

Analysis of Fertilizer Effect in the Tilapia Growth of Mozambique (*Oreochromis mossambicus*)

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Abstract—This paper analyses the effect of fertilizer (organic and inorganic) in the growth of tilapia. An experiment was implemented in the Aquapesca Company of Mozambique; there were considered four different treatments. Each type of fertilizer was applied in two of these treatments; a feed was supplied to the third treatment, and the fourth was taken as control. The weight and length of the tilapia were used as the growth parameters, and to measure the water quality, the physical-chemical parameters were registered. The results show that the weight and length were different for tilapias cultivated in different treatments. These differences were evidenced mainly by organic and feed treatments, where there was the largest and smallest value of these parameters, respectively. In order to prove that these differences were caused only by applied treatment without interference for the aquatic environment, a Fisher discriminant analysis was applied, which confirmed that the treatments were exposed to the same environment condition.

Keywords—Fertilizer, tilapia, growth, statistical methods.

I. INTRODUCTION

AQUACULTURE is defined as production of aquatic organisms, fish creation, molluscs, crustacean, amphibians and cultivation of aquatic plants. It is practiced for long time and the researches indicate that Chinese's and Egyptians were the pioneers to practise this activity. Fish farming has several advantages than other aquatic animals. FAO research (Food and Agricultural Organization) indicates that one hectare of fish farming provides greater yield than any other animal. Unlike the mammals that depend of the air quality for breathing, fish regulates its internal temperature more easily since its density is the same of the water density. So, fish spends very little energy to fluctuate and move, this allows to achieve greater productivity.

One of the limitations of aquaculture in Mozambique is the difficulty in acquiring food for the animals. Economic factor and delay to obtain it are some examples associated with this aspect. Therefore, an alternative to overcome it could be the application of fertilizer in the tanks, to activate sufficient natural food (plankton) to feed the Mozambican tilapia.

Tilapia leverages efficiently a variety of natural foods. It produces protein when consuming phytoplankton in tanks with organic fertilizers of very low cost. The high cost of concentrated foods

is a drawback to obtain a profitable production in intensive aquaculture [6].

The FAO researches [7] show that the Nilotilapia can efficiently use the natural foods and obtain yields of 3000 kg per hectare in well-fertilized tanks without additional food. This food strategy depends on the application of the organic or inorganic fertilizer to stimulate the production of living organisms and plants in the cultivation system.

For Tacon [10] the both fertilizer (organic and inorganic) act stimulating the production of phytoplankton in the tanks. The inorganic fertilizer acts through primary productivity of the tank, whereas the organic fertilizer can also provide organic matter and debris. According to Tacon [10], organic fertilizer is especially suitable for cultivation of tilapia, therefore, besides its value as fertilizers, it represents an immediate source of food, since the tilapia can feed on waste and plant by-products.

This paper analyses the effect of the organic fertilizer (produced through rice scraps), inorganic fertilizer (Urea) and feed in the growth of Mozambican tilapia, therefore, the applied methods seek to achieve this aspect.

II. MATERIAL AND METHODS

A. Design of Experiment

Experimentation is fundamental in research and to develop many fields of science. A good planning and execution provides quality information that allows understanding the system and being able to optimize it [3].

An experiment consists in solving a series of problems using an implementation of an algorithm [4]. Design of experiment is based on the planning of experimental activity.

The present work presents only one factor: Type of treatment, with four levels (organic fertilizer, inorganic fertilizer, feed and control) which was selected to analyze the effect in each treatment on the tilapia growth.

To describe the experimentation process is important to present the following aspects:

1) *Experimental Organisms*: The research analysed the Mozambican tilapia (*Oreochromis mossambicus*) in a population of males of 2050 individuals distributed in four tanks.

2) *Cultivation Phase*: The management of tilapia cultivation is classified as pre-fattening (weight of fish vary from 10 to 100g) and fattening (fish with weight of more than 100g). This research considered only the second phase, so that the tilapias assigned in the tanks had at least 100g.

