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GENETIC PROGRESS FOR THE DAILY WEIGHT GAIN IN NILE TILAPIA USING BLUP METHODOLOGY ASSOCIATED WITH NON-RANDOM MATING OF THE SELECTED PARENTS

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Abstract

The genetic progress for the daily weight gain (DWG) was evaluated in Nile tilapias selected through BLUP methodology associated with two mating designs by 10 generations. It was simulated a genome with 44 chromosomes including only polygenic additive effects for DWG. A historical population gave origin to two selection populations of 4,000 fish/generation with a replacement rate/generation of 50% and 25% for sires and dams, respectively. DWG had heritability (h^2) of 0.30 and phenotypic variance of 1.0. In each generation, the selected parents were mated according to random (AR) and non-random (OIMIN) matings.

The genetic progress, measured as mean of phenotypic values and estimated breeding values, was similar under the two mating designs in all generations. But, the OIMIN mating was more effective than AR mating in minimizing the average inbreeding by generation. Hence, any mating design that constrains the inbreeding level could be applied to a tilapia selective breeding program.

Keywords: aquaculture; data simulation; genetic improvement of freshwater fish.

Introduction

The Nile tilapia (*Oreochromis niloticus*) is the most cultivated freshwater fish specie in Brazil because of its favorable traits. Since this specie was introduced in the country, its cultivation has increased at each year becoming expanded for all the national territory, attracting the attention of producers and researchers of different science areas interested in increasing the production level of the tilapia for important economic traits as: daily weight gain, disease resistance and morphometric measures (height, length, width of body). In Brazil, the aquaculture research is already well established and there are some genetic improvement programs (GIP) for fish in course. The genetic selection aims to apply different methodologies of selection searching to optimize the genetic gain in the traits of economic importance for the consumer market.

But, the intensive cultivation can imply in the lost of genetic variability when few breeders are used to form the next generation, especially when they produce numerous progenies as it happens with the fish. In GIP, if a great volume of data in addition to a higher complexity of relationship information are available, so it is possible to apply the BLUP methodology to accelerate the genetic progress because of its high accuracy (Lynch & Walsh, 1998). However, BLUP can increase the inbreeding level along the time, what could affect negatively the quantitative traits related to adaptation, fertility, vigor and production. Second Falconer (1987), inbreeding rates above 10% can be dangerous, because they put in evidence some undesirable recessive alleles encountered in related parents. In this sense, the non-random mating can be useful to reduce the inbreeding rates and to minimize the lost of genetic gain along generations. However, mating designs have received less attention than selection methods, probably because the selection has higher impact on long-term genetic gain (Henryon et al., 2014).

The aim of this study was to evaluate, through simulation data, the genetic and phenotypic changes in Nile tilapias selected for the daily weight gain, using BLUP methodology and submitting the selected parents to one mating design that minimizes the inbreeding per generation, considering overlapping generations.

Methodology

In this study, the dataset related to the Nile tilapia (*Oreochromis niloticus*) was obtained using the QMSim software (Sargolzaei & Schenkel, 2009). It was simulated a genome for the Nile tilapia consisting of 44 chromosomes with 22 cM of mean length, totalizing about 1,000 cM, which included only the additive polygenic effects to control the daily weight gain (DWG) trait. The heritability (h^2) and the phenotypic variance for DWG trait were 0.30 and 1.0, respectively, resulting in a medium heritability value typical for a performance trait.

