net production									
kg/pond	45.7	37.0	41.4	61.3	57.3	59.3	181.3	154.6	170.0
kg/ha	1 280.0	1 036.0	1 159.0	1 716.0	1 604.0	1 660.0	5 076.0	4 329.0	4 760.0
Feed									
kg/pond	--	--	--	--	--	--	617.2	617.2	617.2
kg/ha	--	--	--	--	--	--	17 282.0	17 282.0	17 282.0
Organic manure									
kg/pond	2 050.0	2 050.0	2 050.0	--	--	--	1 680.0	1 680.0	1 680.0
kg/ha	57 400.0	57 400.0	57 400.0	--	--	--	47 040.0	47 040.0	47 040.0
Chemical fertilizer									
Ammonium sulfate									
kg/pond	--	--	--	62.0	62.0	62.0	--	--	--
kg/ha	--	--	--	1 736.0	1 736.0	1 736.0	--	--	--
Triple superphosphate									
kg/pond	--	--	--	63.0	63.0	63.0	--	--	--
kg/ha	--	--	--	1 764.0	1 764.0	1 764.0	--	--	--
Feed conversion	--	--	--	--	--	--	3.4	3.8	3.6
Percent survival	100.0	94.0	97.0	95.0	99.0	97.0	95.0	98.0	97.0
Days of experiment	356.0	356.0	--	356.0	356.0	--	356.0	356.0	--
Growth, g/day	0.40	0.30	0.35	0.60	0.50	0.65	1.70	1.40	1.55

each replicated three times. Mirror carp were stocked into three ponds at the rate of 2 240/ha, tilapia hybrids were stocked into three ponds at the rate of 8 960/ha, and tilapia hybrids and mirror carp were stocked into three ponds at the rate of 8 960/ha and 1 400/ha respectively. All treatments were initially fertilized with 5 600 kg/ha of cow manure one week before stocking of hybrids to ensure adequate pond fertility. All ponds received additional applications of 1 400 kg/ha/week of cow manure for five months after which fertilization was suspended because of high levels of pond fertility. All ponds were fed a ration of rice polishings containing 14 percent protein. Ponds with mirror carp only were fed 3 percent of the body weight of carp stocked, while the ponds containing tilapia hybrids only, and hybrids and mirror carp together, were fed 3 percent of the body weight of the hybrids stocked. All ponds were fed once a day in the late afternoon. Maximum feeding rate per day with carp only was 22.4 kg/ha, tilapia hybrids and carp together 60.2 kg/ha, and with hybrids only 72.5 kg/ha.

A summary of the results of this experiment is given in Table III. Statistical analysis resulted in no significant difference (0.05 level) in total production of harvestable fish between treatments with tilapia hybrids and hybrids and carp together. The above two treatments had total productions of harvestable fish highly significantly different (0.01 level) from the treatment with carp only. While there was no difference in total production between the treatments with hybrids, 105.9 kg of harvestable hybrids and carp were raised on 295.1 kg of feed, a quantity of 107.9 kg of harvestable hybrids stocked alone were raised on 440.6 kg of feed. Thus, less feed was required to raise an equal weight of hybrids and carps than was needed to raise hybrids alone. Reproduction was found in all but one pond containing hybrids[1/]. The weight of reproduction encountered ranged between 14.6 and 46.1 kg per pond.

3.4 Comparison of Tilapia hybrid and male Tilapia nilotica

Several workers state that tilapia hybrids grow faster than either parent species (Hickling, 1968; Pruginin, 1968). However, no reports compared the growth of tilapia hybrids with male T. nilotica which grows much faster than the female T. nilotica. To test the hypothesis that tilapia hybrids grow faster than male T. nilotica, an experiment was designed utilizing a random design with three treatments, each replicated twice. Tilapia hybrids were stocked into two ponds at 10 000/ha, male T. nilotica were stocked into two ponds at 10 000/ha, and hybrids and male T. nilotica were stocked together into two ponds at 5 000/ha and 5 000/ha respectively. All treatments received initial applications of 224 kg/ha of triple superphosphate and 224 kg/ha of ammonium sulphate applied in four applications over a two-week period before stocking tilapias. After stocking, all ponds received 56 kg/ha of both chemical fertilizers approximately every two weeks. The fertilizers were applied by placing them in floating, perforated plastic pails. All treatments were fed an equal amount of rice polishings, 14 percent protein, once a day in the late afternoon. Maximum daily feeding rate was 84 kg/ha fed for one month.