The assignation was realized through samples of 20 individuals ($n = 20$), corresponding to a total biomass of

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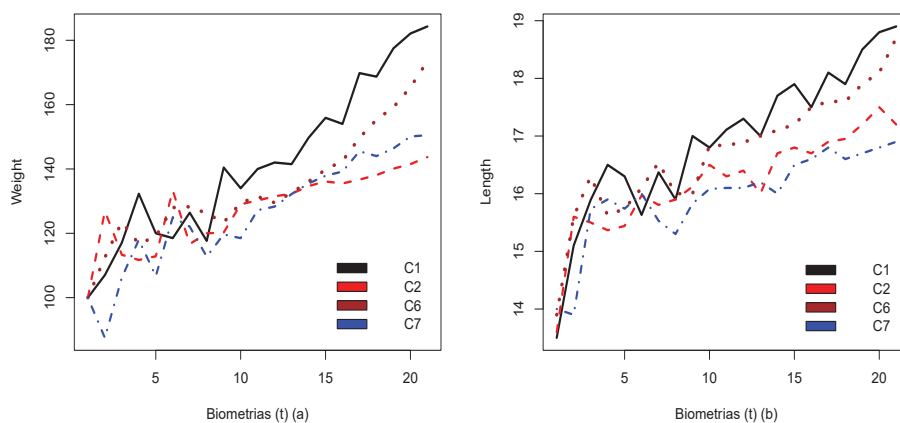


Fig. 1 Biometric parameters

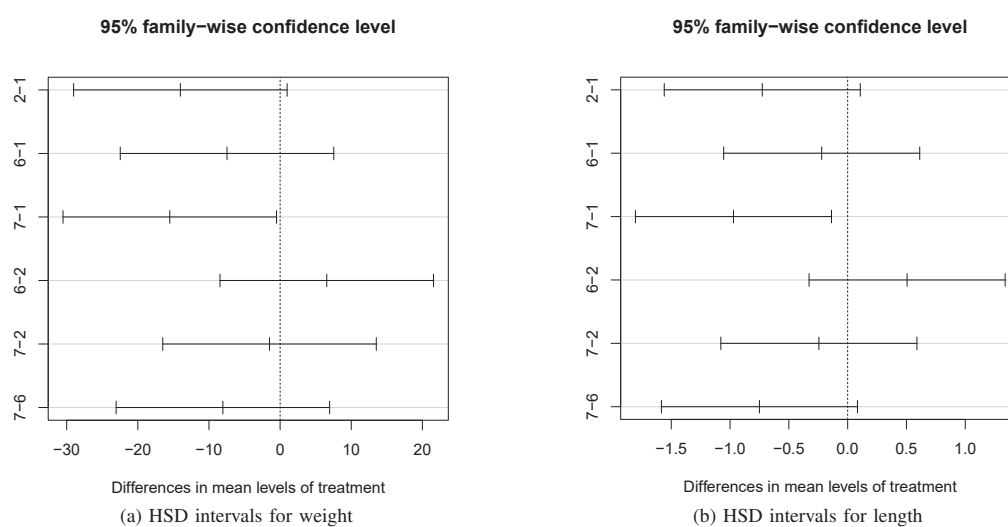


Fig. 2 Comparison of biometric parameters through HSD intervals

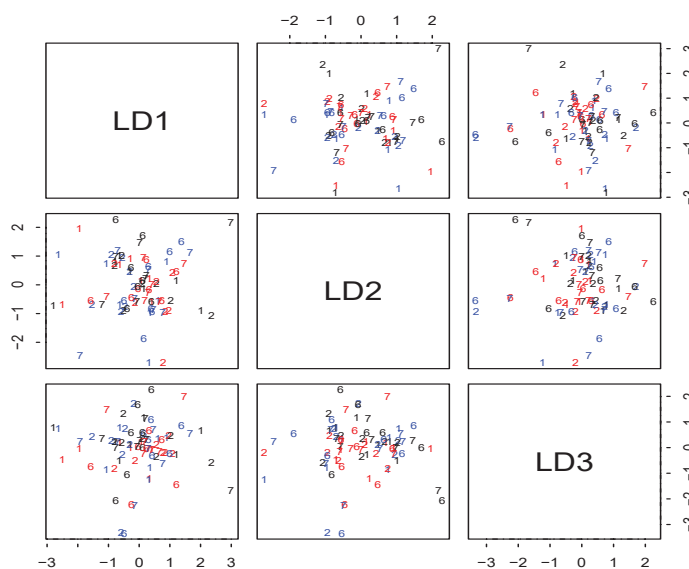


Fig. 3 Classification of treatments according to the aquatic environment

TABLE I
ANOVA RESULTS

V. R	C1	C2	C6	C7	F	sig
Weight	140.7	131.8	139.8	129.4	3.071	0.0324
Length	16,3	15,9	16,2	15,7	3.958	0.011
Growth rate	0,75	-0,15	0,19	-0,69	3,44	0,030

