DEVELOPMENT OF TILAPIA FOR SALINE WATERS IN THE PHILIPPINES

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Abstract

Four *Oreochromis* species were used in Phase 1 study. Progenies from the 28 cross combinations (5 purebreds and 23 crossbreds) were evaluated in 10 environments with different salinity levels and agro-climatic conditions using communal rearing concept. Data obtained after 120 days of culture revealed that among the different cross combinations reared across environments, pure cross of *O. niloticus* FaST gave the highest gain in weight and S4xS2 (*O. niloticus* GIFT♂ x *O. aureus*♀) gave the highest survival. Positive heterosis was observed in crosses between S2xS1 (*O. aureus*♂ x *O. spilurus*♀) and S3xS5 (*O. mossambicus*♂ x *O. niloticus* FaST♀) for growth and S1xS3 (*O. spilurus*♂ x *O. mossambicus*♀) and S3xS5 (*O. mossambicus*♂ x *O. niloticus* FaST♀) for survival. Purebreds (except *O. mossambicus*) showed better performance than hybrids for growth and survival. Positive combining ability of the different strains showed that *O. niloticus* GIFT and *O. spilurus* have potential for hybridization when used as dam and sire, respectively.

In Phase 2 study, sixteen (16) best performing strain combinations formed the base population. Selected fish were bred and tested in different culture systems namely cage, pond and tank. Result from this study showed that progenies from the cross between (S1xS5)♂ x (S5 x S3)♀ was the best among the top ranking families based on body weight while the cross between (S4xS5)♂ x (S1xS2)♀ was the best in terms of survival. The performance in terms of growth and survival of the different families communally reared in various culture systems was significantly different at $P<0.05$ level. Not all top ranking families based on body weight were included in the top ranking families based on survival. All hybrid crosses with *O. spilurus* was included in the top ranking families based on survival.

Introduction

The Philippines increasing population (at 84M) and the decreasing fish catch from the open seas are issues of concern to intensify food production and provide an impetus to produce more fish. Under the Ginintuang Masaganang Ani for Fisheries of the Department of Agriculture's Masterplan for the Tilapia Industry of the Philippines, the main strategy for increasing fish production is through aquaculture by enhancing productivity in brackishwater ponds and freshwater ponds/cages. The operationalization of the Master Plan hopes to improve productivity and economic efficiency of the country's tilapia farmers while increasing production by at least 171% from 2002 to 2010. Production target for 2004 in brackishwater pond is expected to have an incremental productivity of 1.5 MT from 0.8 MT/ha/yr and 10 MT from 2.5 MT/ha/yr for brackishwater cages (DA, 2002). The strategies/actions recommended to achieve the challenge are through step-up technology transfer, improved efficiency and quality of feeds and development of saline tolerant tilapia. The country has 232,065 ha of brackishwater swamplands and about 239,323 ha of existing brackishwater fishponds (BFAR, 2003) but these are not fully utilized. Development of a new breed of tilapia for saline water has a great potential. The saline tolerant tilapia at biomass maintained at 3.0 to 3.5 tons/ha produce "green water" effectively control the devastating luminous bacteria, *Vibrio harveyi* infection in shrimp culture (Corre *et al.*, 1999; Usero, 1999). Tilapia tolerant to high salinity would greatly increase global animal protein production by expanding the range of production in many parts of the country and regions of the world. Several studies have shown the potential of tilapia in saline environment (Hopkins *et al.*, 1989; Stickney, 1986; Philippart and Ruwet, 1982; Villegas, 1990; Watanabe, 1991).

The National Freshwater Fisheries Technology Center of the Philippine Bureau of Fisheries and Aquatic Resources (NFFTC/BFAR), and the Freshwater Aquaculture Center of the Central Luzon State University (FAC/CLSU) with funding from the Philippine Bureau of Agricultural Research (BAR) of the Department of Agriculture have undertaken a project to develop a breed of tilapia for culture in saline waters as the demand for fast growing and high salinity tolerant tilapia is increasing. This paper focuses on the results of series of experiment conducted in line with the development of salt tolerant tilapia for aquaculture.

Materials and methods

Phase 1

Broodstocks from the different *Oreochromis* species were used to produce the thirty reciprocal crosses and pure strains in a diallele cross design (Figure 1). The fish used in the study were *O. spilurus*, *O. aureus*, *O. mossambicus* and three genetically improved strains of *O. niloticus* namely; 8th generation GIFT strain, FAC selected tilapia (FaST) and YY tilapia. Broodstock of *O. mossambicus* were obtained from BFAR-National Integrated Fisheries Technology Center, Bonuan, Pangasinan and from the wild in Bulacan. The *O. spilurus* fingerlings were provided by the Mariculture and Fishery Development, Kuwait Institute for Science and Research. FaST and YY males broodstock were provided by the FAC/CLSU and *O. aureus* and GIFT fingerlings were obtained from NFFTC/BFAR. The genetic groups used in the study were composed of 27 cross combinations, 5 purebred and 22 crossbred. Out of the 30 crosses bred, only 27 cross combinations were produced.

