black, wild red, true recessive red, agouti, brindle, roan, white park pattern, color sided phenotypes, dun dilution

Color Genetics in Galloway Cattle

an informal discussion

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Hatherland Firefox, a wild red Riggit Galloway bull in the Jaslu herd, Dorset

Unfortunately, most registries were started by “laymen” who assign "color classes" by phenotypical observation and not genotype. Not to single out, but let’s just use the American Galloway Breeders Association (AGBA) as an example. The AGBA registers three solid colors; Black, Red and Dun.

There are two immediate issues that arise from this classification of “color”.

First, not all “Reds” are red, i.e. Wild-Type Red is not Red by genotype. Rather, only by phenotypical observation (what can be seen).

Second, “Dun” is a dilution of color, and not a color in itself.

DEFINING Coat Color: Solid coat color in cattle results from the presence or absence of melanin in hair coat.

- eumelanin “black”
- phaeomelanin “red”

(MC1r): The Melanocyte Stimulating Hormone Receptor Gene (MSHr), also called the Melanocortin Receptor 1 gene (MC1r) is the source of black or red color.

EXTENSION: The E stands for Extension. Solid Black, Red and Wild-type red cattle are the result of Extension (E) locus (listed in order of dominance):

- dominant (E^D) (black)
- "wild-type" (E^+) (red)
- recessive (e) (red)

Extension regulates the levels of tyrosinase. High concentrations of this enzyme result in production of eumelanin (black pigment), while low concentrations of this enzyme result in the production of phaeomelanin (red pigment). It is possible Galloways have additional types of Extension other than (E).

BLACK: The black allele is abbreviated (E^D). The subscript D stands for dominant black. An animal with (E^D) present is always black. The (E^D) allele is dominant to (E^+) and (e). The accepted order of dominance is $E^D > E^+ > e$. Cattle that are (e/e) are the recessive red genotype.

RED: The red allele is abbreviated (e). Lower case is used to indicate that the allele is recessive to the other two alleles for color (E^D) & (E^+).

WILDTYPE: The wild-type allele is abbreviated (E^+). The superscript + symbol is used to designate a wildtype allele. Wild-Type Red animals often have deep burgundy red bodies. The extremities (head, neck, feet) appear to be darker or black from a distance. But when viewed up close or in natural sunlight the red coloration is visible down to the root.

Wildtype alleles produce both eumelanin and phaeomelanin through intermediate amounts of tyrosinase. The ratio and distribution of these two pigments may be modified by other genes. The visible expression of eumelanin seems sex linked. This can be observed in wild-type (E^+) bulls, which express a darker head, neck and feet as compared to females.

Heterozygous (E^+/E^D) are most often dark black in color, since even one copy of E^D will produce an over-abundance of eumelanin. In heterozygous (E^+/ee) variability of coloring in these animals is expected, and poorly documented.

AGOUTI: E+ can be further modified by the Agouti (A) locus. Agouti comes in several forms and has distinct effects depending upon combination. It is not well understood or documented across breeds. The existence of a recessive black Agouti allele (a) has been postulated with some supportive documentation, having the effect of modifying Wild-type E^+ black/red to black. Thus, not all phenotypical “black” animals may be black (E^D/E^D).

Again, as with Extension, it is possible Galloways have more than one type of Agouti in genotype. To touch on briefly, the suggested allele (Abp) is epistatic (dominant) to E^D and hypostatic (subordinate) to E^+. In combination with E^D, Agouti is not likely visible. In combination with E^+ results in very dark Wild-type; expressing not only varying degrees of red, but also locations of red on the body.

The allele (aw) is recessive and will remove red pigment; leading to the illusion of evenly distributed black melanocytes on the body of Wild-type E^+, mimicking a black animal.

ROAN: Roan is a single, autosomal semi-dominant (blending) gene.

Tracy Wood's red roan Galloway cow, New Zealand

another rare animal; Balytyckle Quest; a miniature fullblood red roan Galloway cow

WHITE PARK (Cs29) Pattern: White Park is a unique pattern; a form of spotting, i.e. it is not a solid color. White Park (**C**s29) is not a dominant gene ~ it is a co-dominant gene ~ White Park pattern is an autosomal incompletely dominant trait.

Classic White Galloway cow (Pinterest: Inntal Kuh)

A single dose results in expression (dark points) and a double dose results in amplified expression (light points).