The results are summarized in Table IV. Analysis of variance computed for average net growth of hybrids and male T. nilotica revealed no significant difference (0.05 level) in growth between the two fish. Statistical analysis resulted in no significant difference (0.05 level) between treatments for total production. Thus, tilapia hybrids and male T. nilotica did not show any significant difference in growth rates.

1/ The presence of female Tilapia was the result of mistakes in sexing of Tilapia broodfish. The presence of females amongst the male hybrids was known before the start of the experiment, but efforts to eliminate the females by visual inspection was unsuccessful

Table III

Summary of results of Tilapia hybrids and
Mirror Carp cultured separately and in mixed culture

Treatment [1]	Mirror Carp	Tilapia hybrid	Mirror Carp + Tilapia hybrid	
			Carp	Tilapia
Stocking Rate	2 240/ha	8 960/ha	1 785/ha +	8 960/ha
Production - harvestable				
Fish kg/pond	29.0	107.8	105.9	
kg/ha	812.0	3 018.4	2 965.2	
Production - reproduction				
kg/pond	--	34.8	21.5	
kg/ha	--	974.4	602.0	
Total production				
kg/pond	29.2	142.6	127.4	
kg/ha	812.0	3 992.8	3 567.2	
Av. weight at			Carp	Tilapia
harvest, g	379.0	353.0	361.0	285.0
Av. weight at stocking, g	16.0	45.0	18.0	45.0
Feed Fed				
kg/pond	62.7	440.6	295.1	
kg/ha	1 756.0	12 337.0	8 263.0	
Feed conversion harvestable fish	2.3:1	4.8:1	3.2:1	
Harvestable fish + reproduction	2.3:1	3.8:1	2.6:1	
Cow manure				
kg/pond	1 150.0	1 150.0	1 150.0	
kg/ha	32 200.0	32 200.0	32 200.0	
Percent survival	.96.0	96.0	95.0	97.0
Days of experiment	245.0	245.0	245.0	
Growth, g/day	1.45	1.26	1.40	1.00

[1] Treatment results are the averages of three replications (ponds) except the treatment with the Mirror Carp alone which is the average of two replicates because of mortality in one pond.

Table IV

Summary of the results of the comparison between male Tilapia nilotica and Tilapia hybrids under intensive culture

Treatment [1]	Male T. nilotica	T. hybrid	T. hybrid + Male T. nilotica	
			T. hybrid	T. nilotica
Stocking Rate	10 000/ha	10 000/ha	5 000/ha	5 000/ha
Av. weight at harvest, g	299.0	340.0	hybrid --	346
			T. nilotica --	296
Av. weight at stocking, g	63.0	60.0	hybrid --	64
			T. nilotica --	65
Av. weight, g	236.0	280.0	hybrid --	282
			T. nilotica --	231
Total production				
kg/pond	101.4	116.0	106.4	
kg/ha	2 839.0	3 248.0	2 979.0	
Feed				
kg/pond	258.9	258.9	258.9	
kg/ha	7 249.0	7 249.0	7 249.0	
Feed conversion	3.4	2.8	3.2	
Fertilizer				
Ammonium sulfate				
kg/pond	24.0	24.0	24.0	
kg/ha	672.0	672.0	672.0	
Triple superphosphate				
kg/pond	24.0	24.0	24.0	
kg/ha	672.0	672.0	672.0	
Percent survival	96.5	97.5	94.0	
Days of experiment	180.0	180.0	180.0	
Growth, g/day	1.3	1.6	hybrid --	1.6
			T. nilotica --	1.3

[1] Treatment results are the averages of two replications.

