SELECTION FOR LITTER SIZE AND BODY WEIGHT IN MINK *(Mustela vison).*
Reciprocal crossings

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SUMMARY

During a five-generation selection experiment, in which litter size at 3 wk (F line) and September weight (BS line) were selected for, reciprocal crossings between lines were performed in Generations 3 and 4 (1987 and 1988) and after terminating the experiment (1990). Furthermore, one line was subjected to combined selection for litter size and body weight (I line), and a randomly mated control was maintained. In 1987 and 1988, only 2-yr-old animals from the F and BS lines were used for crossings, but in 1990 both yearlings and 2-yr-old animals were crossed. Crossings using F females gave the best reproductive result. The reproductive output of separate selection followed by crossing greatly exceeded that of the I line. The BS females seemed to have a poor maternal ability that concealed any expression of kit heterosis. Body size was also improved by crossing. The results indicate that crossings should be performed with yearling females to maximize reproductive output.

INTRODUCTION

To study selection response and correlated responses, a five-generation selection experiment with standard mink was carried out (Lagerkvist et al. 1993, 1994). Selection of males and females started in autumn 1984 and 1985, respectively. The last generation (Generation 5) was born in 1989. From a common base population, separate and closed lines were formed and subjected to selection for litter size at 3 wk (F line), body weight in September (BS), underfur density (P) and combined selection for litter size and body weight (I). One unselected line served as a control (C). The present report focuses on reciprocal crossings between the F and BS lines, carried out in 1987 and 1988, and in 1990.

MATERIALS AND METHODS

Each selection line consisted of 80 breeding females, except for the I line which included 160 females. The generation interval was set to 1 yr in all lines but the control: in 1986 all females in this line giving birth as yearlings were allowed to have a second litter (n=69).

Reproductive traits. In 1987 and 1988, 40 2-yr-old females each from the F and BS lines were used for reciprocal crossings (F*BS cross and BS*F cross, respectively). In 1990, the groups consisted of approximately 40 yearlings and 20 2-yr-old females, i.e. F, BS and the two reciprocal crosses. Unfortunately, in the BS and BS*F groups many females did not mate and had to be excluded (Table 1). Yearling females were mated 1+9 i.e., they were given a chance to remate on d 9, and matings started on March 7. The 2-yr-old females were mated 1+1, matings started on March 17.

Body Size Traits. Kits in a sample of the population were weighed close to birth and at 3 and 6 wk of age. All kits were weighed on approximately September 20. In all recordings performed after this weighing, data were collected from males only.

Histological study and blood sampling. Ten yearling females each from the F and BS lines were sacrificed on April 1, 1991. Ovaries were removed and corpora lutea (CL) were counted microscopically. Blood was collected by heart puncture at the time of killing and analysed for estradiol-17ß and progesterone (Jones and Madej, 1988; Tauson et al. 1988).

Table 1. No. litters and records in each line and reciprocal crossings (1990)

line/crossing a)	female age 1 yr	2 yr	Kit wt day 0	3 wk	6 wk	Sept	Pelting
F	50	-	115	173	150	204	102
		22	60	109	79	113	55
F*BS	43	-	178	127	89	128	55
		18	96	112	80	114	60
BS*F	27	-	91	52	26	60	24
		12	28	20	37	51	21
BS	36	-	54	33	30	43	28
		12	27	28	31	54	22

a) F = Selected for litter size at 3wk, BS = September weight, F*BS= F females mated to BS males, and BS*F the reciprocal crossing.

