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Genetic Analysis of the Thoroughbred Population in Japan

6. Some demographic parameters

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The authors have studied the genetic structure of the Thoroughbred population in Japan in reports 1–5. This time we represent information about some demographic parameters, particularly those with an inherited tendency.

Material Used

Investigation table for breeding and newborn of the light breed horse.
Reproduction records in the private stock farm.

Result and Discussion

Migration rate

Migration rate is the one in which the genes are supplied from the outside population to the gene pool of the population in question during a certain period. Namely, it is a ratio of the number of newborn from foreign-bred stock to that of all the newborn. In expectation of high priced sales, so-called market breeding, and of nicking by outbreeding, it is easily assumed that the newborn by foreign-bred stallion are mainly kept, as indicated in papers 1 and 2. Migration rate through the stallions is 0.850 on an average, and through the mares is 0.130 on an average (Table 1). Breeding tends to be concentrated to the foreign-bred stallion which has high market value. For mares, due to such factors as investment and foreign resources the migration rate is not so high. But because of the shortage of superior home-bred resources and of avoidance of inbreeding it is assumed that the importation of mares will be increased

Table 1 Migration Rate

	Stallion	Mare
1966	0.791	0.169
1967	0.804	0.175
1968	0.788	0.158
1969	0.815	0.136
1970	0.839	0.124
1971	0.873	0.118
1972	0.893	0.084
1973	0.897	0.098
1974	0.875	0.114
1975	0.900	0.107
1976	0.864	0.134
1977	0.856	0.133
Mean	0.850	0.130

year by year. The number of breeding mares and stallions are tabulated in table 2, 3. It is clearly seen that the importation of both stallions and mares tends to increase year by year, especially from liberalization in 1971 although not so recently. Generation length.

The source of data used was the list of the yearlings. The first yearling in each page in 1969 was taken. Size of sample is 243 males and 265 females. The mean birth dates were calculated, thus allowing the estimation of the four paths of the generation interval. The mean of these is the effective generation length, Where this is defined as the average age of parents at the birth of their offspring. The effective generation length and the four components of the parent-offspring interval are

Table 2 Imported stallions

	1952	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77
United Kingdom	1	1	1	5		1	3	1	6	5	7	2	6	6	8	10	13	20	12	16	13	13	6	16	7	4
France	1			1		1	1	2	1	3	1	4	3	2	2	3	6	7	6	7	11	8	3	4	3	1
Italy										1	1		1					1	1	1		1				
U. S. A.	2	3											4	1		4	5	1	1	7	16	17	9	12	5	4
Argentina	1																					1				
Australia														1						1						
New Zealand														1	1				1		1					
Canada																						2	1			
Germany																						1				
Total	5	4	1	6		2	4	3	7	9	9	6	14	11	11	17	24	29	21	32	41	44	19	32	15	9

Table 3 Imported makes

	1952	'53	'54	'55	'56	'57	'58	'59	'60	'61	'62	'63	'64	'65	'66	'67	'68	'69	'70	'71	'72	'73	'74	'75	'76	'77
United Kingdom		5	18	8	6	12	3		11	54	62	19	46	61	73	63	33	96	28	44	109	181	79	25	19	1
France			2		1	1	1		1	4	5	13	13	16	14	4	7	5	3	14	57	23	43	17	8	1
Italy											1		3	1	3	1	1	1	2		3	1				
Germany														1					1		1		2			
Belgium																	1									
U. S. A	5	9			2						2	1	6	13	26	3	7	6	3	38	45	111	78	44	27	5
Argentina												9										1				
Swiss																					1					
Urgai																				1						
Australia	1	13			7				2	1		3	4	3	6	1		3	1	25	17	8	27			
New Zealand	6	4							4		4		1	12	19	7		2	3	47	38	31	3			
Canada																						3	2			
Peru																						1				
Total	12	31	20	8	16	13	4		18	59	74	45	73	107	141	79	49	113	41	169	271	361	234	86	54	7
Foaling Number	412	456	554	660	727	817	941	1031	1115	1237	1491	1767	2013	2165	2260	2617	3021	3746	4389	5065	5595	6137	7297	8113	8490	7968

Table 4 The parent-off spring intervals and average genertion length

Parent-offspring relationship	Interval(years)
Sire-son	11.27
Sire-daughter	11.71
Dam-son	14.95
Dam-daughter	14.13

Table 5 The differences between the parent-offspring intervals (years)

Sire-son and sire-daughter	Dam-son and dam-daughter	Sire-son and dam-son	Sire-daughter and dam-daughter
0.44	2.86	3.68	2.42
non-sign	sign	sign	sign

shown in Table 4. Table 5 shows the differences between the various parent-offspring intervals and their significance. The sires of colts are significantly younger than their mates, and the sires of fillies are significantly younger than their mates. That is, on the average, stallions used are younger than their mates. The differences between the stallion-son and stallion-daughter intervals are not significant. Effective population size.