Homozygous White Galloways are (**C**s29/**C**s29).
Heterorzygous White Galloways are (**C**s29/cs29).
Non-White Galloways are (cs29/cs29).

Thus, a heterozygous **C**s29/cs29 can produce non-white offspring when mated to **C**s29/cs29 or cs29/cs29.

There is nothing mysterious about White Galloway pattern. Autosomal incompletely dominant White x White breedings, where both parents are heterozygous for White, can produce a 1:2:1 ratio of Homozygous White : Heterozygous White : Black (non-white) offspring. This only applies to the "overall color being white w/points (light or dark)" or solid colored...

2 heterozygous Cs29 White Galloways will produce some solid colored calves; This black calf is out of pure White Galloway cow, sired by a pure White Galloway bull; owned by Donald Zimmerman, KZ Farm, Kalispell, Montana. Photo credit: Kent Meireis 2020.

Variation in flecking (dirty sides), etc... is another story.

Believe it or not, much of the color-sided phenotypes are determined by "masked" genotype found within "solid genotype".

“Overmarked” is a term used in some White Galloway registries that refers to an additional roaning, freckling or spotting (patterns on the side) not typically part of the classic White Park (Cs29) pattern.

H5 Spotty, an “overmarked” White Galloway bull
bred by Sarah Bowman, Hang 5 Galloways, Parkman, Wyoming

RIGGIT: “Riggit is a true (phenotype) trait. Riggit expresses from a combination of two or more genes in co-expression that produce a unique and somewhat variable, multi-factoral phenotype. Riggit, if multifactorial, would fall into a two or more gene co-expression. Similar to other breeds with additional "genetic noise" such as Speckle Park, Texas Longhorn, Randall Lineback, etc.

Costa vom Felde, a brindle Riggit Galloway, Germany

Whereas in some breeds a "static" color-sided pattern is likely produced by a single primary gene (or linked gene complex) with minor variance, i.e. Gloucester Lineback, Lynch Lineback, Pinzgauer, etc...

BROCKITT: There are pattern phenotypes seemingly comprised of at least two primary genes in co-expression such Hereford (Lineback + Brockitt for ease of conversation). Old Scottish publications document White Face Galloways as “Brockitt Faced”. Another autosomal incompletely dominant gene with a defined infusion point. Last I read some years back, likely another Cs6 mutation.”

BRINDLE: With wild-type long present in Galloway populations, it should come as no surprise that this phenotype has been resurrected in the German Neanderthal Galloway herd of Hartmut Kindel (below). Brindle is a striping pattern distinct from spotting (S). Most visible on wild-type black animals, less so or nearly invisible on wild-type red, comprised of black and yellow / red color pigments. Current studies indicate the Wild-Type Red (E^+) allele is responsive to the brindle agouti (Abr) in patterned brindle animals.

Ultra DE 035235687 2, owned by H. Kindel, Neandertal Galloways, Germany

We have long known that both wild-type black (E^+/E^+) and wild-type red (E^+/e) cattle exist in Galloway populations. We now know the brindle trait exists in wild-type (E^D/E^+ Abr, or E^+/E^+ Abr) Galloway populations, thus showing that wild-type can be further modified by pattern and spotting traits.

Brindle genotype is still poorly documented across breeds and in cross-breeding. Among Nordic breeds however, as early as 1949, Berge reported brindle as a result of co-expression of two distinct traits in Nordic cattle. More recently, Oulmouden (2000 & 2006) showed brindle to be the result of Agouti (Abr) in Normande Cattle.

Thus, we now know brindle to be comprised of E^+/Abr. When brindle gene (Abr) is present and E^+/E^+ = very dark brindle. When brindle gene (Abr) is present and E^+/e = lighter red brindle. When brindle gene (Abr) is present and E^D/E^D = non expressed brindle.

4 seite 15 unten_galloway kalb farbschlag dun ~ Galloway-Kalb, Farbschlag dun, oefm.de

DUN: Dun Galloways express in three primary phenotypes: Chocolate, Golden and Silver.

- Golden dun results from heterozygous codon deletion within the PMEL gene (p.Leu18del) PMEL +/del.
- Silver dun results from homozygous codon deletion within the PMEL gene (p.Leu18del) PMEL del/del.

From a breeder aspect this simply means the dun trait within various Galloway populations is an autosomal incompletely dominant trait; .i.e. it only takes a single dose for partial expression on phenotype.

