SELECCIÓN MASAL POR PESO Y COLORACION EN TILAPIA ROJA
MASS SELECTION BY WEIGHT AND COLORATION IN RED TILAPIA

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RESUMEN

Para evaluar la efectividad de la selección masal por color y peso se analizaron dos generaciones (G_1 y G_2) de alevinos de Tilapia Roja *Oreochromis sp.* De 40.000 larvas a la sexta semana se eliminaron los alevinos manchados y blancos y a las 14 semanas se separaron por sexos. Se midió el peso (g), la longitud total (cm), la altura (cm) y el ancho (cm) de 150 individuos a las 6, 14 y 24 semanas de edad. En la semana 24 se escogieron 150 machos y 450 hembras con las coloraciones deseables y mayor peso. La selección resultó efectiva para coloración en G_2, puesto que la proporción de individuos rojos se incrementó en 15% con respecto a los testigos. Entre generaciones (G_1 y G_2) el efecto de la selección fue positivo, debido a que la proporción de rojos se incrementó de 64% a 84% y se redujo la de manchados de 31% a 13%. En ambas generaciones los machos fueron significativamente mas pesados que las hembras. Se encontraron diferencias significativas entre generaciones para peso y talla, puesto que los selectos superaron al control en 27% y 8% (G_1) y en 22% y 11% (G_2) para el peso y la talla, respectivamente.

Palabras clave: Mejoramiento peces; acuicultura; *Oreochromis sp.*

ABSTRACT

In order to evaluate the effectiveness of mass selection by color and weight, two generations (G_1 y G_2) of Red Tilapia *Orechromis sp*. (40,000 larvae) were analyzed. At six weeks old, white fries, and those with black spots were eliminated, and at week 14, the fishes were separated by sex. The weight (g), length, height and width (cm) were measured in a sample of 150 individuals at 6, 14 and 24 weeks. At week 24, the best 150 males and 450 females with desirable colorations and greater weight were chosen. The selection was effective for coloration in G_2, with the proportion of red individuals increasing in 15% compared to the control. The effect of the selection between generations (G_1 y G_2) was positive, as the proportion of red fries increased from 64% to 84%, and the spotted ones were reduced from 31% to 13%. In both generations males were significantly heavier than the females. Significant differences between generations were found for weight and size, with the selection treatments being 27% and 8% (G_1) heavier, and 22% and 11% (G_2) bigger than the controls.

Key words: Fish breeding; aquaculture; *Oreochromis sp.*

INTRODUCTION

The tilapia, *Oreochromis sp.*, the second most important species in aquaculture worldwide, has a rapid growth, hardiness, optimum quality meat, and an absence of spines in a 'Y' form, making it appropriate for the filleting industry (Boscolo, 1999). In South and Central American countries, the importance of the cultivation of red tilapia grew in the decades 80s and 90s (Morales y Morales, 2006). In Colombia 62% of freshwater production is represented by red tilapia (Espejo, 2006), and the consumption *per capita* grew from 3.8 kg año^{-1} in 1998 to 5.3 kg año^{-1} in 2005 (Castillo, 2006). Although consumers prefer red colored fish, in the production of fry, a high proportion of individuals have melanic patches, reducing the market price.

Color inheritance mechanisms in tilapia differ among species, and among populations in the same species. Wohlfarth *et al.* (1990) proposed that the red coloration in *O. mossambica* was determined by a recessive autosomal gene, while for Ferreira (1989) it was controlled by an epistatic interaction between two of more genes. In Taiwanese tilapia the red color seems to result from heterozygosity between two partially dominant alleles at one locus (P_1P_1=wild; P_1P_2=red y P_2P_2=white-pink). The white homozygote is subvital and difficult to distinguish from red individuals; to obtain red progeny, white individuals must be crossed with normal ones (Wohlfarth *et al.*, 1990). In contrast, in *O. niloticus* the red color is determined by a dominant autosomal gene (McAndrew, 1988).

In Thailand, Jarimopas and Veerasidth (1988) performed mass selection for weight and length and found a heritability of 0.18 for weight, and 0.29 for length in red tilapia. In the second generation of mass selection, they obtained a line 16% heavier and 8% longer than the control. In *O. niloticus* significant differences have been seen in weight at 198 days in favor of the selected group (Remolina, 1997). In the non-selected population the heaviest animals were the black ones, although the red individuals increased weight by 7% after a generation of mass selection (Behrends *et al.,* 1988). In a hybrid population of *O. niloticus* x *O. mossambicus* significant differences occurred in the percentage of black spotted individuals, in favor of the selected group, but not in the weight of the different colorations (Nandlal, 1998).

