From *http://dianawalstad.com*

Breeding Guppies: Genetic Pitfalls and Successes

by Diana Walstad

(Revised February 2020)

Most fish keepers view guppies as children's fish. However, if ever there was a fish to study livestock breeding and genetics, it is the guppy *Poecilia reticulata*. Scientists have long used guppies as a study model.

Learning more about the genetics of the strains I work with has definitely increased the success of my breeding projects. As I show in this article, I wasted a lot of time raising batches that were genetically predestined for disappointment. Twenty, thirty years ago there was not much genetic information available. Now, there is plenty [1, 2, 3, 4].

Fig 1 Homebred Blue Guppies c. 1988

My Experiences

I have kept guppies off and on since childhood. In 1988, I created my own blue delta strain [**Fig 1**] by crossing a store-bought male with a "show" female from a breeder's dark blue strain. The male had less impressive finnage but sported vibrant, iridescent sky-blue colors. The resulting progeny (F1) combined the best of both parents. During the two years that I kept these guppies, I simply culled inferior individuals and all orange-colored males.

In 2017 I returned to keeping guppies with a sharper focus and a more serious breeding program. After successfully tackling disease problems in newly purchased guppies[1], I then found myself inadvertently stumbling into several genetic pitfalls.

First jolt came with the Swallowtail strain that I ordered on-line. The breeder sent me 5 juveniles. The males turned out nice, but afterwards the breeder explained that the strain carried a gene that made it impossible for some of the males to breed. Males with the characteristic ribbon-like finnage [**Fig 2a**] also had a long gonopodium fin that was useless for insemmination. Apparently, breeders used males of the strain without the abnormal fin to keep the strain going.[2] Thus, breeding this strain was complicated. I would have to choose males for a functioning male organ as well as color, vigor, size, etc. And if I bred Swallowtail females to another strain, would I have the

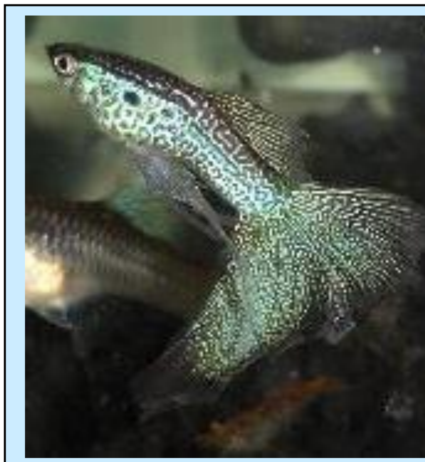


Fig 2a Male Sterility

The abnormally long gonopodium (bottom fin) on this Swallow-tail male prevents him from impregnating females.

[1] This article represents a continuation of 'Small Scale Guppy Breeding'.

[2] Guppy strains with these fins contain one or more fin elongation genes (Kal, #171; Sup, #170; or Rib, #163). {Numbers used here (and throughout article) correspond to genotypes listed in a guppy gene reference table [3].}

same problem? The owner chided me to read up more before I bought fish. Good point, but alas, I never suspected that anyone would breed guppies where some males could not impregnate females.

Sadly, I concluded that the Swallowtails were a dead end for me and discarded them. Later, I learned that it wasn't just Swallowtails that carried fin elongation genes [**Fig 2b**].

A subtler genetic pitfall was the disappointing results from the Metalhead strain. The males were gorgeous, but I got only 1 or 2 beauties out of a batch; the rest were just plain ugly.

Crossing Metalhead males with BG (Blue Grass) females did not improve matters [**Fig 3**]. Breeding Metalheads was getting too complicated. How does one select breeding females from a batch where the majority of males are unacceptable?

At the time, I was not sure whether the problem originated from the BG or the Metalhead strain.

However, the genetic puzzle became a moot point when the two Metalhead males sickened and died. Their disease susceptibility was the last straw. The Metalheads that I purchased were advertised as rare. I now understand why.

While my BG strain was acceptably disease-resistant, they seemed to die at a relatively young age. Moreover, the females produced only about 30% BG males. I was getting a mix of BG, Red Grass, and BT phenotypes. (*More on this later*.)

