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Original article

Crossbreeding effect on sexual dimorphism of body weight in intergeneric hybrids obtained between Muscovy and Pekin duck

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Abstract – From a factorial crossbreeding experiment between two Muscovy and Pekin duck strains it appears that the increased body weight sexual dimorphism in favour of males in the Muscovy growing duck depends on the Muscovy mother in pure breds and in the reciprocal cross. The ratio of male to female body weight averages took the values of 1.19, 1.47, 1.75, 1.77, 1.84 and 1.64, respectively, at 4, 10, 16, 20, 30 and 40 weeks of age in the Muscovy progeny. This tendency was similar in the Pekin × Muscovy progeny. On the contrary this ratio took the values of 1.07 and 1.11 at 10 and 16 weeks of age in the Pekin progeny, being similar in the Muscovy × Pekin progeny (1.06 1.07 and 1.08, respectively, at 16, 20 and 30 weeks of age). These results are evidence of a contribution of the Muscovy female duck to increase the body weight sexual dimorphism in duck by depressing the body weight growth in female progeny and not in the male progeny either in pure or crossbreeding. If the maternal effects are assumed to be similar in male and female progeny, the ranking of the four genotypes in the female progeny could be explained by adding to the effect of sex-linked genes (Z chromosome) the effect of genes on the W chromosome. Within a Mendelian inheritance pattern it may be suggested that, besides the usual sex-linked gene effects, coding genes of the non-pseudo-autosomal region (NPAR) of the Muscovy W chromosome depress growth when compared to the Pekin W chromosome.

ducks / body weight / sexual dimorphism / crossbreeding

Résumé – Effets du croisement sur le dimorphisme sexuel en poids corporel chez les hybrides intergénériques obtenus entre les canards de Barbarie et Pékin. Dans une expérience de croisement factoriel entre deux souches de canards de Barbarie et Pékin, il

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apparaît que le dimorphisme sexuel en faveur des mâles sur les caractères de croissance semble dépendre de la mère Barbarie en pur et dans le croisement réciproque : le rapport entre les moyennes des poids corporels prennent les valeurs de 1,19 ; 1,47 ; 1,75 ; 1,77 ; 1,84 ; 1,64 respectivement aux âges de 4, 10, 16, 20, 30 et 40 semaines dans la descendance Barbarie. Les résultats sont comparables dans la descendance du croisement entre mâle Pékin et femelle Barbarie. Au contraire ce rapport, lorsque la différence entre poids des mâles et des femelles est significative, prend les valeurs de 1,07 et 1,11 aux âges de 10 et 16 semaines dans la descendance des Pékin. Cela est comparable dans la descendance du croisement entre le mâle Barbarie et la cane Pékin, avec des valeurs du rapport de 1,06 ; 1,07 et de 1,08 respectivement aux âges de 16, 20 et 30 semaines. Ces résultats mettent en évidence une contribution de la cane Barbarie, en pur et en croisement, à l'accroissement du dimorphisme sexuel en poids par un effet dépressif sur la croissance corporelle sur sa descendance femelle et non sur sa descendance mâle. Si les effets génétiques maternels sont supposés être comparables dans les descendances mâle et femelle, le classement des quatre génotypes dans le sexe femelle peut s'interpréter en additionnant aux effets de gènes liés au sexe (chromosome Z) un effet de gènes qui seraient situés sur le chromosome W. Dans le cadre de l'hérédité Mendélienne, on peut faire l'hypothèse, outre les effets habituels chez les oiseaux de gènes liés au sexe, d'un effet dépressif sur la croissance de gènes de la région non pseudo-autosomale du chromosome W du Barbarie, comparativement au W du Pékin, si celle-ci contient des gènes codants.

canard / poids corporel / dimorphisme sexuel / croisement.

1. INTRODUCTION

The very large body weight sexual dimorphism in favour of males in the Muscovy duck is well known [9, 10]. Moreover, it seemed to be small in Pekin duck as in the progeny of the mating of Muscovy drake with Pekin duck female which gives the mule duck, and to be as in Muscovy in the reciprocal cross which gives the hinny duck [12]. Olver et al. [8] have pointed out that pure Muscovy and Pekin × Muscovy hybrids showed a body weight sex difference increasing between 5 and 10 weeks of age, and that the pure Pekin and the Muscovy × Pekin hybrids showed very little sex difference. Usually mule ducks are produced, owing to their meat production potential in both sexes [11], but not the reciprocal hybrids (hinny duck). Gomot and Bonin [5] studied the male hybrid between Pekin drake and Muscovy female duck. They concluded that it presents on the whole a predominance of the maternal characteristics.

