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Heterosis and the Genetic Effects on Growth and Weights of Reproductive Organs in Two Strains of Mice

Masahiro SATOH*, Yutaka MIZUMA and Toshihiro YAMAGISHI

Department of Animal Science, Faculty of Agriculture, Tohoku University, Sendai 980, Japan
**National Institute of Animal Industry, Tsukuba Norindanchi, Ibaraki 305, Japan*

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Summary

Mice of two strains (ICR, ddY), their reciprocal cross F_1, backcross and F_2 were used to evaluate heterosis and genetic effects on growth and weight of reproductive organs. Mice were raised until day 17 after birth in a cage with their parents, and one male and one female progenies were selected at random from each cage. Their body weights were recorded at day 21, 28, 35, 42, 49 and 56. These mice were slaughtered at day 60 and body weight, body length, and weights of testes, epididymides and vesicular glands in the males and ovaries in the females were recorded, respectively.

Growth of the males was influenced by the average direct genetic effect ($P<0.01, 0.05$), ICR was heavier than ddY. In the growth of the females, there were maternal heterosis effect and recombination loss ($P<0.01, 0.05$). Body weights of males, and body lengths of males and females at day 60 were influenced by the strain of dam, respectively, and body lengths of males were influenced by the strain of sire, ICR was superior to ddY in each trait. Weights of epididymides and vesicular glands were influenced by the strain of sire and of dam, ICR organs were heavier than those of ddY. And heterosis was significant ($P<0.05$) on testes and epididymides weights, respectively.

Heterosis is widely used for improvement of reproductive traits in animal production, because heritabilities of these traits were low in general. On the other side, improvement of reproductive abilities were carried out by selection for weight or size of reproductive organ (1, 2). And there were some reports of heterosis on testicular and epididymal growth (3-6). It seems that the correlation between testis weight and body weight is high, but heterosis appears on traits more concerned with reproductive organs than body weight.

The purpose of this study was to estimate heterosis and the genetic effects on growth and weight of reproductive organs, and to examine relations between them

used by two prolific strains of mice.

Materials and Methods

Mice of two strains (ICR, ddY), which have large litter sizes, and their reciprocal cross F_1, backcross and F_2 were used in this experiment. Each strain and cross were raised until day 17 after birth in a cage with their parents, and one male and one female progenies were selected at random from each cage. Data were collected on 226 mice representing 133 litters. After weaning, about ten mice of the same sex were kept in the same cage. Body weight was recorded at day 21, 28, 35, 42, 49 and 56, respectively. Two strains and their reciprocal cross F_1 mice were slaughtered at day 60 and body weight, then body length, and weights of testes, epididymides and vesicular glands in males, and ovaries in females were recorded. The average of right and left weights in traits with each pair were used for analysis. Throughout this experiment, a commercial pellet feed and tap water were supplied. Temperature and humidity in the mouse room were 21 ± 1°C and 40 ± 5 per cent, respectively. The light regime was 12 hours of artificial illumination followed by 12 hours of darkness.

Data in this study were analyzed by procedures outlined by Harvey (7). The following model was used (8).

Body weights at day 21-56;

$$Y=\mu+G^I\cdot X_1+G^M\cdot X_2+G^{M'}\cdot X_3+H^I\cdot X_4+H^M\cdot X_5+R^I\cdot X_6+e$$

Body weight, length and weights of reproductive traits at day 60;

$$Y_{ijk}=\mu+S_i+D_j+(SD)_{ij}+e_{ijk}$$

where

Y_{ijk} = The measurement of the k th pair from the i th strain of sire and the j th strain of dam,
μ = the overall mean,
G^I = partial regression of traits on the average direct genetic effect,
G^M = the average maternal genetic effect,
$G^{M'}$ = the average grandmaternal genetic effect,
H^I = direct heterosis effect resulting from crossbred combinations,
H^M = maternal heterosis effect,
R^I = recombination loss,
X_1-X_3 = measures of line composition (recorded as proportion of ICR),
X_4-X_6 = corresponding measurements of breed heterozygosis setting values,
S_i = the effect of the i th strain of sire,
D_j = the effect of the j th strain of dam,
( ) = interaction (heterosis effect),
e = a random error with zero mean and variance, $\sigma_e{}^2$.