We have long known that Dun is capable of both heterozygous and homozygous modification of expression in black (E^D/E^D +/del, E^D/E^D del/del), and in red (e/e +/del, e/e del/del).

While Dun may present in spotted (white park) and patterned (Riggit / color-sided / Lineback / Witrick) & (brindle) Galloways, the locus is only a mutation of solid color, i.e. black or red. The presence of spotting or pattern traits has no effect on the expression of Dun. Thus, there are two common “Dun” phenotypes: Dun Black and Dun Red. Dun modifies black or red, and should be stated first in name or genomic descriptor.

With autosomal mutations of color across species, such as Agouti and Dun, both recessive and incompletely dominant, variation of color (shading) is to be expected. This as a result of “autosomal concentration”, .i.e. a sort of cumulative effect. Just as an autosomal incompletely dominant trait has distinct impact in both heterozygous and homozygous fashion, so does an autosomal recessive trait. Only in the latter it takes much observation to take note of the subtle differences presented in the heterozygous form of a recessive. Thus, all light-colored animals are not the result of Dilution genes.

Dun is dominant to black. The effect on red is more uniform. Homozygous red (e/e) animals that are also heterozygous at the Dun locus will be duns. Animals that are homozygous Dun show a more extensive reduction in pigmentation in both black (E^D/E^D) and red (e/e) coloration. A homozygous black Galloway (E^D/E^D), but also homozygous for Dun, will appear silver. On the other hand, individuals homozygous for Dun and also homozygous red (e/e) would look very light red or even yellow. Animals heterozygous or homozygous for Dun and (E^+/E^+) or (E^+/e) will be darker than (e/e). The actual shading will vary depending upon specific combinations (zygosity).

Black bull, assumed genotype (ED/ED).

Black cow, assumed genotype (ED/ED).

Wild-Type Red cow, assumed genotype (E+/e).

Wild-Type Red bull, assumed genotype (E+/e).

Wild-Type Red bull, assumed genotype (E+/ED).
Possibly an additional Agouti (A)
or Extension (E) modifier.
E+/ED animals I have seen are much darker.

Red bull, genotype (e/e).

Red cow, genotype (e/e).

Golden Dun bull, i.e. Dun Black.
Assumed genotype (+/del, ED/-).

Golden Dun cow, i.e. Dun Black.
Assumed genotype (+/del, ED/-).

Silver Dun bull, i.e. Dun Black.
Genotype (del/del, ED/ED).

Silver Dun cow, i.e. Dun Black.
Genotype (del/del, ED/ED).

CHOCOLATE DUN: Is likely the result of combination of Dun with various types of E and A alleles in co-expression.

Chocolate Dun bull, i.e. Dun Black or Dun Wild-Type,
I assume the latter. Assumed genotype (+/del, ED/E+).
Possibly an additional Agouti (A) or Extension (E) modifier.

These animals are not well documented. They will produce about 50% dun when mated to non-dun. Of the dun offspring, both chocolate and golden dun offspring in about equal numbers.

Chocolate Dun cow, i.e. Dun Black or Dun Wild-Type,
I assume the latter. Assumed genotype (+/del, ED/E+).
Possibly an additional Agouti (A) or Extension (E) modifier.

Dun Red bull, assumed genotype (del/del, e/e).

Dun Wild-Type Red calf, assumed genotype (+/del, E+/e).

Nov 2014 cliftonbeltedgalloways.co.uk; ©MacG photo

Belting is is another unique pattern; another form of spotting, i.e. it is not a solid color. Belting is also an autosomal incompletely dominant gene. Use of a homozgyous Belted sire or dam, even a well marked heterozgyous parent, can actually produce heterozgyous Belted offspring that are "consistently well marked" in F1 outcross with other breeds. Especially, those breeds which do not historically consist of spotting produced by Belting or other genes, i.e. they lack negative concentration to inhibit belted expression. For some reason this does not seem to hold true with F1 when either parent is a Galloway. Canadian herdbook entries should substantiate this? It was well known among breeders at one time. Bottom line is homozgyous Belting in itself does not guarantee "consistently well marked" offspring. Belting in individual herds varies greatly dependant upon "sum total genotype", i.e. has the herd accrued positive or negative autosomal concentration to refine or disrupt belting?

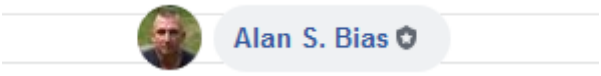
ADDITIONAL NOTES:

As hair grows during embryonic development, melanocytes develop and migrate to the follicles to produce pigment. Further traits can modify color coat in utero, shortly after birth or with aging. Additional traits can modify for spotting or pattern.