In response, I turned to guppies from the pet shops. For I assumed that commercial guppy breeders in Southeast Asia were not going to keep strains that produced only 2-30% saleable fish.

Imported guppies also have more iridescent coloration than many fancier "show" guppies from the American market. Typically, the males pass these bright colors onto their sons.[3] (Many genes for male color are carried solely on the male guppy's Y chromosome.)

Fig 2b Handicapped Male
Genes for fin elongation were incorporated into this particular BG (Blue Grass) strain.

Fig 3 This Breeding Group of beautiful guppies (Metalhead males and BG females) was supposed to produce beautiful babies.

Unfortunately, most (~95%) of the F1 were small and unattractive like the male on the left. I call them BTs (Black Tails). Males that will develop the beautiful Metalhead phenotype like his sibling on the right were few and far between. (Photographed at 5 weeks of age)

[3] In contrast with the female guppies offered in stores, one can only guess at their genetic makeup. The few times that I have bred them, their progeny was disappointing.

I tried working with HB-Blues (Half-black Blues), a popular commercial strain, sometimes called Neon Blues and frequently available in stores. While the body and caudal are a dull blue-black, this strain has a characteristic iridescent white/blue top that stands out when viewed from above, making it a popular fish for ponds. My BG strain has better finnage and more iridescence. Perhaps crossing HB-Blue males with BG females would improve the strain while keeping its unique iridescent blue top?

Earlier, I complained about the lack of uniformity in BG and Metalhead progeny. However, with the HB Blue X BG cross, I got wholesale uniformity [**Fig 4**]. I found it disappointing. Plus, not one of the F1s showed the pretty grass pattern tail of my BG. Apparently, HB-Blues carry dominant genes that over-ride those of the BG strain.[4] The HB coloration showed up on all fry at birth—males and females. I have never been a fan of Half-Black guppies, and this experience cemented my prejudice.

The F2 generation was no better. Their uniformity was boring; I might just as well have been breeding Zebrafish where the progeny all look alike and just like the parents. I decided that the shiny blue top of the HB-Blue did not compensate for its solid dull color elsewhere and its small dorsal fin. So I dispensed with the HB-Blues.

I now viewed my BG (Blue- Grass) strain [**Fig 5**] with greater appreciation. With its big colorful fins, docility, and relative disease-resistance, it was turning out to be my most satisfying strain. I decided to focus on it and learn more about its genetics.

Fig 4a HB-Blue X BG Outcross

Fig 4b Progeny (F1) of HB-Blue X BG show very little influence from their BG dam. They all looked alike.

Fig 5 BG (Blue Grass) Guppies Mature females have big attractive fins—a trait not seen in many guppy strains.

[4] The basic genotype of the HB-Blue strain is Asian Neon (#63) featuring the co-expression of genes NiII and Leucophore White. Asian Blau (Ab), #69 is sometimes added to suppress orange pigment. Black caudal peduncle (Bcp, #65), a dominant genes carried on both X and Y chromosomes, codes for the HB trait. [3].

The blue color of most BG strains is due to Ab (Asian Blau), a partially dominant gene on the autosomes (i.e., non-sex chromosomes). Ab suppresses red and yellow colors to produce an iridescent blue color over the entire body. Depending on how the Ab gene sorts out during meiosis, the progeny of a BG mating will be a mixture of BG, Red Grass and BTs (“black tails”) [**Fig 6**]. BTs are small, weak, light-grey guppies with tiny black tails.

All BG guppies still carry genes for orange and red pigments, but they are suppressed by Ab. In the Red Grass where Ab is absent, these color genes are allowed full expression.

With my BG breeders, I get about 30% nice BG males in a batch. Most breeders cull the BTs.[5] The Red Grass [**Fig 7**] differ only from the BG phenotype in that they are not blue. The Red Grass is every bit as beautiful as the BG. The bonus in breeding BG guppies is that the strain produces not one but two desirable phenotypes.

Moreover, BG are genetically pliable. Its genetic architecture “plays nice” with the genes of other strains. Upon outcrossing, it does not totally dominate like the HB-Blues, where 99% the progeny look exactly like the parents. The BG strain contains a mixture of dominant and recessive genes [6] that upon outcrossing produce new and exciting phenotypes.