Through mass selection in the hybrid *O. niloticus* x *O. mossambicus* coloration has been improved without affecting the weight of the animals. The appearance of black patches is attributed to a second locus, different to that for red coloration, and these patches have been visible in red animals (Rr), although they are masked in black recessive animals (Mather *et al*., 2001). Garduno-Lugo *et al.* (2004) eliminated the black and spotted individuals from a red, spotted population of tilapia from the Stirling line (*O. niloticus*) until they obtained 100% red individuals; in the fifth generation, using progeny tests, they determined the homozygote nature of the red coloration.

The aim of the resent study was to evaluate the response to mass selection for weight and coloration in a population of fry of the red tilapia in the Cauca Valley, Colombia.

MATERIALS AND METHODS

The work was carried out on the fish farm “La Linda”, located in the village of La Tupia, Municipality of Pradera, Department of Valle del Cauca, Colombia (1100 m.a.s.l., 24°C, annual precipitation of 1306 mm. and relative humidity of 80%). The population was composed of a heterogeneous mix of animals originating from Jamaica, Israel, Florida and Taiwan.

Control (C) and Selected (S) groups were formed with 40.000 recently-eclosed larvae, in two tanks in the ground (530 m², 0.80 m of average depth). The animals were fed with commercial concentrate, containing 45% protein until they had reached 10g of weight, then 38% protein until 50g of weight, and then 24% protein until the end of the experiment. At the end of the second generation, the animals had as the only source of feed, the primary production. Two generations were evaluated (G_1 y G_2).

At six weeks, animals with greater and lesser weights were eliminated, and 10,000 individuals were selected with desirable coloring (yellow, orange, pink and red). In week 14 the animals were sexed and the tank divided with mesh. In week 24, 600 individuals were chosen (female:male 3:1) with above average weights, and desirable coloration. At 6, 14 and 24 weeks samples of 150 fish were measured for weight (g), length (cm), height (cm) and width (cm). For the second generation 25000 larvae were used.

The effect of selection on the growth variables was evaluated by comparing the selected population with the controls within each generation. For the growth variables at six weeks, the following statistical model was used:

$Y_{ijk} = \mu + P_i + C_j + P_i \times C_j + e_{ijk}$

μ = mean
P_i = population effect (Selected or Control)
C_j = color effect (red tone, spotted or white)
$P_i \times C_j$ = population x color effect
e_{ijk} = experimental error

At 14 and 24 weeks of age, the following model was used:

$Y_{ijklm} = \mu + E_i + P_j + S_k + E_i \times P_j + P_j \times S_k + E_i \times S_k + E_i \times P_j \times S_k + e_{ijk}$

μ = mean
E_i = age (14 and 21 or 24 weeks)
P_j = population effect
S_k = sex effect
$E_i \times P_j$ = effect of age x population interaction
$P_j \times S_j$ = effect of sex x population interaction
$E_i \times S_k$ = effect of age x sex interaction
$E_i \times P_j \times S_k$ = effect of interaction age x population x sex
e_{ijk} = experimental error

RESULTS AND DISCUSSION

High and significant phenotypic correlations (n=150) were observed in the two generations, in both males and females. Notable correlations were: weight-height (r=0.93; P(α≤0.01), weight-length (r=0.91; P(α≤0.01), length-height (r=0.90; P (α≤0.01) y weight-width (r=0.86; P(α≤0.01), indicating that the variables length, height and width intervene in the determination of weight. Given this, this work concentrates on the analysis of weight.

Effect of selection on body coloration

In G_1 the proportion of different colorations was similar in Control (C) and Selected (S) populations (X^2, $\alpha<5\%$) (Table 1). The selection for coloration was effective in $G_{2,:}$ In S the proportions of red, spotted and white individuals were 84%, 13% and 3% respectively, while in C they were 69%, 24% and 7%, respectively. This difference between C and S represented an increase of 15% in the desired coloration. Between generations (G_1 y G_2) the effect of selection was positive, with the proportion of reds increasing from 64% to 84%, and the spotted individuals reducing from 31% to 13%.

