Canaries -

Breeding and Hybrid Vigor

by
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Debbie Blackwell and her family are well known among canary fanciers. The Blackwells' consistent winnings at canary shows places them among the elite of the canary fancy.

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Those of you who are interested in the National Color Bred Association, a relatively new but very active club, contact Kevin Wirick, 748 Santa Fe, Denver, CO 80204.

Tony Bucci, canary editor.

Genetics is really quite a fascinating and useful science. Many important theories developed in the laboratory have led to significant practical advancements in agriculture and animal husbandry. Although most canary color breeders react to the word "genetics" with a shudder, this interesting science has much to offer us as well, because it provides answers to the classic problem faced by all breeders of domesticated plants and animals: how to achieve the most intense concentration of advantageous genes in the "produce," whether that "produce" is a crop of corn, a herd of dairy cattle, or a line of color breds. Accordingly, the following article will attempt to outline the basic fundamentals of practical genetics—inbreeding, outcrossing, and the principle of hybrid vigor.

A variety of mating systems have been employed throughout the history of plant and animal domestication. That system which has been consistently responsible for the most impressive gains in agriculture is known as inbreeding. Inbreeding involves the pairing of relatives, such as full and half sibs (i.e. sisters and brothers), offspring and parents, cousins, etc.; it is technically defined as the mating of individuals who are more closely related by ancestry than the average relationships of all members of a specific population. The chief advantage of inbreeding is its power to "fix" alleles , and thus phenotype . Any inbred line will become more and more pure, or homozygous*, with each generation because the same basic set of alleles is being circulated among the descendants. Consequently, if inbreeding is maintained, the amount of genetic—and phenotypic—variation *within the line* decreases rapidly; however, the variation *between different inbred lines* increases. (This is an important point, as we'll see.) In other words, the genetic relationship between members of an inbred family is increased as the line becomes more pure, therefore making the line's genetic worth more predictable. At this point I should mention the cardinal rule of inbreeding: for best results, ALWAYS INBREED WITH EXCELLENT BIRDS. Inbreeding with mediocre stock only perpetuates mediocre alleles, and ultimately, mediocre phenotypes.

An important variation of inbreeding is line breeding. Line breeding involves the selection of an excellent bird with

truly desirable qualities; this bird is bred to several mates, then the offspring are bred back to the outstanding parent. Later on, if all the pedigrees of the established line are checked, each will lead back to the outstanding ancestor (which is typically a male, but can also be a hen). The purpose of line breeding is to preserve the good qualities of the ancestor; presumably the descendants will become increasingly homozygous for the ancestor's good qualities, thus "fixing" his phenotype.

As beneficial as inbreeding and line breeding can be, they are not without their disadvantages. Deterioration of overall vigor, stamina, and fertility frequently are other outcomes of inbreeding. In any normal, random breeding population, all individuals will carry various harmful or lethal recessive alleles. However, because random breeding maintains heterozygosity, the recessive alleles generally remain concealed by the corresponding normal alleles which are dominant and therefore visible. Inbreeding decreases that heterozygosity though, causing the damaging recessive alleles to be uncovered. The resulting homozygosity has an especially detrimental effect on those traits associated with reproduction: fitness, viability, stamina, vigor, ability to reproduce, all suffer, because heterozygosity (which allows more genetic variation) is somehow more necessary at the loci of the many genes linked to reproduction. Other traits which are more "morphological" (i.e. dealing with external form and structure, such as size, color, etc.) may not suffer because these harmful recessive alleles can be purged from the line as they appear. In fact, several research studies have shown that surviving inbred offspring frequently have fewer harmful recessive genes than randomly paired offspring which have not gone through this purging process. The big question, though, is: will they reproduce? Inbreeding may bring about many desired improvements in the more superficial physical traits, but it can also interfere significantly with the more vital traits associated with productivity. The breeder is obviously caught in a no-win situation—it is not possible to breed for homozygosity of some genes, while holding others heterozygous. So, what's the solution?

The answer lies in the careful selection of a suitable bird for outcrossing. Outcrossing, or cross breeding, is the opposite of inbreeding and involves the mating of individuals from unrelated populations, such as different inbred lines. The right "outcross" can restore the vigor and productivity the more homozygous inbred lines have lost. This return to heterozygosity produces a phenomenon called heterosis, commonly known as hybrid vigor, which is defined as the additional performance, if any, shown by the crossbred offspring above the average performance of their two parents. It is not uncommon for the offspring of a cross to actually surpass the parents, because the two inbred lines have become homozygous for *different* recessive genes. Intercrossing the lines yields heterozygous hybrids in which the harmful recessives contributed by one parent are covered by the dominant alleles from the other parent, and vice versa. The dominant alleles again mask the effects of the harmful recessives with a consequent return to vigor.