Blue Grass female \ Blue Grass male	A	A^{Ab}
A^{Ab}	A A^{Ab}	A^{Ab} A^{Ab}
A	A A	A A^{Ab}

Fig 6 Fate of Ab (Asian Blau) Gene in a BG Mating

This Punnett Square [1] shows the results of a classic sorting out of the Ab gene during meiosis to produce 3 different genotypes/phenotypes in a batch of BG fry. If Ab is absent on the autosomes (‘A A’ in bottom left box), the individual will be a Red Grass; if heterozygous (‘A A^{AB}’), a BG; and if homozygous (‘A^{Ab} A^{Ab}’), a BT (black tail). [Like humans, the guppy (*Poecilia reticulata*) has 23 pairs of chromosomes, one pair is the sex chromosomes (XX for females, XY for males); the remaining 22 pairs are autosomes (A).]

Fig 7 Red Grass in a BG Batch

These colorful young males (7 weeks old) are red/purple versions of my BG. They do not have the Ab (Asian Blau) gene. Without this gene, the red colors of the BG’s underlying Red Grass genotype are fully expressed.

---

5 After a couple generations, my BG strain inexplicably stopped producing BTs.

6 My BG strain carries genes for: Delta Tail, #146; Hi-fin Dorsal, #158; Ab (Asian Blau), #69; Variegation (grass pattern), #141; and Pb (purple body), #227 [3]. Because many BG strains do not carry the Pb gene; theoretically, my strain could be labeled as a “Purple Grass.”

For example, I crossed a BG male with a yellow female from the pet shop [**Fig 8**]. Most of the fry were rather ordinary, but I got two attractive cobra males that I hoped to propagate. So I mated the male to one of his siblings.

Unfortunately, the F2 from mating F1 siblings produced males with yellow and pink solid coloring and white bellies [**Fig 9**]. These phenotypes represented the homozygous expression of recessive genes[7] from their pet shop granddam. Not one of the F2 had the desired body and tail pattern of their cobra sire. I decided not to pursue breeding these guppies. If I wanted to breed cobra guppies, it would be better to simply purchase a cobra guppy strain of known genotype. No need to re-invent the wheel…

Fig 8 BG Male X Blond Female

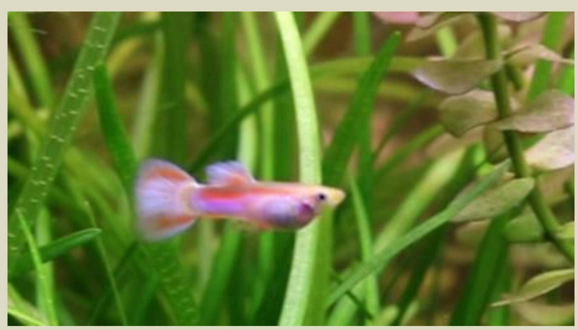
The BG sire eating live brine shrimp.

The dam, an ordinary blond female with yellow fins, came from a pet store.

The mating produced two beautiful males with a cobra body pattern and orange colors like the one shown here at 3 months.

Fig 9 F2 Reveals Genetic Makeup

The parents were these F1 siblings from the BG X Blond outcross [Fig 8].



The F2 contained mostly yellow and pink males with white bellies. This is the pink-white version.

[7] Most of the progeny had white bellies, some with a pink stripe above the lateral line, an expression of the Micariff White gene (Mcw, #99) [3].

Outcrosses with Swordtail Guppies

In 2017 and on a whim, I purchased two swordtail males from a pet store. They were double swords (Ds), advertised simply as lyretails. However, I recognized the iridescent blue body color of the JBs (Japan Blues).[8] Wild guppies with the JB phenotype were first discovered in the late 1980s in a Japanese river. They have a beautiful, iridescent blue peduncle. My two males had a white/purple double sword, but the fins of Japan Blues can be any color or shape.