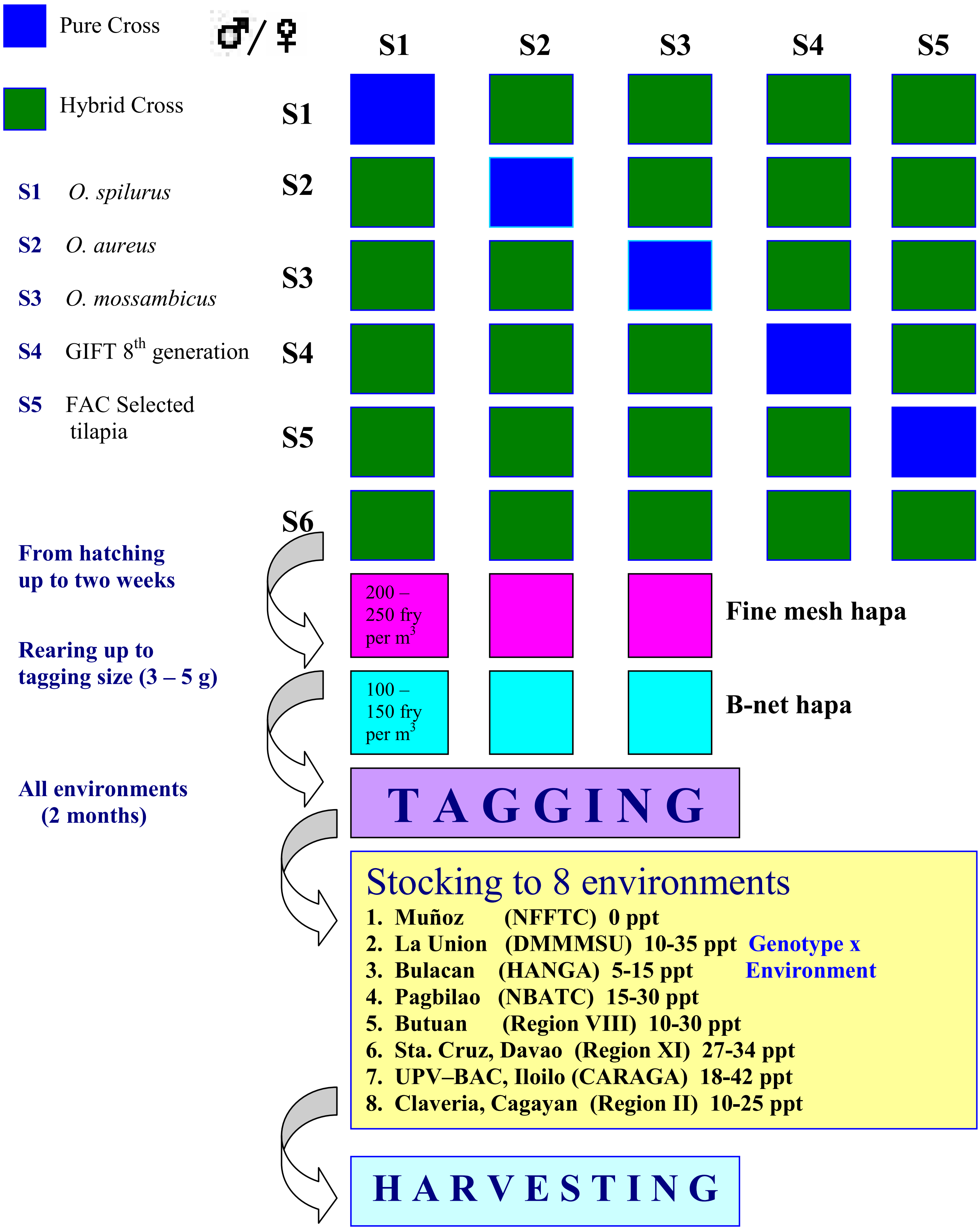

Figure 1. Phase 1 Breeding Plan.

Diallele crossing of different species/strains was carried out following the GIFT Project procedure (Eknath *et al*., 1993). Each of the 30-cross-combinations with ten replicates was stocked with two females and one male, adding up to a total of 300 breeding hapas installed in a 1 ha earthen pond. Prior to stocking the breeders in hapas, premaxilla clipping of male breeders was done to reduce male aggression. One week after stocking, breeding hapas were inspected and fry were collected over a period of two days. Once a female had spawned, males were transferred to another hapa. Fry collected from each hapa were counted, weighed and stocked at 200-250 fry per m^3 in separate fine mesh hapas assigned for each family. Fry collection was done every week to minimize age difference between groups of fry collected. After 21 days of rearing in fine mesh hapas, the fry were transferred to 1 m^3 hapas with larger mesh size (b-net hapas) at a stocking density of 100-150 fry per m^3, still keeping the strain combinations and batches separately. The total number of families collected was 143 from the 27 crosses. Only 127 families were utilized in the study due to age difference of the fish. Fry collected during the same period was referred to as a batch.