Results and Discussion

The analysis of variance of body weights at day 21-56 is presented in Table 1, and changes over weeks in the average direct genetic effect, direct heterosis, maternal heterosis and recombination loss of body weights are shown in Figure 1. The growth of males was influenced by the average direct genetic effect, ICR was heavier than ddY in body weight at day 20, 35, 42 and 56 ($P<0.01, 0.05$). Direct heterosis was very small in both males and females, and significant ($P<0.05$) only in males at day 35. Maternal heterosis and recombination loss were not observed at any age in the body weights of males, but in the weights of females, maternal heterosis were significant ($P<0.01, 0.05$) after day 35 and recombination loss were significant ($P<0.01, 0.05$) at day 21, 35, 42 and 56. It seems that direct heterosis effects on growth of these strains was not caused by both strains already having heavy weights. Maternal heterosis and recombination loss on the growth of females were observed bacause correlation coefficient between X_5 and X_6 was high, and these effects were estimated against one another. The effect of recombination

TABLE 1. *Mean Squares for Postweaning Growth (Body Weight)*

Item \ Day	21	28	35	42	49	56
Male						
Average genetic						
Individual	15.362	53.914*	84.066**	47.622*	19.869	59.190*
Maternal	1.630	1.235	0.012	1.805	10.674	13.301
Grand maternal	0.013	0.168	0.318	0.224	3.869	8.822
Heterosis						
Individual	7.438	8.652	40.921*	25.609	3.725	6.974
Maternal	7.043	4.325	4.516	1.281	13.687	15.435
Recombination loss	43.813**	40.266	13.666	0.001	1.552	0.812
Remainder	4.950	10.595	8.429	10.294	11.815	13.903
Female						
Average gentic						
Individual	3.205	1.215	0.987	4.521	8.226	17.017
Maternal	3.275	3.628	0.979	0.119	26.652	15.872
Grand maternal	4.772	0.923	0.062	6.528	37.707*	15.709
Heterosis						
Individual	4.244	13.156	6.901	2.461	5.223	2.329
Maternal	4.740	18.049	47.314*	76.092**	41.277*	179.714**
Recombination loss	30.253*	32.977	38.508*	67.039**	32.419	173.029**
Remainder	4.772	9.055	8.897	9.477	7.039	13.245

* Significant $P<0.05$

** Significant $P<0.01$

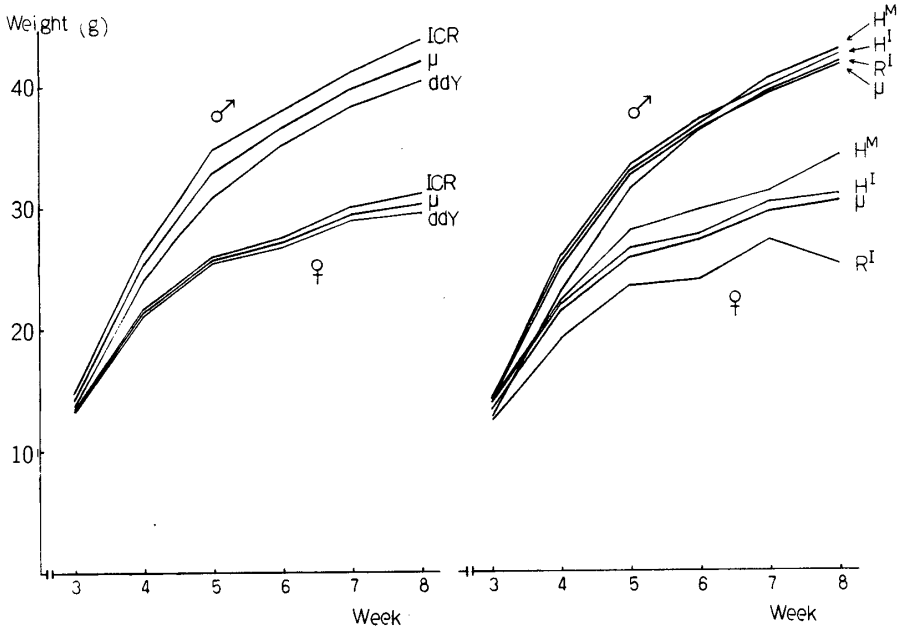

FIG. 1. Changes over weeks in the average direct genetic effect (the left side), direct heterosis [H^I], maternal heterosis [H^M] and recombination loss [R^I] (the right side) of body weights. μ are the overall mean.

loss in chickens was reported by Sheridan (9). Therefore, there was some possibility that recombination loss in body weight was caused by crossing these two strains of mice.