4. DISCUSSION

4.1 Production of Tilapia hybrid fry

The production of hybrid fry is a simple process as long as a few precautions are taken. Workers raising tilapia hybrids should be sure that their source of brood stock is of a pure line and should take adequate measures to ensure that the species remain uncontaminated. As has been noted, hybrids are fertile and will back-cross with either female parent resulting in offspring 50 percent males and 50 percent females. Thus, back-crossing can result in impure strains which have lost the ability of producing all-male offspring. In the present study both species were placed in 36 m^2 concrete tanks which were relatively isolated from other ponds and were covered with nylon netting to prevent birds from entering. In any case, some provision should be made so that pure strains can be kept in well isolated and protected ponds. Brood stock for this study were selected from larger ponds, 355 m^2 to 1 000 m^2, where pure strains of both species were located. Water inlets were protected with fine nylon screens to prevent entrance of unwanted tilapias in the water supply. In the past two years, these ponds have remained uncontaminated, even though predatory birds were active on the station. However, in the case of contamination, the ponds can be easily poisoned, killing all the fish so that reproduction can be reinitiated from the pure stocks available.

Care should be taken in sexing the fish to be used as brood stock, as one mistake can mean the production of female fry. Tilapias can be easily sexed starting with fish of 50 to 60 g. An experienced worker can sex fish of a smaller size, but the work is much more difficult and time-consuming. Male T. hornorum are easily selected when they reach maturity because of their black body colour which differs greatly from the light brown or tan female. The sexing of female T. nilotica is much more difficult because females resemble the males in coloration and, therfore, is not a good criterion for sexing. The surest way of sexing T. nilotica is by the shape and number of orifices on the genital papilla (Fig. 2). Male T. nilotica have a pointed genital papilla with two orifices, the anus and urethra, while the female has a more rounded genital papilla with three orifices: anus, oviduct and urethra. The use of a pointed object like a toothpick or needle can aid in sexing T. nilotica as the pointed object will catch on the oviduct of the female. When selecting females, care should be taken to examine the mouth cavity to be sure that she is not carrying eggs or fry. Females carrying eggs or fry should not be used for hybridization because introduction of T. nilotica eggs or larvae will contaminate the hybrids produced, and the adults having just spawned will not be ready to spawn again for 8 to 12 weeks. Hybrids have been produced in earthen ponds of 355 m^2 and concrete-sided earthen bottom tanks of 36 m^2. All spawning ponds have the water inlets protected by fine nylon screening to preclude wild fish. Males and females are stocked at the ratio of one or two males for every three females (da Silva, 1973).

Good results have been obtained by stocking from 10 to 30 females in a pond of 355 m^2. Optimum stocking rates of females per area has yet to be determined. The brood stock are left in the brood ponds for three months. After three months the ponds are lowered and the brood stock removed by seining. Care must be taken to remove all female parents. The ponds are then refilled and the fry allowed to grow for one or two months longer when they should be ready for stocking. The only drawback to this method is that the female T. nilotica are extremely difficult to remove from a 355 m^2 pond because they tend to lie on their sides in the mud and pass under a seine. An alternate method is to completely drain the spawning pond after three months and remove all adults and fry. The fry are then placed in another pond there they are allowed to grow. This second method also has a drawback; as the female T. nilotica spawn randomly over the three-month period, at draining many small fry are often lost in the mud and cannot be recovered. With these problems in mind, it is suggested that spawning ponds should be small in size (50-150 m^2) to facilitate removal of parents by seine. Where small ponds are not available, brood stock should be placed in screened or fenced areas in shallow water using netting or any suitable material with a large enough mesh that fry can pass through, while adults are retained. The pond can then be partially lowered, adults easily removed and the pond refilled to allow the fry to grow. Fences should be well embedded in the pond bottom and high enough above the water surface so