Table 1. Numbers (and proportion) of colorations in the groups C and S in two generations (G_1 y G_2)

	G_1		G_2	
Coloration	S	C	S	C
Red	95 (0.64)	93 (0.62)	127 (0.84)	104 (0.69)
Spotted	47 (0.31)	45 (0.30)	19 (0.13)	36 (0.24)
White	8 (0.05)	12 (0.08)	4 (0.03)	10 (0.07)

Effect of coloration on growth variables

The spotted animals showed greater weight, length and width at six weeks than those with red coloration in both generations and populations (G_1 and G_2) and populations (C and S), and the white individuals had the lowest weights (Table 2). Similar results were found by Henao and Montero (1994), and Martínez and Velásquez (1998). In both generations significant differences were seen at six weeks of age between populations (C and S), and colors; the interaction population x color was not significant, indicating that the selection affected animals with different coloration in the same way (Table 3).

Table 2. Means of weight (g), length (cm), height (cm) and width (cm) according to color, at six weeks of age in two generations of tilapia.

Generation	Population	Color	weight (g)	length (cm)	height (cm)	width (cm)
G_1	S	R	1.4[b]	4.3	1.3	0.47
		P	1.6[a]	4.6	1.3	0.48
		W	0.5[c]	3.5	0.9	0.55
	C	R	0.9[b]	3.8	1.1	0.49
		P	1.1[a]	4.0	1.2	0.51
		W	0.5[c]	3.4	0.9	0.29
G_2	S	R	1.9[b]	4.8	1.5	0.55
		P	2.1[a]	4.9	1.5	0.61
		W	0.7[c]	3.8	1.0	0.45
	C	R	0.9[b]	3.8	1.1	0.40
		P	1.1[a]	4.0	1.2	0.45
		W	0.3[c]	3.0	0.9	0.30

Selected(S), Control (C); Red (R); Spotted (P), White (W). n = 150

*Means with the same letter are not significantly different

Table 3. Analysis of variance for weight, length, height and width of tilapia at 6, 14, 21 and 24 weeks.

Age (wks)	Generation	Source Variation	d.f.	Weight	Length	Height	Width
6	G_1	P	1	14.43 **	17.42 **	1.52 **	0.00
		C	2	5.77 **	6.22 **	1.13 **	0.08
		P * C	2	0.52	0.40	0.04	0.18
	G_2	P	1	83.02 **	79.15 **	10.86 **	1.61 **
		C	2	5.51 **	6.21 **	0.84 **	0.13 **
		P * C	2	0.71	0.19	0.10	0.00
14 and 24	G_1	E	1	563389.9**	4970.31 **	743.48 **	164.32 **
		P	1	21926.4 **	128.34 **	22.54 **	3.65 **
		S	1	26780.1 **	169.07 **	22.78 **	3.74 **
		E * P	1	18003.9 **	15.90 **	6.80 **	2.75 **
		P * S	1	7096.7 **	15.52 **	3.42 **	0.45 *
		E * S	1	19604.7 **	44.12 **	7.28 **	0.93 **
		E * P * S	1	9206.5 **	37.85 **	5.17 **	1.04 **
14 and 21	G_2	E	1	18651.7 **	1011.14 **	59.79 **	3.68 **
		P	1	1402.4 **	80.00 **	3.02 **	3.17 **
		S	1	1895.7 **	37.95 **	4.37 **	0.15
		E * P	1	1752.7 **	57.47 **	3.08 **	5.15 **
		P * S	1	15.8	0.18	0.22	0.08
		E * S	1	896.7 **	15.84 **	2.51 **	0.52 *
		E * P * S	1	161.1	4.28	0.75	0.02

Population (P), Color (C), Age (E), Sex (S).
** P (<=0.01), * P (<=0.05).

Effect of selection on growth variables

Generation 1: At 14 weeks, the analysis of variance found significant differences between C and S in the growth variables (Table 3). In S, individuals were 9.4% heavier and 6.3% longer, than the controls (Table 4). This result is less that that reported by Jarimopas and Veerasidth (1988), who found that the selected line was 15.7% heavier than the control. At 24 weeks, the variables for the selected line were significantly greater than the controls: 27% heavier, 8% longer, 12% higher and 14% wider than the controls. The difference between the mean of the S population and the C was 23g, 1.3cm, 0.6cm, and 0.29 cm for weight, length, height and width, respectively. This result was greater than that found by Remolina (1997), who increased weight by 17% at 180 days, and by Arango *et al.* (2000) who found a 13.7% increase in average weight at 25 weeks in the selected population.

