COAT COLOUR IN CARMAGNOLA GREY RABBIT : RESULTS OF A PHENOTYPIC SELECTION

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Abstract - To improve knowledge of Carmagnola Grey rabbit results on homogeneity in coat colour, obtained during 8 years of phenotypic selection for the conservation and improvement of this breed, and some hypothesis about its genotype have been studied.
On 13,567 subjects of 1,737 litters evolution of the phenotypic frequencies of normal (standard grey) and anomalous (white, fawn, black, and Dutch spotted) coat colours has been analysed, composition of the anomalous coloured litters has been compared to the expected frequencies (χ^2 test), and degrees of inbreeding (Wright's formula) of the normal and anomalous coloured litters have been tested (ANOVA).
By selection an increase of more than 15 points in percentage has been obtained for the normal coloured subject frequency, and of almost 40 points for the normal coloured litters.
Nowadays three loci (A, C, and *Du*) seem to be involved in determination of coat colour in Carmagnola Grey rabbit, because by selection allele e (fawn) has been eliminated, and frequencies of alleles c (white) and *du* (Dutch spotting) have been reduced, without connections with degrees of inbreeding.

INTRODUCTION

To identify different breeds - in rabbits as in other animals - we normally use coat colours, besides variation in characteristics as body size, conformation, and behaviour, so that many breeds have taken their name from their colour.
In rabbits we can have a big array of different colours and shades, and in this species we are able to identify both loci and alleles of the major coat colour series (A, B, C, D, E) and of the other major coat colour genes (*Du*, En, Si, V, W) (LUKEFAHR, 1986; CHEEKE *et al.*, 1987), so we can describe the coat colour genotype of many and well known breeds of rabbits under selection.
Concerning the Carmagnola Grey - a Italian local rabbit breed - data on male and female reproductive efficiency, maternal behaviour, adaptability to environmental conditions, growth rate, feed conversion ratio, carcass characteristics at slaughter have already been collected and analysed (ZOCCARATO *et al.*, 1986, 1990 ; PAGANO TOSCANO *et al.*, 1990; LAZZARONI et *al.*, 1991 ; PAGANO TOSCANO *et al.*, 1991 ; ZOCCARATO *et al.*, 1991; LAZZARONI *et al.*, 1992; PAGANO TOSCANO *et al.*, 1992; LAZZARONI and LEVERONI CALVI, 1995 ; LAZZARONI *et al.*, 1995), and it is now possible to identify a uniform strain of Carmagnola Grey rabbits, with a low inbreeding coefficient, showing good reproductive performances, good fertility, good growth rate and a fair slaughtering weight.
This note is reporting the results concerning the homogeneity in coat colour obtained during the phenotypic selection for the conservation and improvement of this breed and some hypothesis about its genotype.

MATERIALS AND METHODS

Grey rabbits of an endangered local breed, chosen in small family-run farms, were the original nucleus, given by heterogeneous subjects, on which we have worked.
After the definition of the breed standard (PAGANO TOSCANO *et al.*, 1983) the selection of the Carmagnola Grey rabbit, on the basis of the established morphological characteristics, has been carried on and during 8 years (from 1986 to 1993) data on coat colours have been registered on 13,567 subjects of 1,737 litters, born of only grey parents, considering "normal" the coat colour following the breed standard (grey over-colour, lighter on the ventral regions, on the medial and plantar surfaces of hind legs and on the lower part of tail ; grey or light grey under-colour, never white ; a lighter and triangular spot is present on neck ; ears can be black edged, and the upper part of tail is dark; nails are pigmented, and eyes are dark) and "anomalous" the presence of other

colours (we have found white, fawn, black, and Dutch spotted), so the phenotypic frequency of individual coat colours and the frequency of normal and anomalous coloured litters during selection has been studied.
To have a better knowledge of the anomalous coat colours we have studied the compositions of the anomalous coloured litters and analysed the observed and expected frequencies of different colours by the χ^2 test