Growth performance trials were undertaken using 10 environments with various conditions strategically located in different parts of the country. The test environments included ponds (ENV1 and ENV2 = 0ppt) at BFAR-NFFTC (for back-up), ENV3 (DMMMSU, Sto, Tomas, La Union = 10-35 ppt), BFAR Brackishwater Station ENV4 (Hanga, Hagonoy, Bulacan = 5-15 ppt), ENV5 (CARAGA, Masao, Butuan = 10-30 ppt), ENV6 (pond at Sta. Cruz, Davao = 23-35 ppt), ENV 8 (cage at ponds NBATC, Pagbilao, Quezon = 15-30 ppt), ENV7 (pond at Claveria, Cagayan = 0-10 ppt) and ENV10 (UPV-BAC, Ilo-Ilo = 18-42 ppt). Fish were tagged four days before stocking and were acclimatized to the salinity level where the fish would be stocked. A stocking density of 2 pcs per m^2 and 15 pcs per m^3 for pond and cage was done respectively using communal rearing system. A total of 250 – 391 fingerlings from each of the 27 cross combinations were individually tagged/sampled. This was determined by the number of females contributing to the progeny in each cross combination. Every month 30% of the total fish stocked in each environment were sampled for length and weight. Sex was noted as soon as it could be determined. After 120 days of culture, final weights and lengths of all fish were measured. Dissolved oxygen, temperature and salinity were measured during the growth trial.

Phase 2

Base population obtained from ranking the families within species and among species was adapted (Figure 2). Breeders were randomly stocked using a nested mating design wherein one male was mated to three different females in 50 breeding hapas. Control fish (*O. mossambicus* x *O. mossambicus*), (*O. mossambicus* x *O. niloticus* Egypt strain) was bred with the same sex ratio of 1:2 (M:F). Ten days after stocking, fry were collected and reared in fine mesh rearing hapa at 200-250 fry/m^2. After 21 days, fingerlings were sampled and transferred to b-net hapa at 150-200 fingerlings/m^2 for rearing up to 3-5 g.

Progenies of different cross combinations produced were evaluated for growth performance and survival. Growth performance trials were evaluated using family and group testing. Both evaluations were done using communal stocking technique in cage, pond and tank for 120 days at a stocking density of 15 pcs/$m^{2,}$ 2 pcs/m^2 and 15 pcs/m^3, respectively. Data obtained using family testing was utilized in this paper.

Data analysis

Final body weights of all cross combinations for Phase 1 and 2 corrected for sex effects and survival of fish were analyzed using generalized linear models (GLM) procedure. When means are significantly different, the Duncan's Multiple Range Test at 5 percent level was used to identify the significant differences among cross means.

The heterotic effects were calculated based on the differences in means between growth/survival of a given cross including both reciprocals and the means of purebred of both parental strains. The overall heterosis was computed by mean differences between all purebred and crossbred crosses. Mean differences in growth/survival between purebred and crossbred progenies of a particular cross, were statistically analyzed by T-test (Least Significant Difference).

The combining ability which is defined as the mean performance of a line when expressed as a deviation from the mean of all crosses, was computed based on the differences between growth/survival of strain when it is used to hybridize with other strain and the overall growth/survival of 5 strains.

Value for the combining ability for each strain was determined by subtracting the body weight at harvest and percentage survival of that strain, when used as dam (or sire) with total body weight and survival of five strains when used as dam (or sire). Between strain variation were statistically analyzed using GLM procedure while comparison of means was done using Duncan Multiple Range Test.

