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Genetic architecture of red and yellow plumage variation in domestic pigeon (Columba livia)

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Abstract

In the case of pigeon, ash-red color and its various patterns are very interesting. This ash-red has lots of diversification in the field of Genetics. Some renowned books on pigeons on the basis of these colors suggested dominant red, recessive red, and their dilute yellow coloration for the explanation of reds and yellows in pigeons. Dominant red (BA) is actually ash-red could be homozygous or heterozygous (pure/impure), recessive red (e//e) is always recessive (pure and homozygous recessive), and yellow (d) is a dilute factor. Ruby-red is nothing but only strawberry-eyes, and brick red (solid red/self-red) has no other genetic mutation. After hatching, tip of beak of the squab of red pigeons showed red dot (a remarkable identity of red pigeons). The study highlights epistatic interactions, polygenic modifiers, and sex-linked inheritance as key determinants of plumage diversity.

Keywords: Red pigeon, yellow pigeon, genetics, dilution gene, epistasis, melanin, sex-linked inheritance

Introduction

Further variation in plumage coloration in domestic pigeons is driven by the interaction of major effect genes and multiple modifier loci that collectively influence pigment intensity and distribution. These genetic factors can either enhance or suppress melanin production, leading to a wide spectrum of phenotypes ranging from deep reddish-brown to pale yellow or cream tones. In particular, dilution and modifier genes play a crucial role in reducing phaeomelanin concentration within feather follicles, thereby altering the visual expression of red pigmentation. Such genetic complexity makes pigeon coloration an effective model for studying quantitative inheritance and gene interaction networks in vertebrates. Pigments of eumelanin is rod-shaped and phaeomelanin is granulous. Ample deposits of eumelanin produce black color, and more dilute deposits produce brownish-black,

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blue, or dilute colors. Phaeomelanin gives rise from red to yellow (Muller and Schrag, 1985). The base color, pattern, and any modifiers make a final look of pigeon. The common modifiers in pigeons are dilute, spread, indigo, grizzle, opal, reduced, and recessive red (shift hue, ad speckle, or mask patterns). Blood red is not a complete red pigeon, might have pied marking. A white homer may have ruby-red eyes, orange, pearl or dark eyes. Recessive red pigeon has solid cherry-red feathers. A self-red homer with no pattern is called 'velvet' with dark shield (intense dark pattern, or recessive red. Ash-red plus spread usually is overall ash-red. Homozygous indigo lacking spread often is velvet mimic. It is a descriptive level, not a separate genetic mutation. Brick red is influenced by various bronzes (Rodgers, 2015). Red is often enhanced in its expression by the presence of at least one 'bronze' factor (Rodgers, 2015). Brick red is originated from cross of the black pigeons. Mealy is a phenotype, cannot be dominant. Ash-red and grizzle act side by side and both genes show. Heterozygous male (ash-red and black) will have flecks, spots, and streaks of black particularly in the flights and tail feathers, this may be on the shields as well as and will increase in expression with age (Rodgers, 2015). Many pouter breeds are available as self-colored. The objective of this write-up is to mention some sorts of ideas about the genetics on reds and yellows of pigeons.

Reds and yellows in pigeons

Dominant red (BA): Nuttall (1918) concluded that red factor (R) causes the red in mealy and red checker. Dominant red (B^A) (Table 1) is not a uniform red, having more or less 'washed-out' areas, especially the tail; gray is practically devoid of red. Metzelaar (1928) introduced that red is caused by chemical reduction (black → red → white). Smooth red is ash and coarse red is actually red. This is the duality effect of red (Hollander, 1994). Dominant red is defined when head, neck, and breast are bright brick red, belly dilute red, wing feathers and tail ending light, preferably with few splashes of black in cocks (Muller and Schrag, 1985). Recessive red squabs never have dark skin but dominant-red ones often do. Bar dominant reds are often called 'mealy', where wing bars being red, and coverts ash (Levi, 1992).

Plate 1. Bombai

Plate 2. Kokah

Plate 3. Cassel tumbler

Recessive red locus (e): The primary determinant of red coloration is the autosomal recessive allele commonly referred to as recessive red (e). Recessive red (e//e) always masks pattern and spread (Table 1). Some factors like dominant opal, toy stencil, oriental stencil, grizzle, platinum, and milky are not completely masked by e//e. Very rich recessive red in many cases carry sex-linked genetic code for black color (predominance of eumelanin) and that spread is available too. After hatching, the tip of beak is red for red pigeons. Actually, recessive red is red and yellow coloration. For shield pigeon with dominant red is speculated that recessive red prevents the correct pied marking (Sell, 2012). Recessive red lacks this duality of action. When recessive red is weak the color becomes pale and tail and back bluish (Hollander, 1994). Recessive red is a rich brownish red including under plumage and feather shaft (Muller and Schrag, 1985). The recessive red genotype (e/e) is epistatic over pattern-producing genes, effectively masking typical wing markings such as bars and checks by redirecting all pigment synthesis toward phaeomelanin. As a result, underlying pattern genes remain genetically present but are not phenotypically expressed. In contrast, dilution genes do not exhibit true epistasis; instead, they act as modifying factors that reduce pigment intensity without altering pigment type. Their effect becomes visible only after the base red phenotype is established (Domyan *et al.,* 2014).