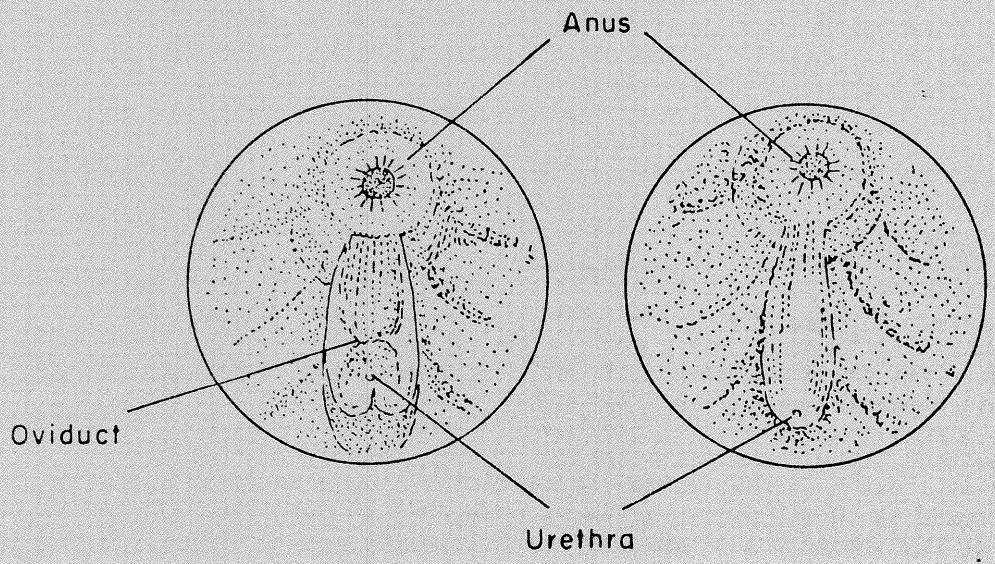

Fig. 2. The genital orifices of the female (left) and male (right) Tilapia nilotica (Adapted from Bard, Lemasson and Lessent (1971)).

that the adults can neither dig under nor jump over the barrier. In summary, production of all-male hybrid tilapias is easily accomplished if pure strains are used, males and females are carefully selected, and parents and offspring are separated before back-crossing occurs.

4.2 Production and growth

Tilapia hybrids have produced excellent crops of fish under intensive culture conditions. Ponds stocked with hybrids at 9 000 to 10 000/ha resulted in higher productions under intensive fertilization, feeding, or both than ponds with hybrids stocked at 5 600/ha. Ponds not receiving fertilizers or feeds produced an average of 422 kg/ha/year. Productions resulting from heavy fertilizing with cow manure ranged from an average of 1 341 to 1 429 kg/ha/year. Heavy fertilizing with chemical fertilizers resulted in an average production of 1 856 kg/ha/year. The addition of feeds or a combination of feeds and fertilization raised production 1.7 to 3.6 times higher than with fertilization alone. Maximum calculated average production for a twelve-month period was 6 423 kg/ha, starting with a 60 g fingerling stocked at 10 000/ha with feeding and chemical fertilization. Minimum calculated average production for a twelve-month period was 2 501 kg/ha, starting with a 7 g fingerling stocked at 8 960/ha with feeding only.

Taking into consideration water quality, availability of feeds, economics and size of fish accepted by the people of the state of Ceará, Brazil, it appears that maximum utilization of ponds and highest economic returns to the farmer can be realized by stocking a 30 to 40 g fish at 10 000/ha and raising the hybrids to a size of 400 g to 500 g in 300 to 330 days with heavy feeding and fertilizing. With ideal conditions and proper management, a total production of 4 000 to 5 000 kg/ha/year can be realized. It is felt that future research may prove that even higher productions are possible with higher rates of stocking, improved feeds and the application of partial harvesting techniques.