Effective population size (N) is estimated by Nozawa's formula.

$$N = 4(\Sigma kmi)^2 / \Sigma k^2 mi = 4Nmdm$$

Nm: number of stallions ith stallion leaving kmi offspring

dm: coefficient of diversity grade of individual difference among stallions as to the number of offspring

The source of data used was the investigation table for breeding and the newborn of the light breed stallion from 1966 to 1970. Effective population size per year, obtained the above formula, as well as the number of stallions and coefficient of diversity are shown in Table 6. The effective population size tends to increase year by year. From the effective population size per year is estimated that per generation. Average generation length of stallions is 11.49 years, those of mares is 14.54 years and the average of both is 13.02 years as shown previously. Average number of years of use of stallions as sires is 9.03 years, calculated from the means of 189 stallions. Accordingly, replacing rate of stallions per generation is $13.02/9.03 = 1.44$. This is multiplied by the average effective population size 450. It is assumed that

Table 6 Effective size

Year	Sire Nm	Mare Nf	Coefficient of diversity dm	Effective size
1966	171	3630	0.524	358.42
1967	191	4471	0.524	400.34
1968	206	5329	0.523	430.95
1969	240	6419	0.545	523.20
1970	267	7290	0.512	546.82

approximately 648 is a estimate of effective population size among one generation. The average age for breeding use is 6.03 years in stallion and 5.51 years in mares. It is seen that they become breeding stock at a young age. Foaling results from 1966 to 1975 were investigated.

Conception rate is 68.80% on an average (62.00%~73.15%). The moderate conception rate in Thoroughbred may have several causes. In order to have increase race-horse production, breeding seasons are gradually shortened which is contrary to natural conditions. Many mares which have poor breeding records are kept with a expection of the quality of their foals. Some of the hormon therapy may be mistaken. Generally in animals the more domestication, the more problems that are encountered reproduction with. In Thoroughbreds, selection has not been for reproduction but for speed.

The sex in the case of death directly after birth, abortion, early parturition and death parturition is not known, so the sex ratio can not be calculated. Colts are more often reared than fillies in general. The cause of death directly after birth is not clear. Some death may be caused by newborn icterus but it seems that there is no death by lethal genes. In early stages of breed origin in Thoroughbred, intense inbreeding might have been practiced, but concurrently intense selection by performance and culling of defective genes seem to have been practiced. Moreover, recently avoidance of inbreeding has been practiced. It is assumed that genetic defects may rarely appear. Accordingly the amount of genetic load seems to be very low. In general, fertility is a lowly heritable trait in all farm mammals, and horses are no exception.

Gestation length

The records analyzed were taken from a private stock farm and cover the period from 1958 to 1971. There are 358 recorded gestation length associated with

Table 7 Analysis of variance of gestation length according to sire

Source of variation	Degree of freedom	Mean square	Expected value of mean square	Variance component
Total	357	71.88		
Sires	12	94.75	25.42S+W	0.93
within sires	345	71.08	W	71.08
				$h^2=0.07$

Table 8 Average gestation length according to sex and season of breeding

Month of breeding	Sex of foal			
	Male		Female	
	k	x	k	x
Feburary-March	25	340.08	38	335.29
April-May	105	340.10	113	338.01
June-July	29	336.31	48	333.10

Table 9 Analysis of variance of gestation length for sex and season of breeding

Source of variation	Degree of freedom	Sum of squares	Mean square
Sex	1	17.04	17.04※※
Season of breeding	2	19.86	7.93※※
Season × Sex	2	1.77	0.89
Error	352		1.50

single live birth resulting from the matings of 13 stallions with 109 mares. The estimation of heritability was used by the analysis of variance for half-sibs. The mating structure of the herd afforded data that could be grouped as paternal half -sibs. The inter-sire difference occurring in the gestation length is estimated as 5% by neglecting epistatic gene effect (Table 7). This value is comparable to that in our previous paper (1957). The pregnancy durations were classified by the three breeding seasons and the sex of foal (Table 8). The season of breeding and the sex of foal constitutes a important source of the gestation length. Foals born in April-May were carried longest. The mean value for male birth is 338.83 days and for the female births is 335.47 days.

Summary

Importation of stallions has been increased year by year after the war. This trend is infered from migration rate up to 1975. Migration rate of mares has

decreased till 1972 in opposition. The former average is 0.850 and the latter average is 0.130. Average generation length is 11.49 years in stallions and 14.54 years is mares. Effective population size has been increased year by year and the mean is 451.95. Fertility seems to be lowly heritable. Gestation lengths do not vary by stallion and the heritability is very low (0.07). Gestation length is significantly longest in April-May breeding months. The mean gestation length for the male is 338.83 days, which is significantly 3.36 days longer than for the female.

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わが国におけるサラブレッド集団の遺伝分析

6. いくつかの集団動静母数

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種雄馬の輸入は戦後毎年，特に１９７１年の自由化以来１９７５年迄増加しており，この傾向は移入率からも推定できる。繁殖雌馬の移入率は逆に1972年迄減少し，その後やや増加している。前者の平均は0.850で，後者のそれは0.130である。世代の長さは，種雄馬では平均11.49年で，繁殖雌馬で14.54年である。

集団の有効な大きさは毎年増加しており，平均451.95である。受胎率は余り高くなく平均75.16%であり，繁殖性の遺伝力は低いようである。妊娠期間は種雄馬によって変動がなく，遺伝力は極めて低く0.07である。妊娠期間は4～5月繁殖季のものは有意に最も長い。

雄仔の妊娠期間は338.83日で，雌仔に対するよりも有意に3.36日長い。