V. R=Variable respuesta

TABLE II
FISHER LINEAR DISCRIMINANTS FUNCTIONS

D. F	λ de Wilks	χ^2	g.l	sig
1 a 3	0,815	5,815	9	0,758
2 a 3	0,918	2,445	4	0,654
3	0,979	0,604	1	0,437

D. F=Discriminant Function

2000g. According to the dimension of each tank, 30 samples (each with 20 individuals) was assigned in the tanks C1, C6 and C7 with 600m² and in the tanks C2 with 250m² there were assigned 13 samples. As previously commented, the tilapias were assigned with 100g mean of weight and 10.71, 6.93, 7.75, 7.15 of standard deviation in the tanks C1, C2, C6 and C7, respectively.

3) *Cultivation System and Type of Water*: The tanks have 100g/m² density, corresponding to one fish for each m². According to the dimension of the tanks and their density, the cultivation system can be considered intensive [5]. On the other hand, the cultivation was realized in brackish water, so it is more profitable than freshwater cultivation.

Harada and King [9] show that the first researches about tilapia cultivation in brackish water were carried out in Hawaii in 1950. Intensive cultivation of *Oreochromis mossambicus* was maintained in tanks of brackish water, with a salinity of 10-15‰. The results of survival and growth were higher than freshwater cultivation.

4) *Sampling*: As previously commented, the control of tilapia growth and water quality was made through two groups of parameters: biometrics and physicochemical, respectively. To register the biometrics parameters, a sample corresponding to no less than 10% of tilapias was extracted in each tank (weekly). The weight was recorded for all individuals in the sample, and then the mean weight was calculated. However, the standard length was obtained for each individual; nevertheless, to ensure the correspondence between the data, mean of length was considered.

The procedure for extracting the sample can be considered random, since in the drag process, which is used to extract the tilapia in the tanks, cannot determine the individual to extract. The rarity in obtaining the same individuals in different biometrics can be justified by the following expressions:

$$C_{60}^{600} \approx 2,8 * 10^{83}$$

different samples in the tanks C1, C6 and C7, and

$$C_{30}^{250} \approx 5,3 * 10^{38}$$

different samples in the tank C2 (in this tank, samples of 30 elements were considered).

5) *Physicochemical Parameters*: In this research four physicochemical parameters were considered (Temperature, oxygen, pH and transparency) considered relevant to ensure the quality of the aquatic environment [1].

These were recorded every day at 6 a.m and 3 p.m, except the transparency that was recorded only at 12h. The data of the physicochemical parameters were modified in averages for each week to ensure that each observation of these parameters corresponds to an observation of biometrics parameters.

B. Statistical Methods

To analyse the effect of the treatments and biometry in the tilapia growth an analysis of variance (ANOVA) was applied; whose growth and length were response variables and treatment as factors. Through the Fisher Linear Discriminant, the similarity of the aquatic environment between tanks was analysed.

1) *Analysis of Variance (ANOVA)*: Analysis of variance is widely used to examine the effect of certain factors on the response variable. It was developed basically as a procedure to study possible effects of factors on the means of the populations involved. However, it is possible to generalize to study effects on the variance of these populations [8].

If it is found that the means of a response variable of two populations are the same, then, it means that the factor does not have any effect on the mean. Analogously, the factor does not affect the variance if the variance of two populations is not significantly different.

In case of factors with more than two levels, the analysis is different. In this case the study is oriented to effects of factor at a certain level. The factor effect can be determined by the expression:

$$Ef_i = m_i - m_{..} \quad (1)$$

where:

Ef_i = effect of factor I

$m_i = \frac{(m_{i1} + \dots + m_{ij})}{j}$ is the population mean of all possible results obtained in all the tests where factor I was at level i .

$m_{..}$ is the general mean in all tests.