$$\chi^2 = \Sigma [F_0 - F_e]^2 / F_e$$

where F_0 is the observed frequency, and F_e the expected one (SNEDECOR and COCHRAN, 1967).
At last we have verified if the grey rabbits obtained by selection, supposed be more homozygous than the anomalous coloured, have a higher degrees of inbreeding than the anomalous ones. The degrees of inbreeding have been calculated going back for 5 generations using the Wright's formula

$$F_x = \Sigma [(½)^{n+n'+1} (1 + F_p)]$$

where n is the number of generations between x's father and a mutual progenitor of father and mother, n' is the number of between x's mother and the same mutual progenitor, and F_p is the degree of inbreeding of the mutual progenitor if inbred (HUTT and RASMUSEN, 1985), in 18 normal and 18 anomalous litters, and compared by ANOVA.

RESULTS AND DISCUSSION

The rabbits with a grey coat colour were 82.05 % when we started our registrations (Table 1), but in five years of selection they raised to 99.60 % to decrease lightly in the following years. Between the 13,567 subjects observed from 1986 to 1993, anomalous coat colours are come out in 380 subjects, from which the biggest amount is represented by the white ones (219 subjects), and only one anomalous colour has been eliminated, since from the first year of work : the fawn one.

Table 1 :Phenotvoic frequencies in coat colours during selection.

year	grey		white		fawn		black		Dutch spotted		overall
	n	%	n	%	n	%	n	%	n	%	n
1986	905	82.05	109	9.88	23	2.08	10	0.91	56	5.08	1103
1987	1593	94.76	59	3.51	-	-	4	0.24	25	1.49	1681
1988	1711	99.13	4	0.23	-	-	2	0.12	9	0.52	1726
1989	2014	98.19	24	1.17	-	-	-	-	13	0.64	2051
1990	3745	99.57	12	0.23	-	-	4	0.11	-	-	3761
1991	1987	99.60	7	0.35	-	-	-	-	1	0.05	1995
1992	868	98.97	4	0.46	-	-	2	0.23	3	0.34	877
1993	364	97.59	-	-	-	-	7	1.88	2	0.53	373
Σ	13187		219		23		29		109		13567

The frequency of normal and anomalous coloured litters has changed more during selection (Table 2) : at the beginning we had quite the same number of normal and anomalous litters (54.61 vs 45.39 %), but in only three years the normal ones raised to 97.29 % and are remained the same.

Table 2 : Frequency of normal and anomalous coloured litters during selection

year	normal colour		anomalous colour		overall
	n	%	n	%	n
1986	83	54.61	69	45.39	152
1987	181	84.98	32	15.02	213
1988	215	97.29	6	2.71	221
1989	247	95.00	13	5.00	260
1990	461	98.29	8	1.71	469
1991	250	98.04	5	1.96	255
1992	110	96.49	4	3.51	114
1993	50	94.34	3	5.66	53
Σ	1597		140		1737

The composition of the anomalous coloured litters registered during the eight years of selection is shown in table 3. The higher number of anomalous litters has presented two different coat colours : the grey-or-white colour is the most representative combination (59.29 %), followed by the grey-or-Dutch spotted (17.14 %), by the grey-or-black (7.86 %), and by the combination of the three different coat colours grey-or-Dutch spotted-or-white (5.72 %). Other combinations of two or three different coat colours (grey-or-fawn, grey-or-white, grey-or-fawn-or-white) are very rare.

Table 3: Composition of anomalous coloured litters during selection.

	n°. of kids		n°. of litter	% of litters
litters with one coat colour				
- fawn	9		1	0.71
- Dutch spotted	41		6	4.29
litters with two coat colours				
- grey or white	454	187	83	59.29
- grey or fawn	14	14	3	2.14
- grey or black	57	26	11	7.86
- grey or Dutch spotted	133	46	24	17.14
- Dutch spotted or white	7	2	1	0.71
litters with three coat colours				
- grey or fawn or white	1	3	1	1	0.71
- grey or black or white	7	3	7	2	1.43
- grey or Dutch spotted or white	37	15	20	8	5.72

Has to be also mentioned some litters without grey coloured kids, in which all subjects are Dutch spotted (4,29 %), fawn (0,71 %), and Dutch spotted-or-white (0,71 %).
The analysis on the observed and expected frequencies of different coat colours in the anomalous coloured litters by the χ^2 test has been carried on only for the combinations of two or three different coat colours come out in more than two litters, and for three combinations the observed frequency agrees with the expected ones (Table 4).

