Tilapia production in shrimp ponds: Salinity tolerance and polyculture

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Abstract

A special genetic breeding program was executed for the production of tilapia hybrids characterized by tolerance to high salinity, fast growth rate and homogeneous red skin color. The male line of this hybrid (commercially known as ND60) is a progeny of a cross between *O. mossambicus* x ND9. The female line is the ND5 line, currently used for commercial production of red tilapia in fresh and slightly brackish water.

The growth performance of the new ND60 hybrid was tested in tanks at water salinity of 41 ppt. As reference, we used the ND21 commercial hybrid, grown in fresh water. When stocked at 103g, ND60 and ND21 demonstrated specific growth rates of 1.17% and 1.32%, respectively. When stocked at 248g, they demonstrated specific growth rates of 0.94% and 1.02%, respectively. It is concluded that ND60 stocked in high salinity grows approximately 10% slower than ND21 in fresh water.

Growth trials in commercial cages in the Mediterranean Sea showed that ND60 is suitable for commercial production in seawater (37 ppt), demonstrating a daily weight gain of 2.2 g/day, between 70 g to 265 g. However, growth slows down significantly when water temperature decreases below 25^{o}C and stops altogether at water temperatures lower than 21^{o}C. In the Red Sea, where water temperature fluctuate between 21oC and 25oC, growth was fairly constant at 0.55 g/day, a slow growth rate which can be explained by the relatively low water temperature.

Our results indicate that the new ND60 hybrid maintained its tolerance to high salinity from its *O. mossambicus* ancestor, while gaining the fast growth rate and red skin color from its ND9 and ND5 ancestors. These hybrids abide by the same temperature restrictions and grow best at water temperatures higher than 25^{o}C.

Tilapia consumption in the world has been increasing steadily in the past several years (RR). Commercial production of tilapia, mostly *Oreochromis*, is expanding rapidly mainly in tropical areas.

Most commercially produced *Oreochromis* lines are suitable for production in fresh water. However, there are several lines such as *O. mossambicus*, which is known to reproduce and grow in water salinity higher than 50 ppt (Popper & Lichatovwich, 1975).

In last few years, an increasing number of marine shrimp farms have been abandoned mostly due to diseases, such as the Taura syndrome (R). These farms are fully equipped and contain facilities that could be used for fish production, provided the right species (i.e. tolerance to high salinity and proven marketability) is identified (ATA, 1996). It should be emphasized that in many of these farms water salinity increases above normal seawater salinity, reaching over 40 ppt during the dry season. It is therefore necessary to identify a fish species, which can withstand large salinity variations, without affecting its growth.

The increasing market demand for tilapia and the availability of vast brackish and seawater resources have led to the attempts to develop new tilapia hybrids, which would be suitable for cultivation in such habitats while meeting the basic requirements of commercial production (Watanabe et al., 1990; ATA, 1996). Such requirements include: (a) high salinity tolerance; (b) acceptable growth rate to market size (>450g); (c) suitable color and body shape to meet market demand (with preference to red tilapia); (d) high uniformity in growth rate, body shape and color; (e) high mating affinity of parental lines, to allow large-scale reproduction of F_1 hybrids; (f) wide genetic basis to neutralize the negative effects of in-breeding.

In order to meet these requirements, we have embarked, at Nir David Fish Breeding Farm, on a genetic selection program, which is comprised of two stages: Stage I – the establishment of a stable MALE LINE, characterized by high-salinity tolerance, fast growth rate and the ability to produce red progeny. Stage II – large-scale production of F_1 hybrids by crossing males from the new male line with females from an existing commercial FEMALE LINE (ND5), characterized by well-established known commercial attributes (Nir David Fish Breeding Farm, 1996). Our objective was to develop a hybrid which would stand a salinity higher than seawater (>35 ppt) which would be a suitable candidate for cultivation in marine shrimp farms, either as an alternative to the shrimp or in polyculture. Figure 1 illustrates the main steps taken in the course of this genetic selection program.