Generation 2: All the variables presented significant differences between ages, populations, sexes and in the interaction age x sex (Table 3). At 21 weeks, the appearance of filamentous algae *Oedorium sp* obliged the selection to brought forward. However, it was effective, as the selected line was 21.5% heavier, 11% longer, 78% higher and 22% wider than the controls (Table 4). At this age, weight was notably less than in the preceding generation. The low rates of growth could be due to deficiencies in the changing of water, in the high hardness (299 mg/l), to the presence of *Oedorium sp*., to the stress caused by the taking of the bio-measures, as well as the low concentration of dissolved oxygen during the night. Stress in fishes could have a negative effect on growth, reproduction, meat quality and susceptibility to disease (Chippari and Gómez, 1999).

Table 4. Comparison of the variables of weight, length, height and width in two generations of tilapia at 6, 14 and 21/24 weeks.

Generation	Age (weeks)	Population	weight (g)	length (cm)	height (cm)	width (cm)
G_1	6	S	1.4[a]	4.3	1.3	0.48
		C	0.97 [a]	3.9	1.1	0.48
	14	S	12.7 [a]	9.5	2.8	0.95
		C	11.5 [a]	8.9	2.6	0.93
	24	S	84.9 [a]	15.6	5.2	2.13
		C	61.9 [b]	14.3	4.6	1.84
G_2	6	S	1.9 [a]	4.8	1.5	0.55
		C	0.9 [a]	3.8	1.1	0.41
	14	S	15.6 [a]	9.2	2.9	1.16
		C	15.9 [a]	9.1	2.9	1.20
	21	S	30.2 [a]	12.4	3.7	1.50
		T	23.7 [b]	11.0	3.4	1.17

*Means with the same letter are not significantly different between C and S.

The effectiveness of mass selection at the different ages could be due to the high genetic diversity at RAPDs detected by Torres (2004) when comparing this fish farm with four others in the Valle del Cauca. This study found this population to have a

greater number of alleles (21), expected heterozygosity (He) was 0.24, and the level of participation of the parental species was: 43% for *O. mossambicus*, 36% for *O. niloticus* and 21% for *O. aureus*.

Effect of sex

In the analysis of variance highly significant differences were detected between sexes for both generations, and for the interaction population x sex in the first generation (Table 3). At 14 weeks (Table 5) no differences were seen in weight between males and females but at 24 and 21 weeks, the males were 29% (G_1) and 20% (G_2) heavier. Behrends *et al.* (1998) found that at 105 days, the red and normal (black) males were 26% and 15% heavier. The interaction sex x population was significant in the G_1, as the selected males were 36% heavier, while the females were 12.8% heavier. In the G_2 no interaction was significant.

Table 5. Comparison of the variables weight, length, height and width in two generations of males and females of tilapia.

Generation	Age (weeks)	Population	Sex	weight (g)	Length (cm)	height (cm)	width (cm)
G_1	14	S	H	12.2[a]	9.3	2.7	0.92
			M	13.2[a]	9.7	2.8	0.97
		T	H	10.1[a]	8.6	2.5	0.87
			M	13.0[a]	9.3	2.7	0.98
	24	S	H	65.2[a]	14.4	4.7	1.94
			M	104.7[b a a]	16.8	5.7	2.31
		T	H	56.8[a]	13.9	4.5	1.79
			M	66.9[b]	14.7	4.7	1.89
G_2	14	S	H	15.4[a]	9.1	2.9	1.16
			M	15.8[a]	9.2	2.9	1.17
		T	H	15.0[a]	8.9	2.8	1.23
			M	16.9[a]	9.2	3.0	1.17
	21	S	H	26.5[a]	11.9	2.5	1.45
			M	33.9[b]	12.9	3.8	1.55
		T	H	21.4[a]	10.7	3.2	1.13
			M	26.0[b]	11.4	3.5	1.21

* Means with the same letter are not significantly different

CONCLUSIONS

High correlations were found between weight-height, weight-length and weight-width, indicating that the producer can select animals based on measures of size.

In both generations significant differences were found in weight, height, and length between populations and colors.

Mass selection was effective for coloration. The proportion of red individuals increased by 15% and the non-desirable colorations (spotted and white) decreased from 36% to 16% in one generation.

The superiority of the selected line in the $G_1$was of 27% in weight, and 8% in size, compared to the control. In the G_2 the response was similar, with the selected line being 21.5% heavier and 11.3% longer.

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