Table 4 : Observed and expected frequency of different colours in the anomalous coloured liners

alomalous coloured litters	frequency		χ^2	χ^2
	observe	expected	calculated	significance
two coat colours		(3 : 1)		(DF = 1)
grey	454	480.75		
white	187	160.25	5.95	*
grey	14	21.00		
fawn	14	7.00	9.33	*
grey	57	62.25		
black	26	20.75	1.77	NS
grey	133	134.25		
Dutch spotted	46	44.75	0.05	NS
three coat colours		(9 : 3 : 4)		(DF = 2)
grey	37	40.50		
Dutch spotted	15	13.50		
white	20	18.00	0.69	NS

The presence of grey-or-white coat colours in the same litter could be caused by heterozygous of locus C, with an expected frequency 3:1, but such a hypothesis is not confirmed by χ^2 test, because the number of white coats is higher than the expected one.
The same expected frequency could be supposed for the grey-or-fawn litters, with heterozygous of locus E, even if the fawn coats are the 50 % (but the subjects have been only 28).
For the grey-or-black litters we can suppose to have a single gene inheritance with complete dominance, the involved locus should be A (alleles A, Agouti, and a, black). The same is for the grey-or-Dutch spotted litters, in which the involved locus should be *Du* (alleles *Du*, normal, and du^d or du^w, Dutch spotted). We can also suppose that the Dutch spotted-or-white litter could come out from double heterozygous for locus C and *Du*, with expected frequency 9:3:3:1, but none analysis is possible.

For the grey-or-Dutch spotted-or-white litters we can suppose to have a recessive double genes inheritance, involving locus C and *Du* (alleles C, grey, and c, white ; *Du*, normal, and du^d or du^w, Dutch spotted).
No difference are found by ANOVA in the degrees of inbreeding calculated for 18 normal (4.57 %) and 18 anomalous (4.43 %) coloured litters, so the homogeneity in coat colour obtained in our grey rabbits hasn't caused more homozygous than in the anomalous coloured population.
So it is now possible suppose that in the Carmagnola Grey rabbit three loci (A, C, and *Du*) are involved in determination of coat colour and by selection we have been able to eliminate the allele *e* (fawn) and to reduce the frequency of alleles *c* and *du*, but we must remember that also with a long and severe selection is impossible to eliminate completely the anomalous coat colours because of the amount of loci and alleles involved (ROBINSON, 1978).

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Il colore del mantello nel coniglio Grigio di Carmagnola : risultati di una selezione fenotipica - Per migliorare la conoscenza del coniglio Grigio di Carmagnola si sono studiati i risultati sull'omogeneità del colore del mantello, ottenuti in 8 anni di selezione fenotipica per la conservazione e il miglioramento della razza, e si sono fatte alcune ipotesi sul suo genotipo.
Su 13.567 soggetti appartenenti a 1.737 nidiate si è analizzata l'evoluzione delle frequenze fenotipiche dei mantelli normali (grigi secondo lo standard) e di quelli anomali (bianchi, fulvi, neri e pezzati olandesi), e si sono confrontati la composizione delle nidiate con colori anomali con le frequenze attese (test χ^2) e i gradi di inincrocio (calcolati secondo la formula di Wright) delle nidiate con colori normali e anomali (ANOVA).
La selezione effettuata ha permesso di ottenere un aumento di più di 15 punti percentuali nella frequenza dei soggetti normalmente colorati, e un aumento di quasi 40 punti nella frequenza delle nidiate normali.
Attualmente i interessati nella determinazione del colore del mantello nel coniglio Grigio di Carmagnola sembrano essere tre (A, C e *Du*), poiché grazie alla selezione l'allele e (fulvo) è stato eliminato e le frequenze degli alleli c (bianco) e *du* (pezzatura olandese) sono state ridotte, senza tuttavia influenzare il grado di inincrocio.