Stage I – The establishment of a MALE LINE

The establishment of a MALE LINE, started with the hybridization of wild type *O. mossambicus* with the commercial line known as ND9 (Nir David Fish Breeding Farm, 1996). In this cross, *O. mossambicus* contributes the high tolerance to salinity, whereas ND9 (the male line currently used for the commercial production of red tilapia) contributes the fast growth rate and the red skin color. Although the F_1 hybrids of this cross already demonstrate high salinity tolerance and fast growth rate, they cannot be used in commercial production for several reasons. Firstly, this cross produces very few progeny and therefore it is not suitable for large-scale fry production. Second, as could be expected, the color of the F_1 progeny of this cross is very unstable, shifting between red fish to fish with spots to gray fish, which are not favorable in the market.

Next, hand-selected red males and red females from this F_1 progeny were crossed with each other. Color inheritance pattern in these lines has been found to follow the dominant-recessive distribution pattern (where AA would appear as gray, Aa would appear as red or red with spots and aa would appear as white, Tave, 1991). The F_2 generation is comprised of about 30% wild-type gray fish, about 55% red fish and red fish with dark spots and about 15% white fish. (The slight deviation from the expected 25% - 50% - 25% distribution is due to the lower survival probability of the white fish.) Only the white fish are suitable for the establishment of a family which could be then used as the source of males for the production of the desired commercial hybrid, since their progeny can be expected to be 100% red, when crossed with red ND5 females (Tave, 1991; personal observations).

The males produced within this family would be the F_3 generation of the original cross of *O. mossambicus* x ND9. At this stage, we have faced a major problem stemming from the fact that the F_2 parents used for the production of the desired F_3, were only a few handpicked, genetically-related individuals, which represent a rather narrow genetic pool. Indeed, when observing the F_3 progeny, a significant percentage of the fish show various types of abnormalities in both body shape and swimming behavior. However, a sufficient number of normal looking, fast growing, white males can be selected to serve as the male parents for the production of the desired salinity tolerant hybrids (since the required ratio of males to females in the broodstock is 4-5:1).

Stage II – large-scale production of salinity tolerant hybrids

ND5 females, currently used for commercial production of red tilapia (Nir David Fish Breeding Farm, 1996), are characterized by an attractive body shape, good growth rate and a moderate resistance to salinity (up to 15ppt, personal observations). Color inheritance mechanism of these females follow the dominance pattern (i.e. RR and Rr both appear as gray or spotted, whereas the homogeneous recessive allel - rr, would appear as orange, Tave, 1991). A cross between the orange ND5 females (rr) and the white males (aa), isolated as described above, yields all-red progeny (ar). The white males, which presumably still carry the ability to withstand high salinity from their *O. mossambicus* ancestor, together with ND5 females demonstrate high mating affinity and can be used as the broodstock for large-scale commercial production of all-red hybrids, which may still be tolerant to high salinity. The use of ND5 females helps to broaden the genetic base and consequently, the stability of the progeny.

At this stage, we have tested the growth performance of these hybrid progeny (known by their commercial name - ND60) in high water salinity (41 ppt). As a reference, we used the commercially grown *O. niloticus x O. aureus* all-male hybrid (known as ND21), a popular hybrid in the Israeli tilapia industry, known for its fast growth rate in fresh and slightly brackish (<5 ppt) water (Nir David Fish Breeding Farm, 1996; Lahav & Lahav, 1990).

The present paper describes the results of the preliminary growth trials that were carried out in tanks, and the outcome of the first commercial trials, which were carried out in cages in the sea. Our results show that ND60, grown in full strength seawater, performs almost as good as ND21 hybrids in fresh water.

Growth rate of the new hybrid - ND60, in seawater, was compared with growth rate of the commercial hybrid types adapted to fresh water. The trials were conducted in a series of round tanks of 12 m^3 each, in several cycles of 40 days each. Fish were stocked with 100 fish per tank, averaging 100 g or 250 g. The salinity was adjusted and maintained at 41 ppt and water was recirculated via a biological filter. In the freshwater tanks, river water was continuously exchanged at a rate of about 10 m^3 per day. In both systems, ammonia level was maintained below 0.5 ppm at all times.