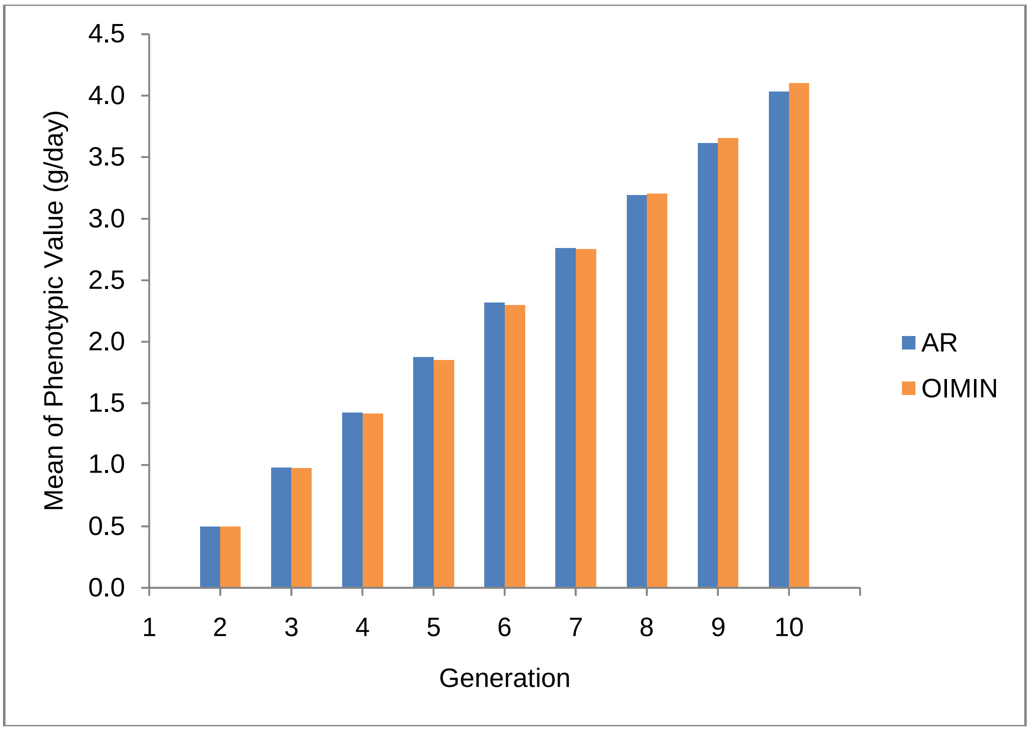
Firstly, a historical population containing 300 fish was simulated by 100 discrete generations, and from its last generation were chosen the mates to breed and generate the selection populations according to the mating ratio of 1:2 (100 sires: 200 dams). Sires and dams were replaced at the rate of 50% and 25%, respectively, per generation. Each female generated 20 progenies (50% males) totalizing 4,000 fish/ generation. The selection was practiced for 10 consecutive and overlapping generations, with 1,000 replicates per generation, and it was based on the BLUP (Best Linear Unbiased Prediction) methodology to estimate the breeding value (or additive genetic value) of each fish for the DWG. In each generation, the fish chosen as parents by their superior EBV were mated with optimization of inbreeding by minimizing its value in the next generation (OIMIN) or mated at random (AR), being this last mating named as control group.

The genetic progress for DWG was evaluated through the change in mean phenotypic values and in mean EBV (estimated breeding values), along the 10 generations of selection, considering both mating designs. These parameters were obtained for all fish of a generation, and, after, it was calculated the mean value of each of them per generation. Besides, it was evaluated the average inbreeding per generation aiming to support the evaluation of the mating designs.

In this simulation study, we provided an insight about the effectiveness of the non-random (OIMIN) mating associated with BLUP methodology to the selection of this important economic trait (DWG) for a cultivation system, aiming to control the inbreeding level along time.

Results and Discussion

The selection based on BLUP estimated breeding values (EBV) increased substantially the genetic gain along the time for the daily weight gain (DWG). Such achieved progress was practically identical between the mating designs (AR and OIMIN) evaluated here. We observed (Figure 1, upper graphic) that the mean phenotypic value in the two selected populations increased to each generation along the time, varying from 0 g/day at the generation 1 to nearly 4.1 g/day at the generation 10. Here, all the phenotypic changes reflected the changes in the estimated breeding values (Figure 1, lower graphic), that also increased along time, in similar magnitude between AR and OIMIN matings.