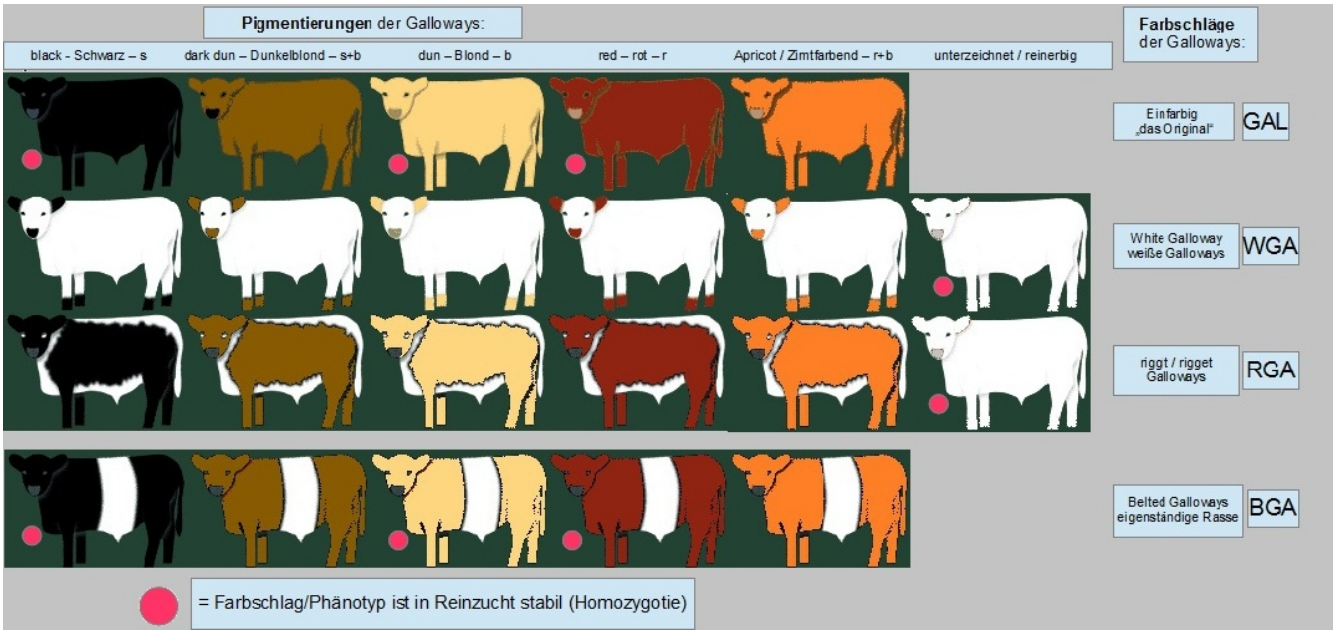
~ Alan S. Bias

This informal article is generously provided by Alan S. Bias, and is the result of discussions mostly in 2018, on the Galloway Cattle Genetic Discussion Group.
https://www.facebook.com/groups/610010689066993

see also:
Dun Galloway Genetics; a discussion of effect on phenotypical expression.



About the Author: Alan S Bias is an independent researcher active in evolutionary biology as a member of Independent Academia, and has published many papers that document his research findings. In this article, he shares some of his knowlege about the genetics of the most common dilution in beef cattle. Alan is a rare Shetland Sheep, Galloway Cattle and Domestic Guppy breeder & exhibitor of 47 years. For the last 35 years he has specialized in strains known to breeders as "Swordtail Guppies". For nearly 20 years he has done cellular level research, combining formulated breeding tests & systematic observation to help breeders understand the complexities of modern Guppy genetics in the strain being produced. Alan lives in Lewisburg, West Virginia, United States. alansbias@aol.com



https://commons.wikimedia.org/wiki/File:Farbschl%C3%A4gePigmentierungenGALLOWAYS.jpg

» see also: "**The Riggit Initiative**" PDF report by Alan S. Bias by request, regarding the subject of AGBA opening a Section IV Riggit Galloway. The Canadian Ministry of Agriculture approved the amendments passed by the Canadian Galloway Breeders Association membership in December 2019 and officially opened a new Section IV in 2020. Their Section IV animals have an R prefix.