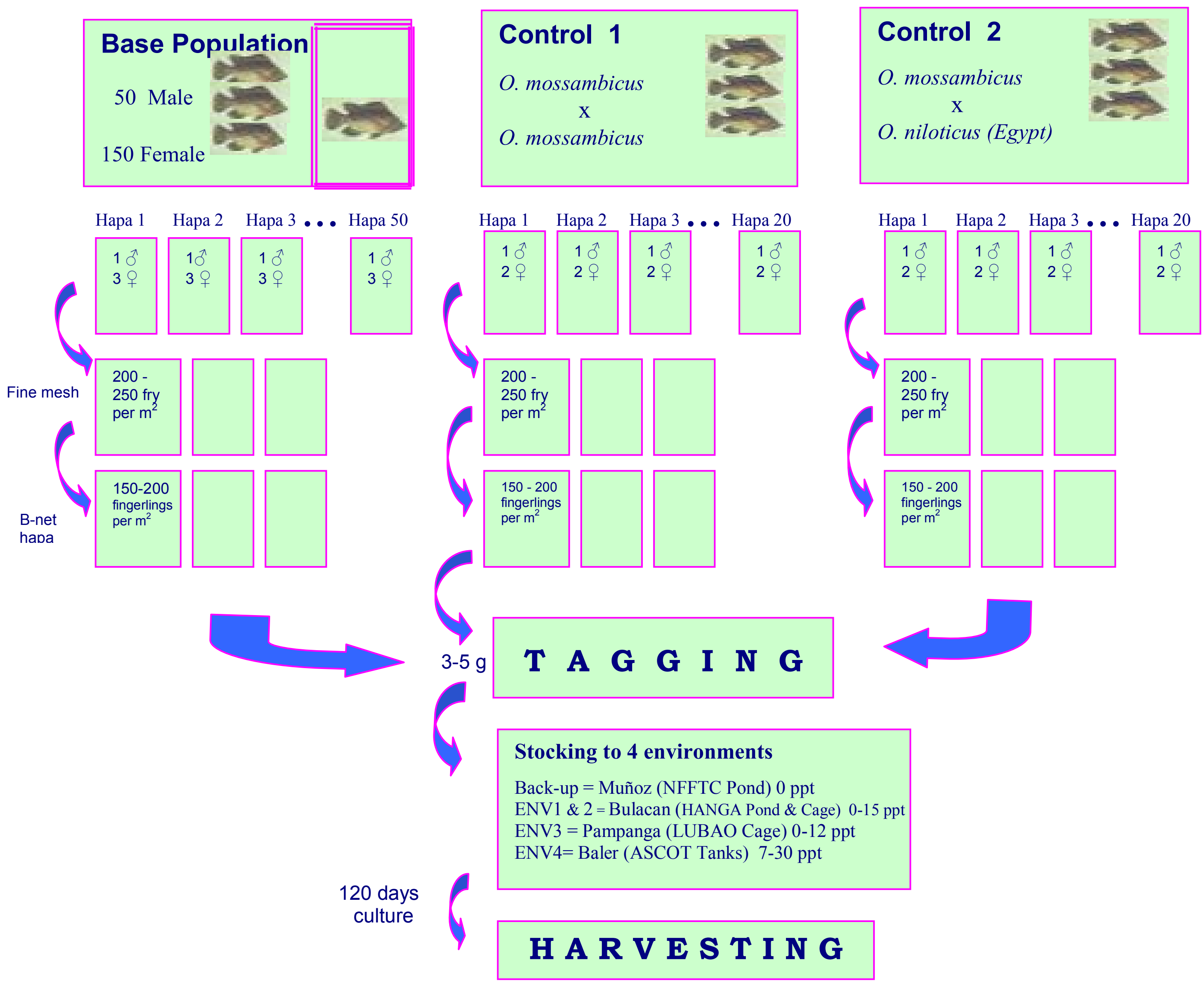

Figure 2. Phase 2 Breeding Plan.

Results and discussion

Growth and survival

The result of various cross combinations based on the mean gain in weight after 120 days of culture is shown in Table 1. Among the different cross combinations reared across environments, S5xS5 (*O. niloticus* FaST x *O. niloticus* FaST) gave the highest gain in weight of 118.779g. Obtained weight was not significantly different at P<0.05 level among the crosses of S4xS5 (*O. niloticus* GIFT x *O. niloticus* FaST), S4xS4 (*O. niloticus* GIFT x *O. niloticus* GIFT) and S6xS4 (*O. niloticus* YY x *O. niloticus* GIFT) which are existing improved breed of *O. niloticus* in the country.

Table 1. Mean gain in weight (g) at harvest across test stations of 27 cross combinations.

	DAM STRAIN				
	S1	S2	S3	S4	S5
S1	102.478 ^{cd}	96.436 ^{de}	48.546 ^{k}	99.802 ^{de}	105.045 ^{bcd}
S2	106.427 ^{bcd}	77.626 ^{gh}	65.279 ^{ij}	-	58.796 j
S3	60.712 ^{j}	-	36.604 ^{l}	-	90.345 ^{ef}
S4	74.686 ^{ghi}	104.747 ^{bcd}	64.266 ^{ij}	113.537 ^{ab}	115.127 ^{ab}
S5	67.786 ^{hij}	82.212 ^{fg}	75.279 ^{ghi}	102.410 ^{cd}	118.779 ^{a}
S6	89.950 ^{ef}	64.373 ^{ij}	64.348 ^{ij}	111.32 ^{abc}	89.710 ^{ef}
Mean weight across environments					82.06g

Means with the same letter are not significantly different (P<0.05).

It is interesting to note that pure cross of S3xS3 (*O. mossambicus*) gave the lowest mean body weight of 36.604g. Hybrid crosses of *O. mossambicus* were faster grower than the pure. These results are consistent with the observations of Auperian and Prunet (1996) and Guerrero (1994) who reported poor growth performance of this salt tolerant species. High tolerance to salinity of FAC selected tilapia and GIFT strain could be explained by their origins. Israel, Singapore and Taiwan strains used to create FAC selected tilapia and GIFT populations were descendants from a founderstock of Ghanaian origin (Eknath *et al*., 1993). It is assumed that the distribution of *O. niloticus* in Ghana was from the Volta River System, which flows through Lake Volta to the Bight of Benin in the Gulf of Guinea. Tolerance of this species may have evolved from its marine ancestors (Villegas, 1990).

