

Inheritance of Red Eyes in Ornamental Koi Carp

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- **The Japanese ornamental carp or koi is one of the most popular decorative fish in many countries worldwide, including the United States.**
- **Approximately 13-14 main color types in koi are known.**
- **Inheritance of many color traits in koi has never been investigated.**

- **There is a type of koi called Akame Kigo that literally means yellow fish with red eyes.**
- **It is generally assumed that Akame Kigo koi are albino.**
- **The initial purpose of this study was to investigate inheritance of albinism in koi.**

- The F₁ progeny was obtained by crossing Akame Kigo male with white-red (Kohaku) female with regular black eyes.
- The F₁ progeny consisted of both red-eyed and black-eyed fish with segregation close to the 1:1 Mendelian ratio:
 - 31 red-eyed fish : 33 black-eyed fish

● The 1:1 Mendelian ratio in F_1 could result from the following crosses:

– Kohaku female x Akame Kigoi male
(black eyes) (red eyes)

Aa

aa

– Kohaku female x Akame Kigoi male
(black eyes) (red eyes)

aa

Aa

- Theoretically, for determination which allele (controlling either red eyes or black eyes) is dominant and which is recessive, results of crosses F_1 fish with the same trait (black eyes x black eyes and red eyes x red eyes) are decisive.
- Cross of two heterozygotes ($Aa \times Aa$) will result in the 3:1 Mendelian ratio in the progeny while cross of two homozygotes for the recessive allele ($aa \times aa$) will give fish with the parental phenotype only.



- Red-eyed fish from F_1 progeny.

- Larvae in obtained progenies differed with regard to color of eye lens.



Table 1. Segregation of larvae in progenies obtained from crossing F₁ fish

Female phenotype	Male phenotype	Segregation		Theor. ratio
		Light lens	Dark lens	
Red-eyed	Red-eyed	77	25	3:1
Red-eyed	Red-eyed	87	28	3:1
Black-eyed	Black-eyed	0	103	0:1
Black-eyed	Black-eyed	0	132	0:1
Red-eyed	Black-eyed	28	41	1:1
Black-eyed	Red-eyed	51	39	1:1

Table 1. Segregation of unpigmented juveniles in progenies obtained from crossing F₁ fish.

Female phenotype	Male phenotype	Segregation, %		Theor. ratio
		Red eyes	Black eyes	
Red-eyed	Red-eyed	128	44	3:1
Red-eyed	Red-eyed	275	74	3:1
Black-eyed	Black-eyed	0	107	0:1
Black-eyed	Black-eyed	0	106	0:1
Red-eyed	Black-eyed	95	75	1:1
Black-eyed	Red-eyed	86	62	1:1

- Based on segregations in progenies it can be suggested that red eye trait in koi is controlled by dominant allele of one gene (*R/r*).

- Koi with genotypes *RR* and *Rr* have red eyes while koi with genotype *rr* have regular black eyes.

Rr x Rr → *2RR : 1Rr : 1rr* (3 red eyes : 1 black eyes)

rr x rr → *rr* (black eyes only)

Rr x rr → *1Rr : 1rr* (1 red eyes : 1 black eyes)

- Part of juveniles in progenies from F_1 fish had black pigmentation on bodies.
- In pigmented juveniles ratio red eyes : black eyes were shifted towards black-eyed fish.
- Pigmented juveniles had darker red eyes than non-pigmented fish.



- **Based on the occurrence of fish with red eyes and black pigmentation on body it can be suggested that the appearance of red eyes in koi is caused not by albino but by another demelanization mutation.**
- **Demelanization mutations decrease the quantity of melanin to some extent in both the skin and eyes but not completely.**