As far as we know, there has been no investigation up to now to study the differences in body weight sexual dimorphism in ducks according to the Muscovy or Pekin mother. A crossbreeding experiment between two Muscovy and Pekin duck strains has been carried out. The purpose of this work is to show evidence of the Muscovy mother influence upon the body weight sexual dimorphism during growth and to discuss related hypotheses such as the effects of sex-linked genes and the Muscovy dam contribution.

2. MATERIAL AND METHODS

2.1. Animals

Progeny from Muscovy drake and Muscovy female (M × M, 22 males, 18 females), Muscovy × Pekin (M × P, 31 males, 28 females), Pekin × Muscovy (P × M, 34 males, 30 females), Pekin × Pekin (P × P, 23 males, 19 females) matings were hatched from two successive batches in June 1995. Ducklings from the four genotypes were raised at the Duck Research Center I-Lan Sub-Institute of the Taiwan Livestock Research Institute. They were produced by artificial insemination of the Muscovy and Pekin female ducks with pooled semen of Muscovy or Pekin drakes. They were raised with mixed genotypes in each pen with ad lib feeding. They were individually weighted at birth, at 4, 10, 16, 20, 30 and 40 weeks of age (WK0, WK4, WK10, WK16, WK20, WK30 and WK40, respectively). Animals of the second batch were not weighed at WK0 and WK40.

2.2. Methods

For male or female progeny, variance analyses [14] have been made according to the model

$$Y_{ijk} = \mu + h_i + t_j + e_{ijk}$$

where Y_{ijk} is the body weight of the ijk duck, μ is the general mean, h_i is the batch effect (two levels), t_j the genotype effect (four levels), e_{ijk} is a random deviation with mean 0 and variance s_e^2. Least square means $\hat{t}_j$ were calculated and compared. The significance of the following contrasts between genotypic least square means calculated in each sex were tested:

$$C_1 = \frac{1}{2}[\overline{M \times M} + \overline{M \times P} - \overline{P \times M} - \overline{P \times P}]$$

$$C_2 = \frac{1}{2}[\overline{P \times M} - \overline{M \times P}]$$

$$C_3 = \frac{1}{2}[\overline{-M \times M} + \overline{M \times P} + \overline{P \times M} - \overline{P \times P}]$$

The expected means $E(\hat{t})$ can be expressed as a linear function of the crossbreeding genetic parameters [3] and as in Rouvier et al. [13]:

$$E(\hat{t}) = \mu + g^{\mathrm{I}} + g^{\mathrm{Is}} + g^{\mathrm{N}} + g^{\mathrm{W}} + h^{\mathrm{I}}$$

where μ is the general mean, g^{I}, g^{Is} are the direct genetic effects from Muscovy or Pekin, respectively, due to the autosomal or sex-linked genes, g^{N} are the reciprocal effects (measured as half of the difference between the average of the two reciprocal crosses) and h^{I} the direct heterosis effects. g^{W} are assumed direct effects of genes on the non-pseudo-autosomal part (NPAR) of the W chromosome.

$C_1 = g_{\mathrm{M}}^{\mathrm{I}} + g_{\mathrm{M}}^{\mathrm{Is}}$ (M for Muscovy), for male and female progeny,

$C_2 = g_{\mathrm{M}}^{\mathrm{N}}$ for male progeny,

$C_2 = g_{\mathrm{M}}^{\mathrm{N}} + \frac{1}{2}g_{\mathrm{P}}^{\mathrm{Is}} + g_{\mathrm{M}}^{\mathrm{W}}$ (P for Pekin), for female progeny,

$C_3 = h^{\mathrm{I}}$

with the usual conditions: $(g_{\mathrm{M}}^{\mathrm{I}} + g_{\mathrm{M}}^{\mathrm{Is}}) + (g_{\mathrm{P}}^{\mathrm{I}} + g_{\mathrm{P}}^{\mathrm{Is}}) = 0$; $g_{\mathrm{M}}^{\mathrm{N}} + g_{\mathrm{P}}^{\mathrm{N}} = 0$; $g_{\mathrm{M}}^{\mathrm{W}} + g_{\mathrm{P}}^{\mathrm{W}} = 0$.

3. RESULTS

Table I gives the least squares means ($\overline{x}$), the phenotypic standard deviations within batches (s) for male or female progeny of the four genotypes, the ratios R of male to female body weight averages (shown only when the male and female body weight averages are statistically different).