Table 2 presents the mean survival across environments of the different cross combinations. The cross of S1xS2 (*O. niloticus GIFT* x *O. aureus*) gave the highest survival of 55.29% followed by the pure cross of S1xS1 (*O. spilurus* x *O. spilurus*) and S5xS4 *(O. niloticus* FaST x *O. niloticus* GIFT). The lowest survival was obtained between the pure cross of S3xS3 (*O. mossambicus* x *O. mossambicus*). The probable cause is the smaller size of *O. mossambicus* (2.57g ±0.78) as compared with the size of the purebred *O. niloticus* FaST (3.65g ±1.57), *O. niloticus* GIFT (2.93g ±1.57), *O. spilurus* (4.33g ±1.41), and *O. aureus* (3.43g ±1.46). This observation was similar to the findings of Watanabe *et al*. (1985), Villegas (1990) as cited by Kongchum (1999) that the ontogenetic changes in salinity tolerance were more closely related to body size than to chronological age.

Table 2. Mean survival (g) across test stations of 27 cross combinations.

	DAM STRAIN				
	S1	S2	S3	S4	S5
S1	53.112 ab	46.188 ef	47.449 def	48.433 cdef	48.951 bcdef
S2	46.866 def	46.254 ef	47.548 def	-	46.459 ef
S3	52.834 ab	-	37.243 h	-	48.304 cdef
S4	46.487 ef	55.290 a	44.793 fg	52.765 ab	41.225 g
S5	51.014 abcd	45.688 ef	47.431 def	53.146 ab	49.679 bcde
S6	48.291 cdef	52.130 abc	46.229 ef	52.435 abc	52.531 abc
Mean survival across environments					48.45%

Means with the same letter are not significantly different (P<0.05)

Percent survival was highest in test environment ENV4 (0-12 ppt) and relatively low in ENV7 (0-10ppt), ENV8 (15-29 ppt) and ENV3 (29-32ppt). There was an incident of almost total mortality in ENV10 (18-42 ppt) caused by entangling of identification tags, intolerance to high salinity and tagging infection, hence ENV10 was excluded in the ranking, as was ENV1 and ENV2 (freshwater environments). Mortality (including tagloss) of the different strain/species combinations varied from 10.47% to 66.95%. Tag loss across test environments (excluding ENV10) was 13.14%. High rate of tag loss in pure breds was due to tagging infection (due to high salinity) and fish size exceeding a certain limit (during fish tagging, an allowance of 3.75 cm of thread was given for growth).

Heterosis

The average heterosis were negative for growth and survival (Table 3). The highest non-additive mean percent heterosis across test environments for growth and survival was observed in the cross between the S3xS5 (*O. mossambicus* x *O. niloticus*) with + 10.02 and 11.26% respectively. This was followed by the cross between *O. spilurus* x *O. aureus* with +7.64% for growth and *O. spilurus* x *O. mossambicus* with + 7.14% for survival. The mean differences between purebred and hybrid progrenies of the seven crossbreds for the indices measured were highly significant (P>0.001).

Result of this study revealed that purebreds performed better than the hybrids indicating no hybrid vigor for growth and survival in saline environment except in the crosses between S3xS5, S1xS2 and S1xS3. The result agrees with the findings of Watanabe *et al.* (1985) that hybrids of *O. mossambicus* and *O. niloticus* showed better growth and feed conversion than their parent species.

Table 3. Heterotic effects on different crosses among five strains of tilapia for growth and survival.

INDICES	CROSSES						
	O. spilurus x O. aureus	*O. spilurus x O. mossambicus*	*O. spilurus x O. niloticus (GIFT)*	*O. spilurus x O. niloticus (FaST)*	*O. aureus x O .niloticus (FaST)*	*O. mossambicus x O. niloticus (FaST)*	*O. niloticus (GIFT) x O. niloticus (FaST)*
Growth Mean value of Crossbred [2/]	101.34 ± 41.65	55.26 ± 32.65	86.68 ± 37.79	83.85 ± 38.70	70.68 ± 34.49	82.00 ± 42.56	105.20 ± 42.65
Mean difference	7.19***	22.11***	19.58***	24.26***	28.00***	7.47***	10.98***
Strain Heterosis	+ 7.64	- 28.58	- 18.43	- 22.44	- 28.37	+ 10.02	- 9.45
Average Heterosis							-12.80
Survival Mean value of Pure breed [1/]	50.81 ± 19.03	47.06 ± 18.35	52.99 ± 22.73	51.93 ± 21.72	48.00 ± 24.50	42.98 ± 22.54	51.21 ± 28.91
Mean value of Crossbred [2/]	46.52 ± 18.94	50.42 ± 13.04	47.42 ± 18.35	50.12 ± 20.86	46.07 ± 19.67	47.82 ± 20.59	47.72 ± 23.90
Mean difference	4.29***	3.36***	5.57***	1.81***	1.93***	4.84***	3.49***
Strain Heterosis	- 8.44	+ 7.14	- 10.51	- 3.48	- 4.02	+ 11.26	- 6.82
Average Heterosis							- 14.87

[1/] Mean Value (± standard deviation) of both parental strain
[2/] Mean Value (± standard deviation) of both reciprocal crosses
*** indicates highly significant differences between pure bred and cross bred at 0.05 level.