The breeder's problem, then, is to find which outcross, when crossed with his own inbred line, will produce the most hybrid vigor. This outcross must be chosen with care and should meet two requirements. Its overall phenotypic quality must be as good as possible—it should meet the same standards you've set for your stock, especially if you have been selecting for any traits in particular. It is important to consistently select for the same qualities, or else other undesired qualities may creep in, causing reversals in your previous gains. Secondly, consider the bird's genetic background; it can be extremely beneficial if *the outcross comes from another inbred but unrelated line,* in which the breeder of that line has been selecting for the same qualities or traits you have. In other words, consider family merit as well as individual merit—you are, in effect, adding another line to yours and it should be an established line that is at least as good as your own. It helps if the "new blood" is also "proven" because generally *populations with the highest performances as purebreds (i.e. inbreds) produce the highest performing crosses.* Intercrossing inbred lines in which the same traits have been selected for may enable some homozygosity for the genes of those traits to be maintained, yet the overall genotype returns to a heterozygous state, thus restoring hybrid vigor. For example, if you are a bronze breeder and you have been intensively selecting for the desired dark pigments in the legs, beak, feet and nails, and you outcross to a second line which has also been bred for that same dark pigment, then it seems reasonable to expect that the relatively few genes responsible for the pigment will remain somewhat homozygous. However, because most of the other genes are again becoming heterozygous, heterosis should occur. The amount of heterosis that does occur varies from cross to cross and is, as far as we are concerned, unpredictable. (In fact, not every cross results in hybrid vigor—outcrossing is usually, but not always, a guarantee of heterosis.)

There is some disagreement among geneticists on just how unrelated the outcross has to be. A majority of them are convinced that the less closely related the inbred lines are, the higher the performance of the crossbred offspring. However, a few others state that heterosis can be restored by crossing inbred lines which have been produced from the same base population, the idea being that inbreeding reduces genetic variation within each line, but *increases genetic distinctiveness between them,* thus making some heterosis possible. The implication of this is important for us, as sometimes it is just not possible to find a suitable bird for outcrossing. An alternative, though, may be in your own aviary: if you have two suitable lines, consider crossing them. I frequently do this with my various melanin mutations —intercrossing pastels, isabels, and agates with each other, and with bronzes. Although the effect on the bronzes is sometimes questionable, "dipping into the green," as the type breeders call it, does seem to help the sex-linked mutations somewhat. Another helpful cross would be a bronze to a clear lipochrome: all the offspring will show varying degrees of variegation—and the variegated bird can be an asset in the breeding room, as it is generally associated with increased stamina, as well as improvements in color and size. The variegation, of course, is not the cause of the improvements, but merely a very obvious manifestation of the real cause—heterozygosity.

Once an outcross has been successfully completed, inbreeding can be resumed with one of the crossbred youngsters. Some advantage may be gained if the youngster is a hen. Since most of the reproductive burden falls on her, presumably she would benefit from the return to heterozygosity. Hatchability and egg production are just two of the important traits adversely affected by inbreeding which are, in turn, restored by heterosis. Other traits controlling aspects of egg quality, size, shell thickness, etc. may be similarly affected. To maintain some degree of heterozygosity among their breeding stock, many commercial livestock breeders use a system called rotational crossbreeding; because it involves crossing three lines, it is sometimes also known as the three breed cross. Such a system not only benefits productivity, but may also have a positive effect on those traits considered to be more morphological. In one study involving pigs, four traits associated with reproduction and viability were used as measurements (i.e. number of pigs born alive, number weaned, etc.), as well as a morphological trait—"body form on the basis of judgment." The experiment involved pairing two distinct inbred lines together, then mating the crossbred females to a male from either one of the two parental breeds (i.e. a backcross) or a third distinct breed. The results consistently showed there was a definite advantage in the production of the first cross pigs (the initial cross), a slightly greater advantage in the production of backcross pigs, and an even greater advantage in the cross involving the three breeds.

Rotational crossbreeding probably goes beyond the needs of most color bred fanciers. However, inbreeding and outcrossing, if combined wisely, can produce solid results. In the end, though, the success of any breeding program rests on the breeder's powers of observation and ability to select. It all boils down to whether or not you know the suitable bird when you see it—in your aviary or someone else's. It is not an intuitive process, you do not need an "eye," as they say—just a little knowledge of your objectives as a breeder and the Color Bred Standards. Your success begins—and ends—with you!

SOME IMPORTANT DEFINITIONS

A bird's *phenotype,* or outward physical appearance, is determined, in part, by its *genotype,* or inheritance, which is spelled out by the bird's own unique complement of paired chromosomes. Just as the chromosomes are arranged in pairs, so are the genes—the members of such a pair of genes are known as *alleles.* The pair of alleles comprising each gene will lie opposite each other in the same sequence on their respective chromosomes; their fixed positions are called *loci* (loci is plural; locus, singular). If the two alleles of a gene pair are the same—for example, if a bird possesses matching alleles, A and A, for a given genetic trait—then it is said to be *homozygous* (i.e. pure). If, on the other hand, the bird possesses dissimilar alleles, A and a, then it is in a *heterozygous* condition. Alleles, then, are alternative forms affecting the same trait. "A" is said to be the allele of "a," and vice versa. Sometimes a clear dominant-recessive relationship will exist between the two alleles; in other cases the relationship may be more complicated. •