Most important factors in high productions with tilapia hybrids is the maintenance of high levels of pond fertility resulting in heavy algal blooms and rich layers of organic matter on the pond bottom. When hybrids are stocked, ponds should be at a high level of fertility and this level of fertility should be maintained throughout the culture period. Highest daily weight gains of hybrids have been achieved when ponds were literally polluted and unfit for the culture of many species of fish. Tables V and VI show the average weight gain per day for hybrids under two different systems of culture. The experiment in Table V was given two pre-stocking applications of cattle manure and as a result the first month's growth was good. However, growth during the next three months was poor because the level of fertility fell. Growth again reached an acceptable level in the fifth month when water fertility improved. It is interesting to note that the highest rates of growth were obtained in the tenth and eleventh months when high levels of feeding resulted in extremely rich pond waters.

Table VI shows the average daily weight gain in hybrids when an effort was made to keep water qualities at a high level. This experiment was given several pre-stocking applications of chemical fertilizer and the hybrids grew well throughout the experimental period with additional applications of chemical fertilizer and feeding.

It is recommended that during the first three months of the culture period, and especially when raising hybrids in new ponds, care be taken to ensure continuous high levels of pond water fertility even if extra applications of fertilizers are needed or a higher rate of feeding (5-10 percent) is used initially. In the case of tilapia hybrids, over-fertility is much more desirable than under-fertility. With high levels of fertilizers and feeding of simple agricultural waste products, tilapia hybrids should average close to 1.5 g of growth per day when stocked at 10 000/ha. This will ensure satisfactory growth throughout the culture period.

Table V

Average weight gain per day in grams between monthly samples taken over a one-year period for Tilapia hybrids treated with organic manure and feeding stocked at 8 960/ha

Date	No. of days	Av. weight gain, g[1/]	g/day
04/04 to 04/05, 1973	30	47	1.6
04/05 to 06/06	33	28	0.8
06/06 to 03/07	27	23	0.9
03/07 to 01/08	29	28	1.0
01/08 to 04/09	34	49	1.4
04/09 to 04/10	30	48	1.6
04/10 to 30/10	26	49	1.9
30/10 to 04/12	35	42	1.2
04/12 to 08/01, 1974	35	52	1.5
08/01 to 05/02	28	72	2.6
05/02 to 06/03	29	79	2.7
06/03 to 26/03	19	29	1.5

[1/] The average of two ponds, 355 m^2, in the same treatment.

Table VI

Average weight gain per day in grams between monthly samples taken over a six-month period for Tilapia hybrids treated with chemical fertilizer and feeding stocked at 10 000/ha

Date	No. of days	Av. weight gain, g[1/]	g/day
05/09 to 18/10, 1973	43	68	1.6
18/10 to 20/11	33	44	1.3
20/11 to 27/12	37	77	2.1
27/12 to 30/01, 1974	34	51	1.5
30/01 to 05/03	33	39	1.2

[1/] The average of two ponds, 355 m^2, in the same treatment.

4.3 Feeds and fertilizers

Tilapia hybrids are an excellent culture fish because of their ability to utilize a wide range of cheap agricultural waste products and animal manures as feeds. Cattle manure was used here because it was readily available, but pig and chicken manure are even better because they are richer in nutrients. These manures are eaten readily by the hybrids and can be considered a direct source of nutrients. Those nutrients not utilized directly are used indirectly, enriching pond waters and producing food organisms. The disadvantage of animal manures is that they vary considerably in nutrient and moisture content, making it difficult to constantly add a known quantity of nutrients. Large amounts are needed to provide a small quantity of nutrients. This is especially true with cattle manure where a great amount of effort may be expended in the transport and application of the manure. In some areas, the addition of animal manures may present aesthetic problems and make marketing the fish difficult.

Chemical fertilizers are excellent sources of elements, but cannot be directly utilized by hybrids. A small quantity provides a large amount of elements in known concentrations. For example, 1 kg of triple superphosphate, 48 percent P_2O_5, provides the P_2O_5 found in 165 kg of cow manure. Thus, labour and transportation costs are less than with organic manures. The main disadvantages of chemical fertilizers are that they cannot be directly consumed by the hybrids and prices have risen very sharply so that chemical fertilizers are becoming difficult to find and expensive to buy in many developing countries.