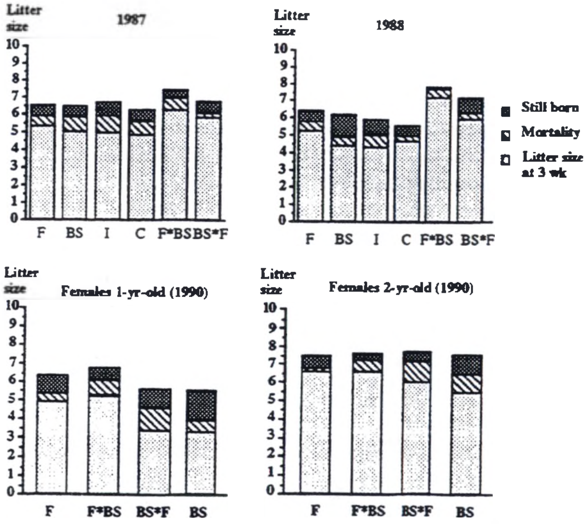

Figure 1. Litter size and kit mortality in single lines and reciprocal crossings, in 1987,1988 and 1990. F = litter size at 3 wk, BS = September weight, I = combined selection for litter size and Sept. wt, C = control, F*BS and BS*F = reciprocal crossings of F and BS (females 2-yr-old).

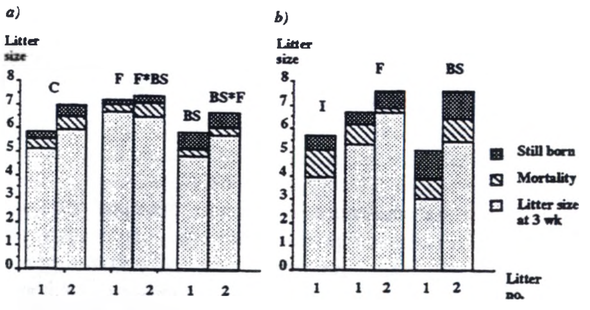

Figure 2 a. Litter size and kit mortality in control, F and BS females first and second litters.The F and BS females were used in reciprocal crossings in the 2nd year.
b. I females first litter (1989) and F and BS females first and second litters (1989 and 1990).

RESULTS

Reproductive Performance. Figure 1 shows the reproductive result for the individual lines and 2-yr-old reciprocal crossings in 1987 and 1988. The effects of crossing could not be distinguished from that of female age. The F*BS cross gave the superior result, in terms of litter size, barren females, stillborn kits and lost litters.

In 1990, crossings were performed within age category. Extremely high empty rates were observed in all yearlings, except those in the F-line. Maternal ability and survival of the kits were poor for yearlings in the heavy lines (BS and BS*F). Stillborn kits were more common in the BS line, whereas they tended to die after birth in the BS*F cross (Figure 1). In the 2-yr-old females, the total number of kits born differed little between lines/crosses, but the maternal ability and (or) fitness of the kits was clearly best in the F- and F*BS groups. In both crosses, the rate of stillborn kits seemed to decrease and, conversely, the number of kits lost after birth increased. This may indicate an improved health of the kits, in terms of "surviving birth". The effects of crossing on litter size, calculated as the deviations between means of all combinations, are given in Table 2.

Effect of female age. It is sometimes argued that the difference in reproductive performance between yearlings and 2-yr-old females is mainly an effect of selection and does not represent a biological difference (i.e. it is not the litters of the same females that are being recorded and compared). Figure 2 compares the reproductive performance of females during their first and second reproductive seasons. The differences in C females total born, live born and kits at 3 wk were significant ($P < .01$).

Body Size. Kit weights from BS*F were higher than F*BS weights, as would be expected because early kit weights are

Table 2. Differences in litter size between lines and crosses in 1990, within age category. (TB = total born, LB = live born, T3W = at 3 wk)

Comparison/ trait	Line/cross and age of female F 1-yr-old	F 2-yr-old	BS 1-yr-old	BS 2-yr-old	BS*F 1-yr-old	BS*F 2-yr-old
F*BS						
TB	.6	.1	1.2	.1	1.1	.1
LB	.9	.4	1.2	.8	1.5 *	.4
T3W	.5	0	2.0 **	1.2	1.5 *	.7
BS*F						
TB	- .5	0	.1	0		
LB	- 1.3	.2	.7	.6		
T3W	- 1.4 *	- .7	.1	.5		
BS						
TB	.6	0				
LB	1.3 *	.2				
T3W	1.5 *	.7				

* P < .05; ** P < .01.