Demelanization mutations in medaka

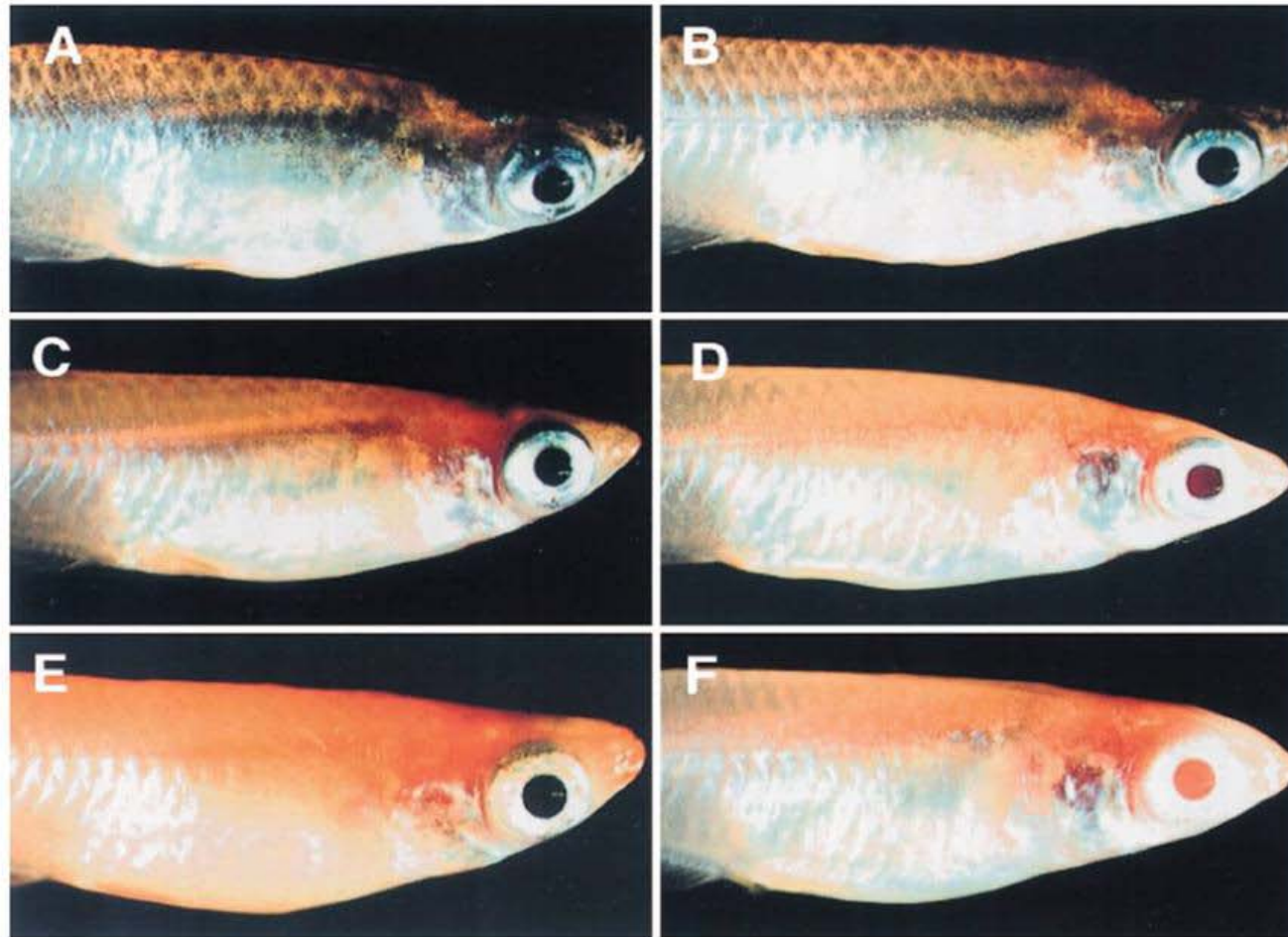


Fig. 2. Adult homozygous mutants. A, wildtype; B, b^{d21} (ENU-induced); C, b^{d2} (ENU-induced); D, b^{d8} (γ -ray-induced); E, b (spontaneous); F, i^1 (shown as control).