Base population

Since only three crosses gave a positive heterosis or hybrid vigor in terms of growth and survival, the effect of crossbreeding was too low to be of significance in an applied breeding program. A simple pure breeding strategy was adopted by selecting best growing individuals from the 16 best performing purebred and crossbred groups (out of 27 crosses evaluated) to build a genetically mixed base population (synthetic breed). Table 4 shows the number of male and female breeders of 16 best performing species combination used to build a new base population.

Table 4. Number of male and female breeders of the 16 best performing strain combination used to build the base population.

RANK	CROSS	MALE (n)	FEMALE (n)	% Composition to Base Population
1	S2 x S1	6	17	11.5
2	S5 x S5	6	16	11
3	S1 x S1	5	15	10
4	S5 x S1	5	15	10
5	S4 x S4	4	14	9
6	S4 x S2	4	14	9
7	S1 x S5	4	12	8
8	S4 x S5	3	10	6.5
9	S6 x S4	3	-	1.5
10	S5 x S4	2	9	5.5
11	S1 x S4	2	8	5
12	S6 x S5	2	-	1
13	S3 x S5	1	8	4.5
14	S1 x S2	1	6	3.5
15	S5 x S3	1	4	2.5
16	S5 x S2	1	2	1.5
		50	150	100

Combining ability

The combining ability estimates for growth and survival are shown in Table 5. *O. niloticus* GIFT strain when used as maternal strain gave positive values of + 23.73g and + 2.81% for growth and survival respectively. The GIFT combining ability for growth were significantly different (P <0.05) from *O. spilurus, O. aureus, O. mossambicus* and *O. niloticus* FaST, while for survival it was significantly different (P<0.05) from *O. aureus, O. mossambicus* and *O. niloticus* FaST. The use of *O. niloticus* GIFT strain as maternal strain increased growth by 23.21g and 1.19% when compared to *O. spilurus*, 19.50g and 2.56% for *O. aureus*, 45.34g and 5.69% for *O. mossambicus* and by 12.54g and 3.07% when compared with *O. niloticus* FaST strain.

On the other hand the use of *O. spilurus* as paternal strain with the positive values of + 7.63g and + 0.47% gave significantly different (P<0.05) from *O. aureus, O. mossambicus*

O. niloticus FaST and *O. niloticus* YY in terms of growth and from *O. aureus* in terms of survival but not with *O. niloticus* YY which gave the highest value of +1.28.

In relation to the positive values of general combining ability, *O. niloticus* GIFT strain and *O. spilurus* showed a potential for hybridization and appears to increase growth and survival when used as dam and sire, respectively.

Table 5. Combining ability for growth (g) and survival (%) of the different tilapia strains.

	Combining Abilities	
	Growth (g)	Survival (%)
Fish was used as Maternal Strain		
O. spilurus	+ 0.515 [c]	+ 1.6173 [ab]
O aureus	+ 4.228 [c]	+ 0.2549 [bc]
O. mossambicus	- 21.615 [d]	- 2.8854 [d]
O. niloticus (GIFT)	+ 23.726 [a]	+ 2.8107 [a]
O. niloticus (FaST)	+ 11.190 [b]	- 0.2581 [c]
Fish was used as Paternal Strain		
O. spilurus	+ 7.634 [a]	+ 0.4717 [ab]
O aureus	- 4.390 [d]	- 1.6010 [c]
O. mossambicus	- 17.971 [e]	- 0.7855 [bc]
O. niloticus (GIFT)	+ 6.241 [ab]	- 0.5058 [abc]
O. niloticus (FaST)	+ 2.270 [bc]	+ 0.5992 [ab]
O. niloticus (YY)	- 1.079 [cd]	+ 1.2812 [a]

Means within parental groups in the same column with the same letter are not significantly different ($P<0.05$).

Result of on-farm trial from the Phase 2 experiment shows that from the different families the cross combination of (S1xS5) x (S5xS3) *O. spilurus*♂ x *O. niloticus* FaST♀ and *O. niloticus* FaST♂ x *O. mossambicus*♀ was the best among the top ranking families based on body weight (Table 6). About 18 and 36 families gave the highest gain in weight and 20 and 26 families in terms of survival was the ranking achieved over the two control groups *O. mossambicus*♂ x Egypt ♀ and *O. mossambicus.*

It is interesting to note that a different ranking in terms of survival was obtained. All hybrids cross with pure *O. spilurus* was included in the top ranking families based on survival. Not all top ranking families based on body weight were included in the top ranking families based on survival. Similar result was obtained from the study of Dureza as cited by Ma Pablico of Manila Times Agribusiness (2003). Dureza of the University of the Philippines in the Visayas (UPV) observed that the male of the hybrid *O. spilurus* and the female of the introduced *O. niloticus* FaST had the highest growth (1.5g a day), biomass (1.9 kg /m^2) and survival (93%) in cages held in brackishwater (20 to 25 ppt) pond for 60 days.