The between genotype differences in mean body weights were always significant, except at WK0. At WK4 the ranking of the means is P × P = P × M > M × P > M × M in the male progeny and P × P > M × P > P × M = M × M in the female progeny. From WK10, the ranking of the means of the male progeny was always M × M > M × P = P × M > P × P. It was not the same in the female progeny where M × P > M × M = P × P > P × M (WK10 and WK20) or M × P > M × M > P × P > P × M (WK16, WK30, WK40). The significant body weight sexual dimorphism, increasing with age, is observed only when the mother is the Muscovy.

Table II gives the values of the contrasts C_1, C_2, C_3, in male and female progeny. In both sexes the direct genetic effects (C_1) were in favour of Pekin at WK4, in favour of Muscovy later. Reciprocal effects (C_2) were not significant in the male progeny, except at WK4 and WK40 where they were in favour of the Muscovy dam. They were on the contrary, highly significant in favour of the Pekin dam in the female progeny. Heterosis effects (C_3) were negative in the male progeny from WK16, but they were not significant in the female progeny, except at WK4 and WK40 where they were negative.

4. DISCUSSION

Since Mott et al. [6] it has been well known that Muscovy and Pekin duck do not have the same chromosome complement. Denjean et al. [2] found that the karyotypes of the two genera are very similar and that the only differences involved chromosomes 3, 5, 7 and Z. These two duck genera can be reciprocally crossbred and give sterile progeny.

In both sexes of the progeny, the direct genetic effects for growth, from autosomal and sex-linked genes, were in favour of Pekin at WK4, and in favour of Muscovy from WK10 up to WK40. That is consistent with the finding that Pekin duck have maximum growth rate earlier than Muscovy ducks [16]. The body weight sexual dimorphism seems to depend on the Muscovy duck dam and not on the Pekin one. One possible explanation could involve a Z linkage if one supposes that the Pekin breed brings a fixed sex-linked gene with very unfavourable effect on growth (Z^P), and that on the contrary Muscovy is fixed for the sex-linked favourable allele (Z^M). Thus, males have the same genotype whatever the cross, whereas females carry different alleles, Z^M or Z^P, depending on the cross. Consequently, reciprocal effects are expected to be much more important in females than in males, which is indeed the case. But that does not explain why the P × M females (Z^PW^M) are much lighter than the P × P females (Z^PW^P) which have the same Z^P (but different W); and why M × P females (Z^MW^P) are much heavier than the M × M females (Z^MW^M) which have the same Z^M but different W; especially because also, from WK10, the direct genetic effects are in favour of the Muscovy, which explains

Table I. Body weight least square means ($\overline{x}$), phenotypic standard deviations (s) for males and females of the four genotypes, ratios R of male to female averages.

		Genotypes															
		M × M				M × P				P × M				P × P			
Trait	Sex	n	$\overline{x}$	s	R	n	$\overline{x}$	s	R	n	$\overline{x}$	s	R	n	$\overline{x}$	s	R
WK0	males	10	52.8	2.6		18	53.9	4.4		20	52.2	4.6		11	53.3	5.6	
	females	10	49.3	4.8		17	52.1	2.9		19	51.7	5.0		11	52.8	4.4	
WK4	males	22	915^{c}	106	1.19	31	960^{b}	114		34	$1\,024^{a}$	133	1.33	23	$1\,045^{a}$	92	
	females	18	769^{c}	68		28	906^{b}	103		30	769^{c}	118		19	$1\,013^{a}$	98	
WK10	males	22	$3\,550^{a}$	321	1.47	31	$2\,996^{b}$	221		34	$3\,045^{b}$	364	1.53	23	$2\,630^{c}$	232	1.07
	females	18	$2\,416^{b}$	221		28	$2\,892^{a}$	263		30	$1\,989^{c}$	178		19	$2\,469^{b}$	202	
WK16	males	22	$4\,918^{a}$	364	1.75	31	$3\,651^{b}$	236	1.06	34	$3\,609^{b}$	487	1.63	22	$3\,005^{c}$	254	1.11
	females	18	$2\,812^{b}$	234		28	$3\,437^{a}$	275		30	$2\,211^{d}$	338		19	$2\,712^{c}$	236	
WK20	males	22	$5\,323^{a}$	351	1.77	31	$3\,738^{b}$	316	1.07	34	$3\,723^{b}$	441	1.70	22	$2\,935^{c}$	275	
	females	18	$3\,004^{b}$	258		28	$3\,491^{a}$	310		29	$2\,190^{c}$	386		19	$2\,815^{b}$	215	
WK30	males	21	$5\,854^{a}$	436	1.84	31	$3\,892^{b}$	322	1.08	33	$3\,748^{b}$	472	1.57	21	$2\,765^{c}$	291	
	females	18	$3\,176^{b}$	234		28	$3\,609^{a}$	301		28	$2\,389^{d}$	506		19	$2\,802^{c}$	274	
WK40	males	10	$5\,808^{a}$	598	1.64	18	$3\,698^{c}$	317		20	$4\,062^{b}$	542	1.79	10	$2\,922^{d}$	508	
	females	10	$3\,534^{b}$	270		17	$3\,785^{a}$	402		17	$2\,275^{d}$	246		11	$2\,925^{c}$	277	

