2. Selective breeding

2.1. Traits

A trait is any observable or measurable characteristic of an individual. In breeding programs one is often concerned with a range of characteristics. It may be conceptually convenient to group such characteristics in some logical way:

(i) Traits showing a relatively small number of classes, and often controlled by a small number of genes. Examples of this type of traits are some fish colors, and scale patterns in certain species.

(ii) Traits showing continuous variation, and assumed to be controlled by several genes, each one having a relatively small effect. There are traits in this category that are easily assessed or measured, such as size or weight, growth rate, body length, depth, width or shape. By contrast, there are some other traits that are difficult to measure, such as efficiency of feed utilization, yield of certain cuts (e.g. fillet), or flesh quality. The recording of this latter group of traits requires a special effort, and often it is carried out in relatives of the selection candidates especially designated for that purpose.

(iii) Traits that are discrete in their expression but assumed to be controlled by many genes. These traits usually take the form of ‘Yes’ or ‘No’, ‘Present’ or ‘Absent’, ‘Dead’ or ‘Alive’, and so on. ‘Survival’ and ‘Achievement of sexual maturity at a particular age’ may be used as examples of this type of trait. Generally, for the recording of these traits to be meaningful from a genetic evaluation point of view, it has to be carried out in groups of relatives, such as half-sibs, full-sibs, or progeny.

The above made classification is, of course, arbitrary to some extent. However, it is not only important from a conceptual standpoint, but also from a practical one, as the genetic improvement of traits in different groups may be the subject of different selection strategies.

2.2. Phenotypes, genotypes and breeding values

The observed category or measured level of performance for a specific trait in an individual is referred to as its phenotype. We may say that an individual has as many phenotypes as there are traits to be observed or measured on that individual. The purpose of selective breeding is to allow individuals with the best sets of genes to reproduce so that the next generation has, on average, more desirable genes than the current generation. By contrast, the genetic makeup of an individual is referred to as its genotype. Both the genotype and the environment an individual experiences determine its phenotype. Note, however, that an individual does not transmit to its progeny all of its genotype. Each progeny receives half of the genes from the female parent, and the other half from the male parent. The breeding value of an individual is the value of the genes it has to its progeny, that is, the value of the individual as a parent. On average, an individual will transmit the sum of the average effects of the alleles it carries, and this is its breeding value. A major challenge in selective breeding
is to estimate an individual’s breeding value based on its own phenotype and (or) the phenotypes of its relatives.

2.3. Breeding goal

Selective breeding is a long-term strategy to improve the production performance and quality of Tilapias. Therefore, it is important to define a breeding goal, that is, a direction for the genetic improvement program. The breeding goal should be defined by a set of traits that are of economic and (or) social importance, that are to some extent inherited, and, preferably, that may be recorded in an applied selection program. Note, however, that there may be traits that are very difficult or sometimes impossible to record, but that still have to be included in the breeding objective. Disease resistance is in some circumstances one such trait.

2.4. Selection strategies

Several selection strategies are available for genetically improving the performance of Tilapias. The strategies differ in terms of which kind of relative provides information to estimate the breeding value of the selection candidates. The choice of selection strategy depends on the nature of traits (e.g. see earlier classification in section 2.1) and the heritability of traits (i.e. the relationship between an individual’s phenotype and its breeding value).

2.4.1. Individual selection

Individual selection, or ‘mass selection’, is a strategy where the breeding candidates are selected based on their own phenotype, that is, on their own performance. It has been the most frequently applied selection strategy in fish due to its simplicity. However, it can only be used to improve traits that are recorded on the breeding candidates while they are still alive (e.g. growth, shape, color), and it is not efficient to improve discrete and lowly heritable traits such as survival rate.

If practiced without constraints, the accumulation of inbreeding can be a major problem of individual selection in fish. The selected broodstock can become more and more related to each other. If large families are naturally produced or stocked in the test environment, the wide genetic variation and common non-genetic effects (e.g. maternal and age effects) may easily result in a disproportionately high contribution of individuals from just a few parents to the next generation, and a consequent accumulation of inbreeding. Inbreeding reduces the genetic variation and the potential for further genetic improvement in the breeding population. Generally, it also lowers the performance of fish, due to the phenomenon known as inbreeding depression. To prevent inbreeding, only a restricted number of individuals from each full and half-sib family should be tested as breeding candidates when applying individual selection. However, this requires that each family be produced and kept separately from each other before testing.
2.4.2. Family selection

Family selection is a strategy whereby the breeding candidates are ranked based on records taken on their full and half-sibs, that is, individuals that have genes in common with them. This selection strategy can be applied to improve traits that cannot be recorded on the breeding candidates while they are alive (e.g. carcass quality traits), traits that can only be recorded for groups of fish (e.g. feed utilization), and discrete traits at high or low incidences (e.g. survival rate, age at sexual maturity). Furthermore, family selection is more effective than individual selection when the heritability of a trait is low. However, family selection requires that each family be produced and kept separately and that all fish are tagged before testing in common test environments.

2.4.3. Combined selection

When traits can be recorded on the breeding candidates, family selection can be combined with individual selection to increase the accuracy of the estimates of breeding values, and thereby achieve a greater selection response. Combined selection increases the rate of selection response relative to the earlier mentioned methods. It optimally combines all available sources of information used in the estimation of an individual’s breeding value. With fish, most often this means information from full and half-sibs. More generally, it may mean information from parents, offspring, or any other group of relatives.

Combined selection may take the form of an index, in which individual, full-sib and half-sib information are included and weighted. It may also be implemented using Best Linear Unbiased Prediction (BLUP) procedures, which allow the simultaneous estimation of breeding values and adjustment for fixed effects. For relatively balanced designs, one may expect good agreement between the selection index and BLUP approaches.

2.5. The GIFT technology

What is broadly known as the GIFT technology includes a number of different and complementary tools to produce and test Tilapia of known ancestry, to statistically analyze collected grow-out data, and finally, to estimate breeding values for each individual, based on the performance of the breeding candidates themselves and their relatives in the population.