From Shimada et al. 2002



Pigmented retinal epithelium in koi larvae with light eye lens

Unpigmented retinal epithelium in albino zebrafish larvae



(from Tsetkhaladze et al. 2012)

- **Additional information on expression and inheritance of investigated mutation was obtained from cross of F₁ red-eyed female with wild-type colored common carp male.**

**Larvae from progeny from cross
red-eyed koi female x common carp male**



**Juveniles from progeny from cross
red-eyed koi female x common carp male**

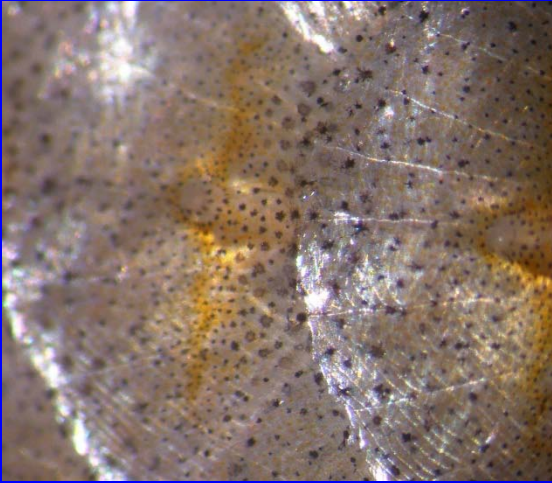


**Fish with wild-type
common carp body
color**

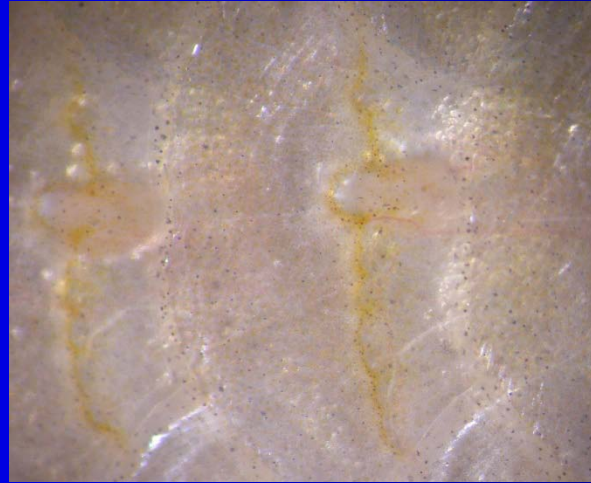
**Fish with light
body color**

Presence of Chromatophores in Skin and Tail

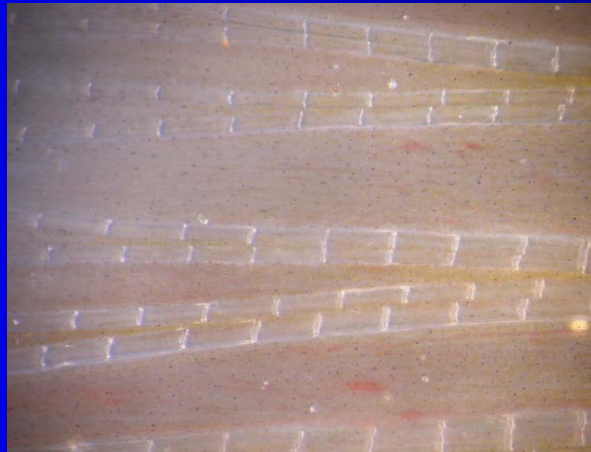
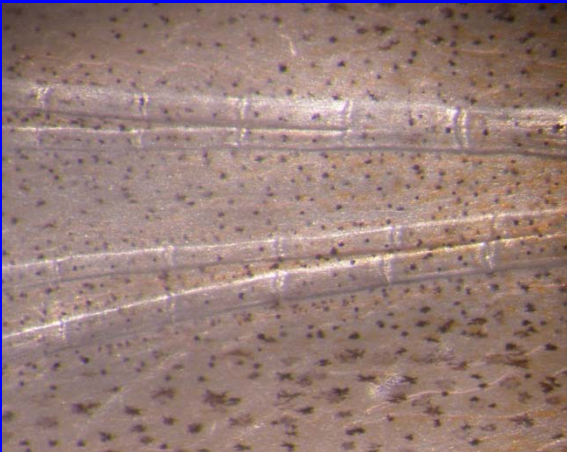
**Fish with
wild-type color**



**Fish with
light body color**



**Koi without
black pigmentation**




- Investigated mutation *R* causes appearance of red eyes only in koi, which do not have melanin in skin.
- In wild-type color common carp this mutation causes only partial demelanization of fish body.


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Transparent-Scaled and Red-Eyed Koi [CC]

 KSU Aquaculture

https://www.youtube.com/watch?v=BJp_FRVnChA



Transparent-scaled red-eyed koi



Thank you!

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