n: number of animals; M (Muscovy), P (Pekin), drake first, duck second. WK0, WK4, WK10, WK16, WK20, WK30, WK40: body weights, in *g* at birth, 4,10, 16, 20, 30 and 40 weeks of age. Different superscripts a, b, c, d, indicate that the means are statistically different ($P < 0.05$).

Table II. Crossbreeding genetic effects in male and female progeny.

Effects	Muscovy direct genetic effects (C1)		Reciprocal effects Muscovy / Pekin (C2)		Heterosis (C3)	
Sex	Males	Females	Males	Females	Males	Females
Trait:						
WK0	0.6	−1.6	−0.9	−0.2	0	0.8
WK4	−97**	−54**	40*	−64*	46	−37*
WK10	436**	424**	33	−444**	−26	−3
WK16	978**	662**	−3	−606**	−311**	58
WK20	1 202**	744**	19	−650**	−395**	74
WK30	1 616**	796**	−34	−622**	−463**	6
WK40	1 260**	1 060**	182*	−755**	−485**	−200*

Estimates from least square means. * significant $P < 0.05$; ** highly significant $P < 0.01$.

why in that period the M × P females are heavier than the P × P females, that the P × M females are lighter than the M × M females. This was not the case at WK4 where the direct genetic effects were in favour of Pekin.

In all cases it appears that a depressive effect on growth seems to be linked to the W chromosome of the Muscovy, relative to that of the Pekin. According to Fairfull [4] reciprocal effects in poultry are the result of sex-linked genes on the Z chromosome and maternal (confounded by effects of genes on the W chromosome in females and by effects of mitochondrial genes) effects. The reciprocal effects (C_2 term) in the male progeny can be interpreted as maternal effect, positive (WK4 and WK40) or non-significant (WK10 up to WK30). If we assume that the maternal effects do not depend on the sex of the progeny, the very high negative values of the reciprocal effects in the female progeny (order of magnitude of the direct genetic effects, reverse sign) could be attributed to joint effects $\frac{1}{2}g_{\mathrm{P}}^{\mathrm{Is}} + g_{\mathrm{M}}^{\mathrm{W}}$. Negative heterosis for body weight traits, as in the male progeny in our data, have been quoted by Fairfull [4] in duck crosses. The different results in the female progeny (heterosis not statistically different from zero from WK10 up to WK30) could be explained by the fact that the M × P females ($Z^M W^P$) are much heavier than the M × M females ($Z^M W^M$), even when the direct genetic effects are in favour of the Muscovy. W^P and W^M could act in the same way to explain why the P × P females are heavier than the P × M females, and so when P × P = M × M. An hypothesis which could explain all the results is that an unfavourable Muscovy dam effect on the growth of its progeny could be attributed to genes on the NPAR of the W chromosome. Recently, Bünger et al. [1] found a paternal contribution on the parent offspring correlation for body weight at 63 days of age in mice which could be attributed to the non-pseudo-autosomal part regions (NPAR) of the Y chromosome if they contain coding genes. Fairfull [4] indicated that some evidence suggested that genes on the W chromosome are responsible for maternal effects for body and egg weight in poultry. Recently, the finding of female-specific random amplified polymorphic DNA (RAPD) in different poultry species including Brown Tsaiya duck, Muscovy duck, Native chicken and Chinese geese [15], showed that the W chromosome could contain non-repetitive DNA sequences. Ogawara et al. [7] studied molecular characterization and cytological mapping of a non-repetitive DNA sequence region from the W chromosome of chicken which can be used as universal probe for sexing Carinatae birds. The existence of coding genes on the duck W chromosome could be suspected. As the F1 males between Muscovy and Pekin ducks are sterile, population genetics can not provide additional data on the effects of the W chromosome on sexual dimorphism, but progress in molecular genetics could provide new experimental tools in order to test for the hypothesis of the existence of coding genes for body weight on the NPAR of the W chromosome in these Mucovy and Pekin ducks.

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