When I crossed the JB males with one of my BG females, the resulting progeny (F1s) were uniformly fast-growing, vigorous, and absolutely lovely [**Figs 10** and **11**]. All the males had the iridescent blue bodies of their sire plus the big delta tail and grass pattern of their BG dam. As juveniles, some males had a "caudal gap," suggesting that the might be double swords, but by adulthood they filled in this gap and developed delta tails.

Fig 10 Outcross between JB Male and BG Female

The sire, a JB (Japan Blue) Double sword (Ds) carries the gene for his unique blue body color. (Unfortunately, the lighting that I used for this photo gave his body color a purplish hue.)

BG dam used for the outcross.

The progeny had the JB body color of their sire and the delta/grass tails of their BG dam.

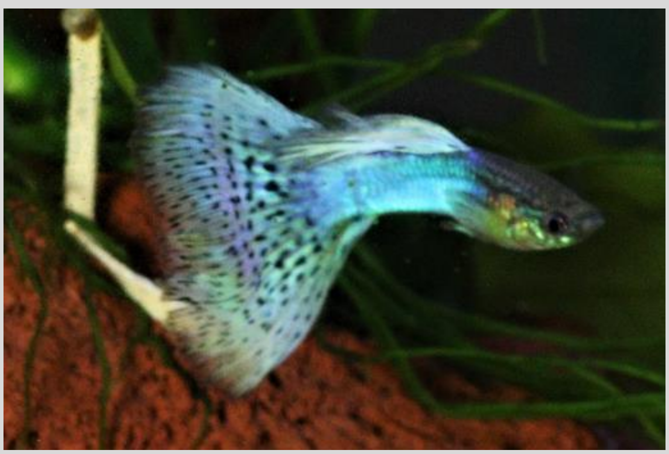


Fig 11 An F1 (JB X BG) male at 8 mos. (Here, I used a light source that would bring out the iridescent blue body color that characterizes Japan Blues.)

[8] The Ca (Caeruleus, #74) gene is expressed in Japan Blue males as a heavy density of blue reflective cells (iridophores) AND the absence of red and yellow pigment cells on the body [3]. The Ca gene is dominant and carried on the male's Y-chromosome, so it is only passed from males to their sons.

Fig 12 shows how the two tail genotypes sorted out from this mating. Genes for the delta tail (Dt) of the BG female dominated the recessive gene for the double sword (Ds).[9] Thus, all males had delta tails.

To confirm that the F1s were actually carrying the recessive Ds gene, I allowed some F1 siblings to mate and raised a batch of F2 progeny. About half of the F2 males had double swords like their JB grandsire [**Fig 13**]. The F2 swordtails are due to recessive Ds genes coming from both F1 parents and pairing up together on a chromosome [**Fig 14**]. This homozygous expression of recessive genes in the F2 is classic Mendelian inheritance.

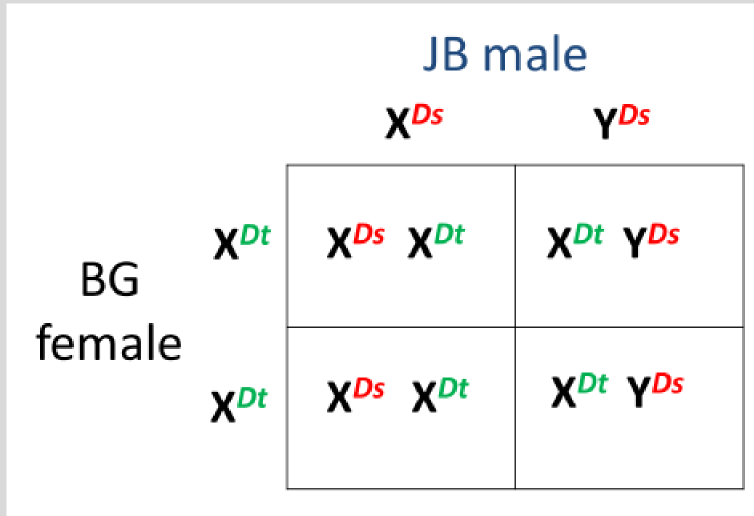


Fig 12 Genotypes of the F1 Progeny (JB X BG) are shown in boxes of this Punnett Square. Female progeny (XX) are in the two left boxes; males (XY) are in the two right boxes. All the F1 carry genes for both the delta tail (Dt) and the double sword (Ds).