Plate 4. Red gorra

Yellow phenotypes for dilution mechanism: From a black cock heterozygous for recessive red and a recessive red hen might get yellow hens, by this is very special case. Light yellow is canary and rich is buff. Yellow is the dilute of dominant and also of recessive red (Table 1). The yellow squabs often have albino-like eyes (Levi, 1992). Yellow phenotypes in *Columba livia* arise when the expression of the recessive red genotype (e/e) is further modified by dilution genes that reduce pigment intensity. In this interaction, the red base phenotype is not replaced but attenuated, resulting in a spectrum of lighter shades ranging from yellow to cream. This effect is primarily driven by a reduction in

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phaeomelanin granule density within feather structures, which decreases overall pigment concentration. Consequently, feather coloration appears visibly lighter and less saturated compared to the typical red phenotype. These dilution modifiers, often sex-linked, play a significant role in fine-tuning plumage coloration and contribute to the continuous variation observed among domestic pigeon color morphs.

Plate 5. Ghia sulli

Table 1. Differences among dominant red, recessive red, and yellow

Features	Dominant red/Ash-red	Recessive red/Self-red/Solid red	Yellow
Genetics	Sex-linked	Autosomal	Sex-linked
Symbol	B^A	e	d (dilute)
Color	Reddish-brown	Cherry-red	Yellow is basically recessive red + dilute gene; dilute halves the pigment, so yellow is not recessive red itself.
Pigeon breeds	Any types of red pied (eg. Gorra pigeon (Plate 1) of Bangladesh).	Bombai (Plate 2); Kokah (Plate 3) (then spread black); Cassel tumbler (Plate 4) (self-red with white primaries when pied gene is just kicking in on the flight feathers).	Ghia sulli(Plate 5) of Bangladesh is an excellent example of yellow-colored pigeon.

Conceptual genetic model of red–yellow spectrum

The red–yellow color spectrum in *Columba livia* is explained through a hierarchical genetic model. The primary locus (e/e) produces the recessive red phenotype by promoting phaeomelanin synthesis. Polygenic factors further influence shading, pigment density, and feather distribution. Epistatic interactions mask pattern genes, resulting in reduced wing markings in red and yellow forms. Yellow coloration does not arise from a separate gene but from dilution of red pigmentation. This dilution reduces phaeomelanin concentration in feathers. As a result, red appears lighter and shifts toward yellow or cream shades (Domyan *et al.*, 2014).

Molecular and functional effects

Although the precise molecular identity of the genes involved remains under investigation, their functional consequences on pigmentation are well characterized. The expression of the recessive red phenotype leads to the inhibition of eumelanin (black pigment) granule formation, effectively suppressing darker coloration. Concurrently, there is an increased synthesis and deposition of phaeomelanin, resulting in red to yellow pigmentation across the plumage. In addition, typical wing pattern elements such as bars and checks are largely absent, indicating a disruption in spatial pattern regulation. Together, these effects produce a uniform, solid red phenotype extending across the entire body, demonstrating the strong regulatory influence of this genetic system on both pigment type and pattern expression.

Conclusions

Red and yellow coloration in the rock-pigeon (*Columba livia*) is controlled by a combination of genetic mechanisms, primarily the autosomal recessive red gene (*e*) and the sex-linked dilution gene (*d*). The mystery of the pigments of ash-red in pigeons played a significant role on the various patterns of this color. The recessive red gene exerts a strong epistatic effect by masking underlying plumage patterns and suppressing eumelanin expression, thereby promoting phaeomelanin-based red coloration. Yellow phenotypes arise through the additional influence of the dilution gene, which reduces pigment intensity and modifies red to yellow. The interaction between these genes highlights the critical role of epistasis and gene modification in shaping phenotypic expression. Collectively, these genetic processes provide important insights for selective breeding practices and contribute to a broader understanding of avian pigmentation and inheritance. To understand more about the genetics of ash-red, recessive red, and yellow, need to organize further experimental design.

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