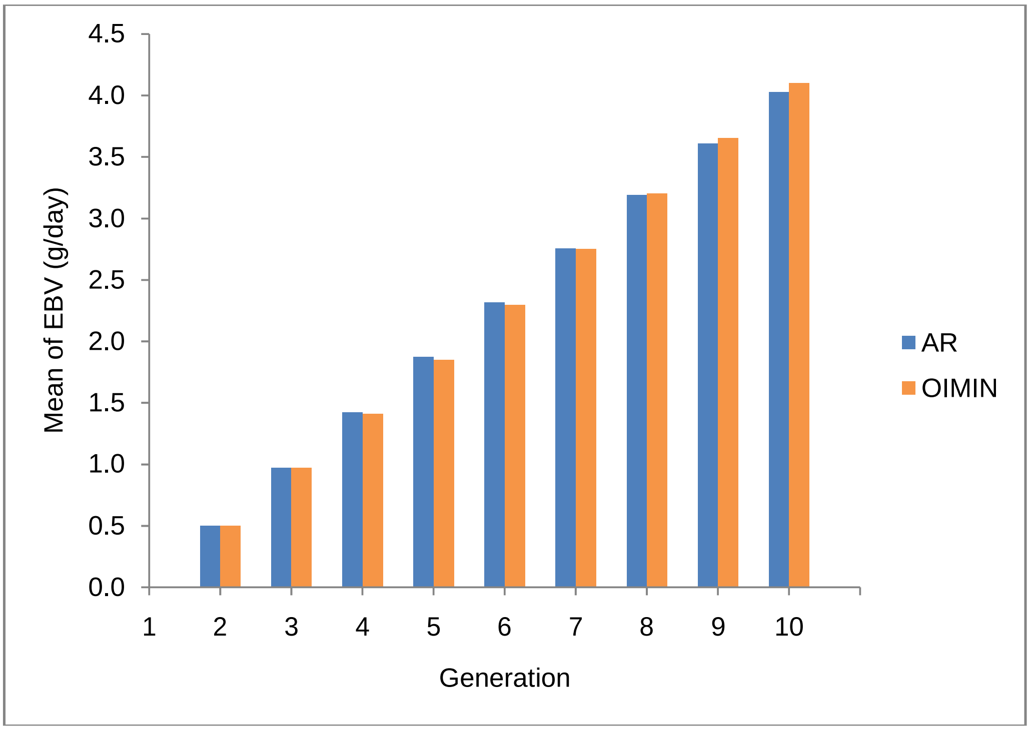


Figure 1 - Evolution of the phenotypic value (upper graphic) and of the estimated breeding value (EBV) (lower graphic), in terms of mean, along 10 generations of BLUP selection, under AR and OIMIN matings.

Considering our results and their application to a commercial cultivation of Nile tilapias, in which one productive cycle has the duration of 6 months and for which the initial weight of the tilapia fingerling is 2.0 g, then, at the end of one cycle, we would have a fish weighing about 0.74 kg at the slaughter. According to professor Hilsdorf, interviewed by Pesquisa FAPESP (2016), in the end of 1980, the commercial weight of the black tilapia with 6 months of cultivation was about 0.5 kg. Nowadays, in the São Paulo State, some varieties of tilapia, like the red tilapia, have already reached 0.85 kg at 8 months of cultivation after the initial phase of a genetic improvement program.

In the genetic breeding research, it is already well-defined and mathematically proved that the selection based on BLUP results in a higher genetic gain, because BLUP uses all the available information about the candidate to selection (own and from its relatives) in its evaluation if compared to the phenotypic selection. However, this higher efficiency in the genetic evaluation can be compromised by the expressive increase in the inbreeding in little generations of selection, reducing the genetic progress for the selected trait. Several authors also have demonstrated this through simulation studies, as exemplified by Belonsky & Kennedy (1988) for swine herd and by Hely et al. (2013) and Sonesson & Odegard (2016) for aquatic species. All of them have evaluated the selection based on BLUP under different mating designs that aimed to minimize or to constrain the level of inbreeding along the generations, considering different mating ratios between sires and dams.

In this study, in which the mating ratio was 1:2 (sire: dam), i.e. the families were formed by paternal half-sibs, the average inbreeding was higher under AR mating in all generations (no shown data), staying below 4% against nearly 0% under OIMIN mating until 4th generation. Afterwards, the average inbreeding increased significantly of 6% to 18% under AR *vs*. from 1% to 9% under OIMIN. Therefore, the average inbreeding rate increased substantially along the time, mainly under the AR mating, in which the average per generation was at least twice higher than in the OIMIN mating. Here, this fact did not have impact on the genetic progress under AR and OIMIN matings, because of the similarity between their results along the 10 generations. But, it could negatively affect the performance for several economic traits or to cause the death of fish by genetic defects.

According to Cunha et al. (2003), the performance of mating designs aiming to avoid the mating between related individuals is an efficient strategy in populations for which the sexual ratio (number of dams/number of sires) is lower than 10, like in this simulation study (sexual ratio = 2). This would serve at least to delay the onset of the inbreeding in population, once it is impossible to prevent its progressive increase and accumulation along the generations.

Conclusions

There was not difference between the genetic gain for this production trait (DWG) obtained by random or non-random (OIMIN) matings, but the average inbreeding was lower under this last mating design.

Then, the major advantage of the OIMIN mating applied to the selected parents to form the next generation through BLUP methodology was to control the increasing in the inbreeding rates along the generations.

Therefore, considering that inbreeding levels above 10% can be harmful for the cultivation systems, any mating design that implies a reduction of inbreeding rate per generation, like OIMIN mating, should be applied to a Nile tilapia genetic improvement program.

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