Fig 13 F2 from Mating F1 (JB X BG) Siblings show the predicted mix of double swords and delta tails.

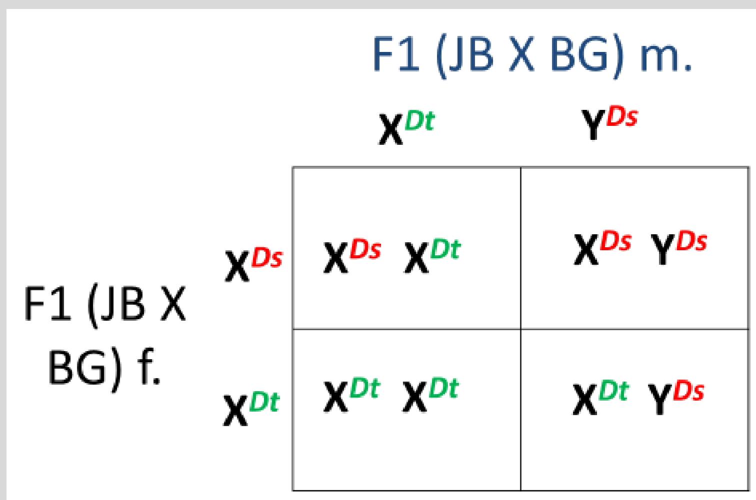


Fig 14 F2 Genotype from Mating F1 Siblings
Half the males produced are homozygous for Ds (upper right box), and thus, will be double swords. The rest of the males (lower right box) will be heterozygous (Ds + Dt) but have delta tails, because Dt is dominant over Ds. (The derivation of the F1 parental genotypes is shown in Fig 12.)

---

[9] Genes for the double sword (Ds, #147) are on the X and Y chromosomes. Delta tails (#146) are a complex trait resulting from a combination of Pigmentierte Caudalis (Cp, #138) and the double sword gene (Ds, #147) [3]. Females carrying the Cp gene will have dark tails; females without the gene will have clear tails. Thus, if you are breeding swordtail guppies, you select females with clear tails; if you are breeding for delta tails, you select females with dark tails.

The results with the Japan Blue swordtails were so stunning that I repeated it with swordtail guppies (Ls or Lower swords) purchased from a recognized and long-term breeder [5]. The Ls guppies carried genes for iridescent colors that I was interested in. Moreover, swordtails have a reputation for "fitness factors" (i.e., longevity, fertility, growth rate, etc).

One Ls male [**Fig 15**] turned out to be a wonderful sire when crossed with a BG female.[10] All the F1 males were absolutely stunning [**Figs 16, 17**]. They displayed brilliant iridescent colors inherited from their sire and the grass/delta tails inherited from their BG dam.

Fig 15 My Ls Male Guppy carries a boatload of iridescent color genes, many masked here by the blue color from the Stoerzbach gene.

In contrast, progeny from reverse crosses (mating BG males to an Ls female) produced swordtails and small, less impressive offspring. Thus, I did not pursue the outcrossing of Ls swordtail females.