2) *Fisher Linear Discriminant Analysis*: Consider $\Omega_1, \dots, \Omega_g$ different populations, and in each of these we observe a sample of a certain vector $X = (X_1, \dots, X_p)'$. Discriminant analysis consists of describing through the variables X_i , differential resources between these populations. The aim is to find differential functions or decisions rules $h = h(x_1, \dots, x_p)'$ to a population Ω_i minimizing the error in these assignments. The most common is the method of Fisher Linear Discriminant, where h is the linear function of x [2].

(1) Classification in Normal Populations

Suppose that the distribution of X_1, \dots, X_p in Ω_1 is $N_p(\mu_1, \Sigma_1)$ and in Ω_2 is $N_p(\mu_2, \Sigma_2)$, i.e:

$$f_i = (2\pi)^{-\frac{p}{2}} |\Sigma_i|^{-\frac{1}{2}} * \exp\left(-\frac{1}{2}(x - \mu_i)' \Sigma_i^{-1} (x - \mu_i)\right) \quad (2)$$

(2) Linear Classifier

If $\mu_1 \neq \mu_2$. $\Sigma_1 = \Sigma_2 = \Sigma$, then:

$$V(x) = -\frac{1}{2}(x - \mu_1)' \Sigma^{-1} (x - \mu_1) + \frac{1}{2}(x - \mu_2)' \Sigma^{-1} (x - \mu_2) \quad (3)$$

$$= L(x)$$

Thus, these are the discriminators of maximum likelihood and linear, respectively.

Let α denote the Mahalanobis distance between two populations, then α can be represented as following:

$$\delta_M^2 x, \mu_i = (x - \mu_i)' \Sigma^{-1} (x - \mu_i), \quad (4)$$

with $i = 1, 2$. and, we suppose that x was taken from a normal distribution $N_p(\mu_2, \Sigma)$, with $x - \mu_1 = x - \mu_2 + \mu_2 - \mu_1$ and $E(x - \mu_2)(x - \mu_2)' = \Sigma$, $(x - \mu_2)' \Sigma^{-1} (x - \mu_2) \sim \chi_p^2$, then, the mean of $U = (x - \mu_1)' \Sigma^{-1} (x - \mu_1)$ is:

$$E(U) = E((x - \mu_2)' \Sigma^{-1} (x - \mu_2) + \alpha + 2(x - \mu_2)' \Sigma^{-1} (\mu_2 - \mu_1)) \quad (5)$$

$$= p + \alpha$$

and the variance of $V(x) = (x - \mu_2)' \Sigma^{-1} (x - \mu_2)$ is the same as that of $L(x)$ and can be represented as following:

$$Var(V) = E((\mu_2 - \mu_1)' \sigma^{-1} (x - \mu_2) * (x - \mu_2)' \Sigma^{-1} (\mu_2 - \mu_1)) \quad (6)$$

$$= \alpha.$$

So we easily find the discriminant function of $L(x)$: $L(x)$ is $N(+\frac{1}{2}\alpha, \alpha)$ if x was taken from $N_p(\mu_1, \Sigma)$.

$L(x)$ is $N(-\frac{1}{2}\alpha, \frac{1}{2}\alpha)$ if x was taken from $N_p(\mu_2, \Sigma)$

III. RESULT AND INTERPRETATION

In this section there are presented the main results obtained. Through ANOVA method, the experiment factors are considered and its effect in the means of the biometrics variables was studied.

The records of weight and length were obtained through the experiment process, and its mean was calculated to ensure correspondence in the data. These biometrics parameters measure the same individual, so these are highly correlated. Therefore, a variable that provides a structure of correlation between weight and length was calculated as a linear combination of these, and was denominated *growth rate*, which presents similar characteristics of the biometric parameters in the four treatments.

This new variable was not directly measured in the experiment process, but it was obtained through a first principal component analysis (PCA) represented by the expression:

$$growth - rate = 0,707 * (peso + longitud)$$

with a variability of 94,53% of the original data.

Since the variables weight and length have different units of measurement, these were standardized by the means and standard deviation and the variable *growth rate* is not dimensional with mean zero and standard deviation one.

The results show that the differences of weight (F - Fisher = 3.071, sig = 0.0324) and length (F - Fisher = 3.958, p - valor = 0.011) are statistically different in the treatments (Table I).