Water temperature in all tanks was maintained at 27-29^oC. All tanks were aerated by airlifts, which also served to slowly circulate the water in the tank. The sludge sinking in the center was removed once a day. A stand-by seawater tank was used to compensate for the water washed out during daily rinsing.

Results of the growth trials showed that the growth rates demonstrated by ND60 in seawater was a little lower (1.17% per day) than those demonstrated by the commercial hybrids ND21, raised in fresh water (1.32% per day).

Table I. Growth rates of ND21 and ND60, raised in fresh water and seawater, respectively.

	ND21 in freshwater			**ND60 in seawater**		
	Size at stocking (g)	**Size at harvest (g)**	**Daily weight increase (g/day)**	**Size at stocking (g)**	**Size at harvest (g)**	**Daily weight increase (g/day)**
Cycle I	103	175.0	1.80	103	164.2	1.53
Cycle II	248	372.4	3.11	248	360.4	2.81

Based on the encouraging results of the tank study, we examined the production potential of the ND60 hybrid in cages in the sea. Two farms in Israel participated in these trials, one located in the Mediterranean Sea and the second in the Red Sea.

These two seas differ in basic environmental parameters. The salinity of the Red Sea is 41 ppt, whereas that of the Mediterranean Sea is approximately 37 ppt. Water temperature in the Red Sea does not vary much throughout the year, changing within a relatively narrow range of 21-25^oC. Temperature fluctuations in the Mediterranean Sea are much more significant, getting as low as 16^oC during winter and as high as 30^oC during summer.

In both cases, ND60 hybrids averaging 2 g, were stocked, following a short adaptation, in the cages. The density of the fish stocked in the Mediterranean was 75/m^3 (15,000 per cage), whereas the density of fish stocked in the Red Sea was 100/m^3 (7,000 per cage). In both cases, fish were fed floating extruded pellets, according to a standard feeding table.

The duration of the growth trial in the Red Sea was 260 days and in the Mediterranean sea 360 days.

Results show that ND60 hybrids reached an average weight of 265g in 6-7 months, when seawater temperature is higher than 23°C. Thus, the actual number of growout days was around 200 days, and the fish had demonstrated a growth rate of 1.32 g/day. When examining the last section of the growth curve (from the onset of summer in May, once water temperature increased over 24°C), it can be seen that fish averaging 70g grew to an average weight of 265g within 90 days, demonstrating a daily increase of 2.2g.

The results obtained from the tank growth trials indicate that the growth rate of ND60 in high salinity (41ppt) is almost comparable to that of ND21 hybrids in freshwater.

Our results, showing specific growth rates of 1.17% for ND60 hybrids within a weight range of 100 to 200 g in seawater, are approximately 8-10% lower than growth rates achieved by the fastest growing hybrids, commercially produced in fresh or slightly brackish water (personal observations). The fish grew at a uniform rate and all had a homogeneous red skin color, with very few individuals bearing darker or lighter spots on their heads.

ND60 hybrids, stocked in the Mediterranean Sea (water salinity 37 ppt), demonstrated an acceptable growth rate of 0.76 g/day between 2 to 60 grams, and a weight increase of 2.2 g/day between 70g to 265g. These results are comparable to production of other fast-growing hybrids in fresh water. During the warm period, the production in the cage was equivalent to 165 g/m^3 per day.

Our results indicate that the new ND60 hybrid maintained its tolerance to high salinity from its *O. mossambicus* ancestor, while gaining the fast growth rate and red skin color from its ND9 and ND5 ancestors. These hybrids abide by the same temperature restrictions and grow best at water temperatures higher than 25°C.

ND60 hybrids are presently grown in sea lagoons in Mauritius, in a brackish water farm in Suriname and in a marine shrimp farm in Guatemala.