Conclusions

Overall result of the Phase 1 study revealed that purebreds performed better than the hybrids in almost all crosses indicating no hybrid vigor for growth and survival in crossbred progenies except for S1xS2 and S3xS5 for growth and S1xS3 and S3xS5 for survival. The average negative heterosis reflects the minimal non-additive genetic variance and therefore does not justify a crossbreeding approach. It is possible to improve the trait for salinity tolerance of this species through selection that exploits the additive effects of genes controlling this trait. Alternatively, specialized hybrids may be produced using specialized sire and dam lines such as reciprocal crosses of S1xS2 and S3xS5 for growth and S1xS3, S3xS5 for survival. Another option is by producing a hybrid based in the general combining ability of the different strains wherein, *O. niloticus* GIFT strain and *O. spilurus* showed a potential for hybridization and appears to increase growth and survival when used as dam and sire respectively.

Phase 2 study revealed that an increased growth and survival rate was achieved through selection. About 18 and 36 families gave the highest gain in weight and 20 and 26 families in terms of survival was the ranking achieved over the two control groups *O. mossambicus*♂ x Egypt ♀ and *O. mossambicus.* Salinity tolerance in terms of growth and survival was influenced by the male parent *O. spilurus* while the female parent *O. niloticus* FaST influenced the growth rate. Different ranking in terms of growth and survival was obtained across environment. All hybrids cross with pure *O. spilurus* was included in the top ranking families based on survival but not all top ranking families based on body weight were included in the top ranking families based on survival.

Table 6. Phase 2 rank-order and significance of ranks for final body weight corrected for sex effect and survival of the different cross combinations across and within environments (ranks within test environments sharing the same superscript letters are not significantly different *P*<0.05).

Crosses	Group cross	ENV1 CAGE	ENV2 POND	ENV3 CAGE	ENV4 TANK	Across ENV	Mean SURV
(S1S5)x(S5S3)	9	10^{bcdef}	3^{bc}	1^{a}	$12^{abcdefgh}$	1^{a}	39^{no}
(S1S4)x(S4S4)	6	3^{bc}	$16^{bcdefghi}$	24^{bcde}	1^{a}	2^{ab}	17^{defghi}
(S5S1)x(S1S4)	27	9^{bcde}	-	2^{ab}	18^{defgh}	3^{ab}	16^{defghi}
(S4S4)x(S2S1)	20	2^{ab}	$25^{cdefghi}$	34^{de}	-	4^{abc}	19^{efghij}
(S5S5)x(S4S2)	36	13^{cdefg}	4^{bc}	10^{bcde}	22^{defgh}	5^{abcd}	36^{mn}
(S1S1)x(S4S4)	3	8^{bcd}	$20^{cdefghi}$	8^{abcd}	$8^{abcdefg}$	6^{abcd}	7^{cd}
(S4S4)x(S5S4)	23	4^{bc}	30^{defghi}	19^{bcde}	$11^{abcdefgh}$	7^{abcd}	29^{hijkl}
(S5S5)x(S3S5)	35	12^{cdefg}	1^{a}	37^{de}	$14^{abcdefgh}$	8^{abcde}	35^{klmn}
(S1S1)x(S4S5)	4	11^{bcdef}	11^{bcdef}	13^{bcde}	$7^{abcdefg}$	9^{abcdef}	2^{b}
(S4S4)x(S4S5)	21	$18^{cdefghij}$	$15^{bcdefghi}$	6^{abcd}	3^{abc}	10^{abcdef}	12^{defg}
(S1S1)x(S5S5)	5	$16^{cdefghi}$	2^{b}	7^{abcd}	17^{cdefgh}	11^{abcdef}	33^{jklm}
(S2S1)x(S1S5)	12	5^{bc}	38^{i}	15^{bcde}	4^{abcd}	12^{abcdef}	13^{defg}
(S1S1)x(S4S2)	2	15^{cdefgh}	12^{bcdefg}	5^{abcd}	26^{defgh}	13^{bcdefg}	3^{bc}
(S2S1)x(S5S4)	16	7^{bcd}	$18^{cdefghi}$	18^{bcde}	$16^{bcdefgh}$	$14^{bcdefgh}$	15^{defgh}
(S2S1)x(S5S1)	15	$21^{efghijk}$	9^{bcde}	11^{bcde}	2^{ab}	$15^{cdefghi}$	22^{ghij}
(S2S1)x(S4S4)	14	14^{cdefgh}	$27^{cdefghi}$	16^{bcde}	$9^{abcdefgh}$	$16^{cdefghi}$	31^{ijklm}
(S4S4)x(S5S1)	22	$17^{cdefghij}$	31^{defghi}	14^{bcde}	5^{abcde}	$17^{cdefghi}$	24^{ghijk}
(S4S4)x(S1S2)	18	6^{bcd}	37^{hi}	29^{bcde}	34^{gh}	$18^{cdefghi}$	14^{defg}
(S5S1)x(S5S5)	28	1^{a}	$23^{cdefghi}$	23^{bcde}	29^{efgh}	$20^{defghijk}$	40^{o}
(S4S2)x(S5	17	$27^{fghijkl}$	8^{bcde}	36^{de}	20^{defgh}	$21^{defghijk}$	28^{hijkl}