Another advantage of tilapia hybrids is their ability to utilize cheap sources of vegetable protein, along with a wide range of natural aquatic plants and animals, and convert it into fish flesh at an efficient rate. Hybrids are able to filter algae from the water. They have the ability to ingest bottom muds removing the nutrients from the rich layer of living and dead organic matter. Hybrids were observed eating the soft leaves of Hydrothrix gardneri which is a common nuisance submerged aquatic weed similar to pickerel weed. Infestations of this weed were eliminated from ponds stocked with at least 5 000 hybrids per hectare. Tilapia hybrids are not able to eliminate coarser, grass-like aquatic plants. Aquatic insects, shrimps and tadpoles are eaten by the hybrids.

A variety of agricultural waste products including rice polishings, wheat bran, cottonseed cake, castor bean meal, cashew nut by-products, and babaçu cake have been accepted by the hybrid tilapia. Many agricultural by-products have been used to feed tilapias in other countries so that whatever is available and most economical on a regional basis can be utilized.

4.4 Water quality

Tilapia hybrids were extremely resistant to poor water quality. Under conditions of heavy feeding and fertilizing not one hybrid was observed to die from adverse environmental conditions. When surface dissolved oxygen levels fall below 0.8 ppm, the hybrids will come to the surface and utilize atmospheric oxygen. The amount of time that hybrids can remain at the surface using atmospheric oxygen is not known, but this fish was observed on the surface at sunrise, day after day without mortalities. Maximum feeding rate was 122.4 kg/ha/day maintained over a two-month period. Even when fish were at the surface in stress, in the early morning, feeding was continued as scheduled, and the hybrids continued to eat and grow at normal rates. Minimum level of surface dissolved oxygen encountered was 0.3 ppm. The range of pH in culture ponds was from a minimum of 7.7 in the early morning to 10+ in the afternoon. Surface water temperatures ranged from 25.0 to 35.0°C.

There must certainly be a degradation of water quality at which growth of tilapia hybrids will be affected and, finally, mortality will be experienced. At this time, these water quality criteria are not known. However, it is felt that hybrids will not likely suffer mortality due to poor water quality under normal culture conditions.

4.5 Diseases and parasites

Tilapia hybrids are extremely resistant to bacterial diseases and parasitic infestations. Even under poor environmental conditions, no mortality due to parasites or diseases has been recorded. The only recorded disease found in the literature were attacks of fungus caused by a weakening of the fish due to low water temperatures.

4.6 Mixed culture

The addition of mirror carp to hybrid ponds did not significantly raise total production but did result in better feed conversions because less feed was needed to raise an equal weight of fish. Thus, the advantage of mixed culture with carp appears to be a more efficient utilization of feeds and natural food organisms. However, several disadvantages were encountered that raises doubt as to the advantage of a mixed culture with carp. Data indicate that hybrids and carp compete for feed and food organisms. The average weight of hybrids cultured with carp was 285 g while average weight of hybrids cultured alone was 353 g.

A second disadvantage is that where the hybrids are the primary fish cultured, the addition of a second fish less resistant to poor water qualities presents some unwanted problems. Mirror carp are not as resistant to low dissolved oxygen levels as are the hybrids and begin dying when dissolved oxygen levels fall to 0.8 ppm. Less feed was added to ponds with hybrids and carp as dissolved oxygen was approaching the danger level. More effort and a higher level of technology is needed to raise hybrids and carps together because of the constant danger of oxygen depletion and fish mortality. It is felt that future experiments will find that higher productions can be obtained culturing hybrids alone because higher levels of feeding can be used.

No significant difference was calculated between the growth of tilapia hybrid and male T. nilotica. While the data indicate that the hybrids had a 17 percent advantage in average weight, this difference was not detected in the experiment with two replications per treatment. T. nilotica males were found to be as resistant to poor water quality as hybrids. The only real difference between the two was that male T. nilotica are much more difficult to catch with a seine. Further, the sexing of large numbers of male T. nilotica is a tedious and time-consuming job, if one uses this alternative stocking method.