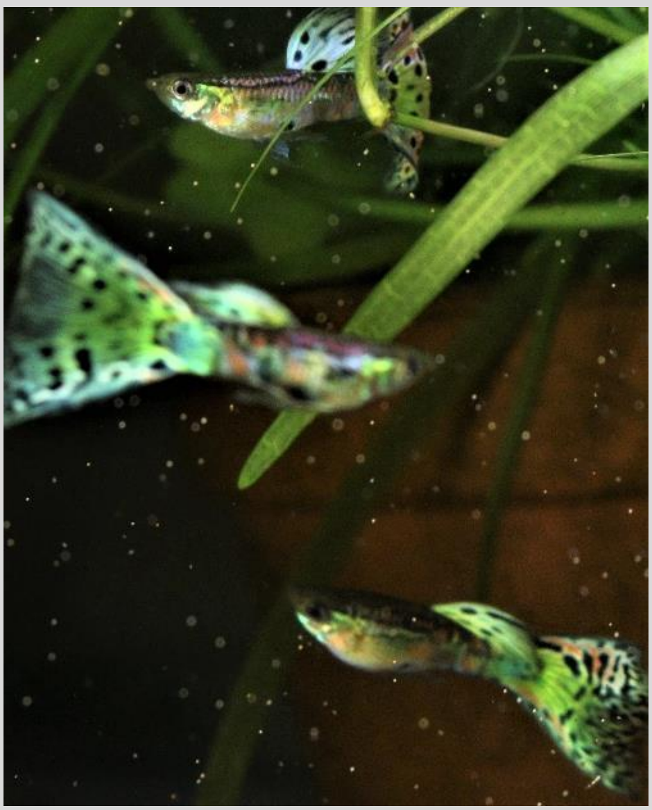


Fig 16 F1 (Ls X BG) Males were not uniform in color and pattern, but in my opinion, they were uniformly pretty.

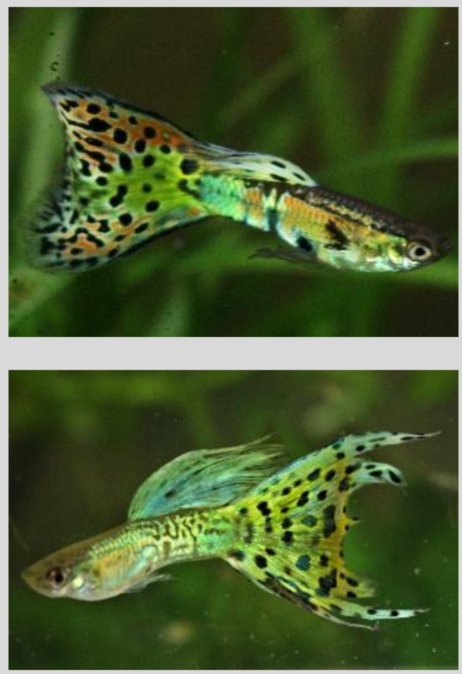


Fig 17 F1 (Ls X BG) Males that I kept for breeding: Red F1 (top photo) shown at 3 mos. Yellow F1 (bottom photo) shown at 15 mos. The green patch at caudal base is from their Ls sire's Emerald Green Iridescent (EGI) gene.

[10] My Bias Ls male carries genes for yellow color [Metal Gold (Mg), #96]; blue color [Stoerzbach (me), #97]; blue color [Asian Blau (Ab), #69)]; green color [Vienna Emerald Green (VEG), #124]; green color [Emerald Green Iridescent (EGI), #78]; and vertical stripes [Zebrinus (Ze), #249]. Genes for the Lower swordtail (Ls, #145) are on both X and Y chromosomes [3].

Breeding the F1s

Because I wanted delta tails—not swordtails—I next had to breed out the swordtail genes. Based on preliminary work with the JBs, I knew that breeding F1 siblings to each other would produce a mix of swords and deltas.

The recommended method to keep and re-enforce the delta tail genotype is a backcross, but it should be with F1 males to delta-strain females. With the preferred pairing shown in **Fig 18**, F2 females will not carry Ls genes; with a reverse cross (BG male as sire), they would. I also did not want to lose any genes for the vibrant colors of my F1 males. (Many color genes are carried on the male's Y chromosome.)