S5)							
(S2S1)x(S1S4)	11	$24^{fghijkl}$	$21^{cdefghi}$	33^{cde}	-	$22^{efghijkl}$	23^{ghijk}
(S4S4)x(S1S5)	19	30^{hijklm}	5^{bcd}	22^{bcde}	27^{efgh}	$23^{fghijkl}$	18^{defghi}
(S5S5)x(S1S4)	32	29^{hijklm}	$17^{bcdefghi}$	9^{bcde}	30^{efgh}	$24^{fghijkl}$	34^{jklm}
(S2S1)x(S4S2)	13	$19^{defghijk}$	$19^{cdefghi}$	26^{bcde}	28^{efgh}	$25^{fghijkl}$	8^{cde}
(S2S1)x(S1S2)	10	$23^{fghijkl}$	$26^{cdefghi}$	21^{bcde}	19^{defgh}	26^{ghijkl}	5^{bcd}
(S5S1)x(S1S1)	25	33^{klm}	7^{bcd}	32^{bcde}	$10^{abcdefgh}$	27^{ghijkl}	25^{ghijk}
(S1S1)x(S3S5)	1	$19^{efghijk}$	36^{hi}	35^{de}	6^{abcdef}	28^{ghijkl}	11^{defg}
(S5S5)x(S1S5)	33	$25^{fghijkl}$	$13^{bcdefgh}$	20^{bcde}	21^{defgh}	$29^{ghijklm}$	4^{bc}
(S4S5)x(S1S2)	24	$28^{ghijklm}$	$14^{bcdefghi}$	27^{bcde}	$15^{abcdefgh}$	30^{hijklm}	1^{a}
(S5S4)x(S5S5)	30	32^{jklm}	29^{defghi}	4^{abcd}	35^{gh}	31^{ijklm}	26^{ghijk}
(S5S5)x(S2S1)	34	$26^{fghijkl}$	39^{i}	38^{de}	23^{defgh}	32^{ijklm}	36^{klmn}
(S1S5)x(S1S1)	7	31^{ijklm}	32^{efghi}	30^{bcde}	25^{defgh}	33^{jklmn}	6^{bcd}
(S1S5)x(S5S1)	8	22^{fghijk}	35^{ghi}	40^{e}	32^{efgh}	34^{jklmn}	9^{cdef}
(S5S5)x(S5S4)	38	38^{m}	33^{efghi}	12^{bcde}	-	35^{jklmn}	37^{lmn}
(S5S2)x(S1S5)	29	35^{klm}	$24^{cdefghi}$	25^{bcde}	37^{h}	36^{klmn}	20^{fghij}
(S5S1)x(S1S2)	26	36^{lm}	$28^{cdefghi}$	17^{bcde}	31^{efgh}	38^{lmn}	10^{defg}
(S5S5)x(S1S1)	31	40^{m}	34^{fghi}	31^{bcde}	33^{fgh}	39^{mn}	32^{ijklm}
(S5S5)x(S5S1)	37	39^{m}	10^{bcdef}	39^{e}	36^{h}	40^{n}	30^{ijklm}

CONTROL							
O. mossambicus	39	37^{m}	$22^{cdefghi}$	28^{bcde}	24^{defgh}	37^{lmn}	21^{ghij}
O. mossambicus x *O. niloticus* Egypt	40	34^{klm}	6^{bcd}	3^{abc}	$13^{abcdefgh}$	$19^{defghij}$	27^{hijkl}
MEAN WT. (g)		101.13	85.54	100.89	60.21	91.10	
MEAN SURV. (%)*		62.18 (547)	50.46 (228)	43.88 (368)	51.81 (253)	53.56 (1,396)	

*Excluding tag loss

Legend:

ENV1 = Bulacan Cage (0-15 ppt)
ENV2 = Bulacan Pond (0-15 ppt)
ENV3 = Pampanga Cage (0-15 ppt)
ENV4 = Aurora Tank (7-30 ppt)

STRAINS: S1 = *O. spilurus*
S2 = *O. aureus*
S3 = *O. mossambicus*
S4 = *O. niloticus* GIFT
S5 = *O. niloticus* FaST

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