4.7 Reproduction in ponds

In several cases, reproduction occurred in hybrid culture ponds. It is believed that even in cases of extreme care, some accidents will occur and reproduction will be an occasional nuisance. The frequency of unwanted reproduction can be reduced with proper isolation techniques, sexing of brood stock and filtering of water supplies. When removing brood stock from spawning ponds, they should be checked for sex and if a mistake is found, the fry should be discarded. When fry are removed from spawning ponds and held for stocking in another pond, small fry may be encountered when removing the fingerling hybrids so that it is often best to kill all the fingerlings in the pond or stock only those hybrids that are large enough to be manually sexed.

However, it will be difficult to eliminate all human errors and the introduction of females into production ponds by predator birds and animals. It was found that reproduction reduces total production of hybrids as the offspring compete with the hybrids for food. The amount of reproduction present in a culture pond will be proportional to the number of females present and the length of the culture period. One way of controlling the influence of unwanted reproduction is to limit the culture period to five or six months which will allow a female to spawn at maximum twice and the offspring will have very little if any chance to reach sexual maturity and spawn. A second method to control reproduction would be to stock a predator with the hybrids.

If reproduction is encountered in production ponds, the ponds should be allowed to dry in order to kill the fry. In cases where complete drying is not possible, the ponds should be carefully poisoned. Small fry are able to live in a small puddle of water so that every hole containing water should be poisoned. In some cases, it may be easier to fill the pond a quarter full before poisoning as poison can be evenly distributed and the risk of missing a hole containing hybrids eliminated.

4.8 Miscellaneous

Several additional observations concerning hybrid culture have been made. While the males are unable to spawn in the absence of females, they do dig nests as a part of the pre-spawning ritual. Ten thousand hybrids per hectare can dig a large number of nests. For an unknown reason the preferred location for nest construction is on the pond dikes which causes damage to the dikes. It is recommended that inside slopes to pond dikes be 3 to 1 to help prevent collapse of pond walls. Reinforcement of pond dikes with rocks or lumber would eliminate the problem but is often expensive.

Tilapia hybrids are not extremely difficult to catch with a seine. The hybrid appears in this characteristic more similar to its male parent, T. hornorum, which is fairly easy to catch. T. nilotica is very difficult to seine, and lies on its side in the bottom mud as the seine passes over.

Dressed weight of hybrids with an average weight of 209 g with scales, fins, gills, and viscera removed was 80 percent, and dressed weight with head removed was 65 percent. The authors have eaten hybrids and found the flesh to be of excellent flavour even when taken from ponds with high levels of fertility. The hybrid has no intra-muscular bones that would hinder its market acceptance.

4.9 Culture potential

It is felt that tilapia hybrids offer excellent culture potential in most tropical areas of the world. Large productions can be raised easily and cheaply providing a cheap source of animal protein to consumers and economic benefits to the culturist. Farmers with little understanding of culture techniques can raise hybrids by following simple feeding and fertilizing instructions. The hybrids are very resistant to disease and poor water quality, thus, few problems are encountered during culture. Any locally available agricultural waste product or fertilizer source can be utilized to increase production.

In the northeast of Brazil, a fish culture extension programme is being built around the tilapia hybrid. A simple manual with many illustrations is given to interested farmers. With the aid of government extentionists, farmers are aided in pond construction. Hybrid fingerlings raised at government hatcheries are provided free of charge as an incentive to farmers. Established fish farmers will be required to buy fingerlings from government hatcheries or produce their own fingerlings with assistance from extension biologists. Training programmes in hybrid culture and fingerling production will be provided at government hatcheries and research stations. Economic studies showed that the highest profits were returned to the farmer when hybrids were intensively cultured with feeding and fertilizing. A hybrid of 200 g to 500 g was readily accepted by the consumer. Extension biologists are recommending a culture period of 10 to 11 months so that with proper management a production of 4 000 to 5 000 kg/ha/year can be obtained.

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