Table 3. Effects of crossing on male kit weights and body size traits, in terms of deviations from the average of single lines, 1990

Age category trait	Average of F and BS lines	Deviations of crosses F*BS	BS*F
Yearlings			
Birth wt, g	8.6	.2	- .2
3 wk wt, g	116	- 6	5
6 wk wt, g	360	- 29	-45
September wt, g	2,023	13	45
Pelting wt, g	2,422	110	89
Body length, cm	45.3	.5	- .1
Skin length, cm	77.1	.7	.1
Females 2 yr			
Birth wt, g	9.0	.2	- 1.9
3 wk wt, g	132	- 8	- 11
6 wk wt, g	381	3	44
September wt.g	2,056	22	73
Pelting wt, g	2,550	63	180
Body length, cm	45.8	.1	.4
Skin length, cm	77.9	.9	1.1

influenced by female weight and litter size. Table 3 presents weights in terms of deviations of crosses from the average weights of the F and BS lines. This comparison could not be made for reproductive traits becauce the sire has little direct effect on female fertility. The F*BS kits had significantly higher pelting weights than the F kits (P < .05) of 2-yr-old females.

No C L and Concentrations of Estradiol-17ß and Progesterone. Table 4 presents average ovulation rates and hormone concentrations. The point in time at which animals were killed coincided approximately with implantation, when concentrations of estradiol are known to increase (Lagerkvist et al., 1992). Progesterone generally starts to increase around the vernal equinox and reaches its maximum in mid-April.

DISCUSSION

Positive effects of crossing were observed in this study. The higher total number of kits born was most likely a result of an increased pre- and postnatal viability of the kits, i.e. reduced losses during gestation. Ovulation rate should not be a limiting factor for litter size as long as the ova shed are normal. The mink exhibits an obligatory period of delayed implantation. Under the influence of prolactin, the corpora lutea are acti-

Table 4. Average number of corpora lutea (CL) and concentrations of estradiol-17ß (E2) and progesterone (P). Ten females each from the F and BS lines, April 1 1991

Selection line	No. of CL left ovary Mean	left ovary Range	right ovary Mean	right ovary Range	total Mean	total Range	E2, pmol/l Mean	E2, pmol/l Range	P nmol/l Mean	P nmol/l Range
F	11.0	3 - 15	9.3	4 - 16	20.3	13 - 30	88	50 - 124	83	27 - 146
BS	8.9	7 - 14	10.5	2 - 17	19.4	11 - 27	74	54 - 91	74	31 - 132

vated, and secrete large amounts of progesterone, in addition to an unknown luteal factor, both of which are required for implantation (Murphy et al., 1983). High ovulation rates may promote survival of the embryos and implantation. Bradford and Nott (1969) suggested that embryonic survival, particularly at the pre-implantation stage, exhibits more heterosis than ovulation rate. In mice, it has been demonstrated that crossbreeding the dam rather than the litter improved fertility (Bowman and Falconer, 1960; Roberts, 1960). There was a tendency for ovulation rates and hormone concentrations to be higher in the F line, but also the BS line had a higher average number of ovulations than earlier reported for mink, (Lagerkvist et al. 1992).

Land (1970) concluded that there is a consistent positive genetic relationship between body weight and ovulation rate, whereas body weight seems to be negatively correlated with embryonic survival.

Becauce selection was performed in yearlings, it was expected to find the largest differences in these. There is reason to regard yearling and adult reproductive performance as different traits (i.e., to some degree controlled by different gene systems). Interactions between female age and reproductive parameters were demonstrated earlier by Elofson et al. (1989) and Tauson (1991).

Crossing resulted in a smaller weight increase compared with combined selection for both traits (I line), which may be preferable owing to the adverse effects of weight on fertility and fur traits. The progress of selection for both traits simultanously was counteracted by a negative correlation between them. (Lagerkvist et al., 1993, 1994).

Reciprocal crossings between lines selected for litter size and September weight resulted in an improved reproductive performance in the F females. The BS females have a poor maternal ability that prevents the expression of kit heterosis. The most pronounced positive effects on reproduction were observed in yearlings. Breeding systems employing backcrossing or three-line crossing, in order to take advantage of and evaluate the effects of maternal heterosis, should be given high priority in future research.

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