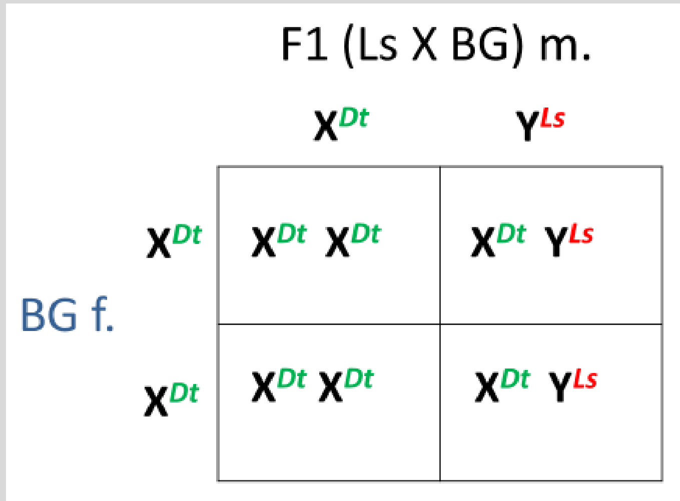


Fig 18 Backcross using an F1 Male

So I paired the reddish F1 (Ls X BG) male (Fig 17) to a "foundation" BG female and saved as many of her progeny as possible. From 4 batches, she produced 3 beautiful male phenotypes (**Figs 19- 21**). Amazingly, this included the BG and Red Grass that had been absent in the F1.

I did not get any yellow phenotypes from the F1 X BG backcross. I did get yellows, though, by mating a yellow-colored F1 (Ls X BG) male to a female sibling (Ls X BG) selected for her yellow-colored fins. From a large batch of F2s, I obtained a very pretty "Yellow Grass" male (**Fig 22**).[11]

Discussion

This article describes a few pitfalls I encountered in breeding guppies. I quickly learned that a basic understanding of guppy genetics could save a lot of time, money, and effort. The deceptively simple Punnett square became an invaluable tool.

In doing outcrosses, it makes a big difference which strain is used as the sire. For example, because the gene for the Japan Blue (JB) color is on the Y-chromosome, I did not waste time breeding a male BG to a female JB. In general and in nature, the male's Y-chromosome carries the color genes, so when in doubt I will use the male for bringing color into the progeny. The opposite situation (e.g., BG guppies carrying the Ab blue color gene on the autosomes of both sexes) is less common.

I would ask readers not to judge highly bred strains (Metalheads, BG, etc) on my limited experience. Other hobbyists may do well with Metalheads and not so well with BG. A strain's quality can vary depending on the breeder. It can diminish rapidly by random inbreeding or unfortunate choices of breeding stock. Moreover, accidents and disease can wipe out prime breeding stock leaving only a small population of inferior individuals to work with.

I used outcrosses to create colorful guppies, increase fish fitness, and learn more about guppy genetics. Outcrosses produced beautiful F1 hybrids, but I did not declare victory until the F2 generation. For it is in the F2, especially with inbreeding (backcrosses and sibling mating), where recessive genes would be expressed. The F2s shown on this page are far better than I ever expected. I obtained not one but four beautiful phenotypes to work with.

---

[11] His yellow color is from the presence of the Mg gene and the *absence* of the Ab gene. Both genes are autosomal and dominant [3]. If present, Ab would have suppressed the yellow color. (*See* Footnote 9 for more.)

Fig 19 F2 Red Grass Guppies

Fig 20 F2 Blue Grass (4-5 months old).

Fig 21 F2 "Christmas Guppies"
Notice how the green color from the EGI gene has migrated into the tail itself.

Fig 22 F2 "Yellow Grass"

Diana Walstad is the author of *Ecology of the Planted Aquarium* (2013). For more articles, plus information about her book, see: http://dianawalstad.com.

REFERENCES

1. Shaddock, Philip. 2008. Genetics Primer. An introduction to guppy genetics for the absolute beginner. https://www.myaquariumclub.com/images/fbfiles/files/GuppyGeneticsPrimer.pdf (22 pp.)
2. Shaddock, Philip. 2012. *Guppy Color Strains*. 240 pp. http://www.petbh.com.br/guppy/wp-content/uploads/2017/12/Guppy-Color-Strains_Philip-Shaddock-1.pdf (Also available from Amazon.com)
3. Bias, Alan S. and Carl Groenewegen. 2017. *Poecilia reticulata*: Domestic Breeder Trait Matrix Reference Guide. Database (18 pp.) maintained by the authors available at: https://www.academia.edu/29928596/Poecilia_reticulata_Domestic_Breeder_Trait_Matrix_Reference_Guide
4. Tripathi, N *et al*. 2009. Genetic linkage map of the guppy, *Poecilia reticulata*, and quantitative trait loci analysis of male size and colour variation. *Proc. Royal Society B* 276: 2195-2208.
5. Alan Bias website: http://www.swordtailguppies.com/home.html