The analysis of variance, and least-squares means in body weight, body length and weight of reproductive organs at day 60 are shown in Table 2 and Figure 2, respectively. ICR was superior to ddY in the effect of strain of sire and dam on body weight and body length. And the heterosis effect on body weight was not singnificant in days 21-56 except day 35 in the male. ICR was heavier than ddY in the effect of strain of sire and dam on weight of testes and epididymides. And weights of testes and epididymides were significantly ($P<0.05$) influenced by heterosis effect. But heterosis was of no significance in the

TABLE 2. *Mean Squares for Body Weight and Length, and Weights of Reproductive Organs at Day 60*

Source	Body weight		Body length		Testes	Epididymides	Vesicular glands	Ovaries
	Male	Female	Male	Female				
Sires (S)	43.41*	5.74	0.503*	0.295	2.16E-4	1.81E-4**	99.42E-4**	0.004E-4
Dams (D)	54.08*	39.90	0.614*	1.448**	0.01E-4	1.40E-4*	36.86E-4*	0.00E-4
S×D	4.99	0.01	0.083	0.240	10.12E-4*	1.42E-4*	0.09E-4	0.00E-4
Remainder	11.45	11.25	0.109	0.134	2.09E-4	0.22E-4	7.52E-4	0.00E-4

* Significant $P<0.05$
** Significant $P<0.01$

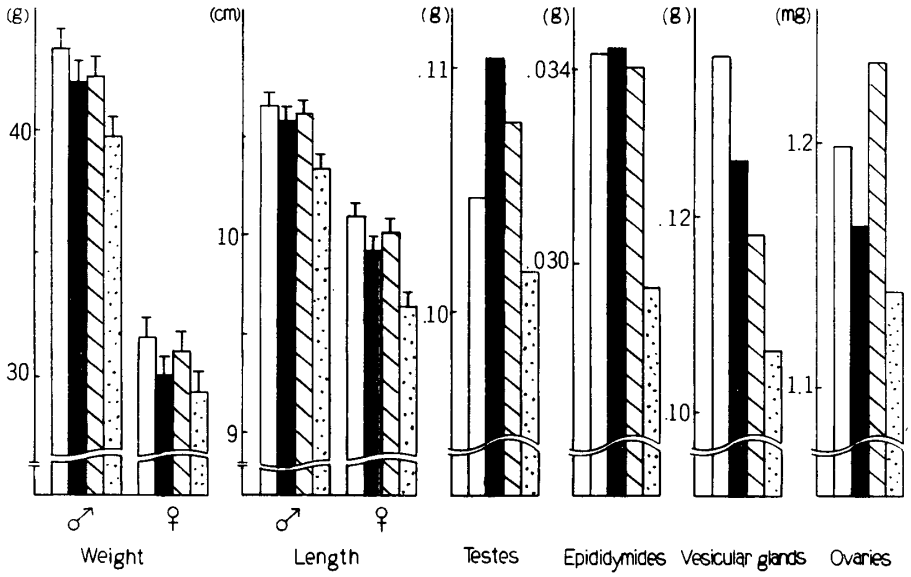

FIG. 2. Least-squares means in body weight, body length and weight of reproductive organs at day 60. ICR (♂)×ICR (♀): □; ICR (♂)×ddY (♀): ■; ddY (♂)×ICR (♀): ▨; ddY (♂)×ddY (♀): ▩.

weights of vesicular glands and ovaries. Some studies in heterosis on testes weight of boars were done. Hauser *et al.* (5) and Neely *et al.* (6) reported that crossbred boars exceeded the parental lines on the weight of testes and epididymal organs. And Wilson *et al.* (10) showed that crossbred boars exceeded the parental lines in several testicular and epididymal traits, conception rate, embroyo number and libido. In mice, Johnson and Eisen (11) found heterosis on testicular and epididymal organs. In the present study, the results of heterosis on weight of testes and epididymal organs were consistent with the above. Land (12) reported that the correlation between testis weight and natural ovulation rate is 0.97 in

TABLE 3. *Correlation Coefficients among Body Weight, Length and Weights of Reproductive Organs*

Male	B.W.	B.L.	T.W.	E.W.
Body weight				
Body length	0.498			
Testes weight	0.311	0.357		
Epididymides weight	0.272	0.339	0.704	
Vesicular glands weight	0.120	0.187	0.122	0.366
Female	**B.W.**	**B.L.**		
Body weight				
Body length	0.373			
Ovaries weight	0.150	−0.013		

mice. The testes of F_1 mice being heavier than those of parental strains may be related to having more litters by heterosis.

The correlations among weight and length of body and weight of reproductive organs are shown in Table 3. The correlation coefficients were low among all of the traits. Hauser *et al.* (5) suggested that testicular development was associated with body weight. Neely *et al.* (6) reported that adjustment of testes weight for body weight tended to reduce the heterosis values, but crossbred boars still showed heavier testes weights. The results of this study suggest that heterosis in these testicular organs is due to some physiological mechanism in addition to body weight.

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