Let $p_{ij} = p_i - p_j$ and $l_{ij} = l_i - l_j$ denote the differences of weight and length between treatments i and j , respectively. Through HSD Tukey test it is verified that the differences $p_{17} > 0$ (sig = 0,017 < 0,05) (Fig. 2 (a)) and $l_{17} > 0$ (sig = 0,021 < 0,05) (Fig. 2 (b)) are significant. This difference is evidenced by the treatment C1 (feed) and C7 (organic fertilizer) that present the largest and smallest growth, respectively.

Figs. 1 and 2 highlight this aspect. The intervals HSD presented in Fig. 2 shows that the difference between weights and lengths obtained in the treatments C7 and C1 are less than zero, indicating that in Treatment C1 there is a significantly higher growth of tilapia than in C7.

Although the difference of weight and length between treatments C2, C6 and C7 is not significant; however, it can be observed that the values in C6 are higher than the others.

With ANOVA it was demonstrated that the growth of the tilapia in the treatments was different. However, it is important to analyze the influence of the aquatic environment, since this can contribute to such growth differentials. For this purpose, the Fisher Lineal Discriminant Analyses was applied, where the four physicochemical parameters were considered as independent variables and the treatments as the discriminant category.

The results shown that tree discriminant functions were determined (number of discriminant function is equal to the minimum between number of independent variables and number of response category minus 1). The determined lineal discriminant functions have not a significantly discriminatory capacity to classify consistently the observations of each category (Table II), and Fig. 3 shows the dispersion of observations, where there is no criterion for separating each observation from each treatment. Therefore, it is assumed that individuals are exposed to similar environments, and finally, it is assumed that the differences observed in growth of the tilapias are due to the treatments considered.

IV. CONCLUSION

Through the presented results, the following can be concluded:

- (1) The tilapias presented a significantly growth over time of experimentation in the four treatments considered,

with an average growth of 100g to 180g for weight and 13.5 to 18.8 cm for length. The highest growth occurred in the treatment C1 (feed) and this was significantly higher than C7.

- (2) It was found that the growth evidenced in the best treatment C1 was not significantly different from that obtained in the C6. Therefore, in cases of food shortage, the inorganic fertilizer can be used to obtain reasonable results in the cultivation of Mozambican tilapia.

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REFERENCES

- [1] S. Alves and L. Mello, *Manual para Monitoramento Hidrobiológico em Fazendas de cultivo de camarão*, Recife, 2007.
- [2] A. Baillio and A., Grané, *100 Problemas resueltos de Estadística Multivariante implementados en Matlab*, Delta Publicaciones, 2017.
- [3] J. Ferré and F. X., Rius, *Introducción al Diseño Estadístico de Experimentos*, Departamento de Química Analítica y Química Orgánica Universitat Rovira i Virgili, 2002.
- [4] W. G., Cochran and G. M., Cox, *Experimental Designs*, 1992.
- [5] Nicovita, *Manual de Cranza Tilapia*, Disponível em www.alicorp.com.pe, 2002.
- [6] M., Lagos, M., Héctor, D., Meyer and R., Castillo, *Comparación de la sobrevivencia y crecimiento de dos líneas de tilapia cultivadas bajo dos sistemas de manejo*, Escuela Agrícola Panamericana, Zamorano, 2000.
- [7] FAO, *Fertilizantes y fertilización*, (<http://www.fao.org/fishery/culturedspecies/Oreochromis-niloticus>), 2016.
- [8] R., Romero and L., Zúñica, *Métodos estadísticos para Ingenieros*, Universidad Politécnica de Valencia, 2013.
- [9] T., Martínez, *Adaptación y crecimiento de las tilapias Oreochromis niloticus, Oreochromis aureus, Oreochromis mossambicus x Oreochromis niloticus en agua salada*, Universidad de Colima. Disponible en <http://digeset.uco.mx/tesis-posgrado.Pdf>, 2003.
- [10] A. G. J, Tacon, *The nutrition and feeding of farmed fish and shrimp-a training manual.3. Feeding methods*. FAO field Document. Project GCP/RLA/075/ITA/Field Document 7/E.FAO, Brasília, Brazil. 208 p, 1988.

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