STUDY ON MATING SYSTEMS FOR CONTROLLING INBREEDING LEVELS IN DOMESTIC ANIMAL POPULATIONS WITH OVERLAPPING GENERATIONS

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SUMMARY

Using a simulation model on inbreeding in small populations with overlapping generations, 2 mating methods (age—mating, AM; parentage—mating, PM) and 4 single trait selection methods (family—selection, FS; age—selection, AS; inbreeding—selection, IS; and parentage—selection, PS) proposed by us previously, 6 two—trait selection index (FAS, FIS, FPS, AIS, APS, IPS) and 1 three—trait selection index (AIPS) composed of the 4 single trait selection are developed and their effects on inbreeding in a conservation population of Qinchuan Cattle in 200 years are studied. Each trait in every index is weighed by the inverse of its population average. Results show that, under random mating(RM), AIPS had the biggest inbreeding control effect. Compared with random selection (RS), AIS, APS, and IPS could decrease the average inbreeding coefficient of populations conserved for 200 years by 37% plus. Of the 36 mating systems studied, the lowest inbreeding is observed in populations by AIS, APS or IPS under age—mating. No matter for short—term or long—term conservation purposes, AIS: AM has the best inbreeding controlling effect.

INTRODUCTION

Though several conservation methods are available (Bodo, 1990), the ordinary one in practice now and in the near future is to manage genetic variability in some small living populations. A lot of studies have been done on this topic. Some more conservation—oriented studies are by Bodo (1987), Maijala et al. (1984), Smith (1984), Simon (1984), Rochambeau (1985). Using a simulation model, Yamada (1980) explored the effect of subdivision and mating systems on loss of genes and inbreeding coefficient. However, most studies on conservation assume populations with discrete generations. In fact domestic animals are generally in overlapping generations in practice. Relative to populations of the same size with just one age class, inbreeding and genetic drift are delayed in populations with several age classes (Choy and Weir, 1978). Formulae for effective number (Ne) and for predicting inbreeding coefficient have been derived for ideal populations by Hill (1972), Johnson (1977). However in practice, the ideal situation is seldom found and these formulae can only be used as a coarse guide. Rochambeau and Chevalet (1985) proposed a simulation model in small populations taking into acount of the usual breeding constraits: age—specific birth and death rates, subdivision et al. They suggest to select individuals by an index which is the inverse of the product of frequencies of all alleles carried by the individuals. This selection could delay the decrease of genetic variability. It, however, is on the premise that individual genotypes are known, which is diffcult or even impossible in practice. Wang (1992) proposed a simulation model for small populations with overlapping generations of Qinchuan Cattle. Using the model the effects of all evolutionary factors and particularly, of age structure and mating systems on inbreeding and genetic drift are studied (Wang et al., 1991; Wang and Qiu, 1993) and the results are partly verified by the analysis on the practical conservation results (Wang et al., 1992a, 1992b, 1993). In the present paper, different combinations of 2 or 3 of the four simple selection methods proposed previously by us will be utilized to construct various selection indexes and their effects on inbreeding be evaluated under different mating methods.

MATERIALS AND METHODS

Pedigree records of the Qinchuan Cattle conservation population from 1965 to 1990 in Qinchuan Cattle Farm of Shanxi Province are utilized to make demographic analysis.

Using the expanded Leslie matrix plus an artificial control vector, a dynamic matrix model describing the development of size, age and sex structure can be got as the following

$$N_{t+1} = LN_t + C$$

where N_{t+1} and N_t are population structures at time t+1 and t (usually year is used as time unit). L is expanded Leslie matrix, C is a vector used to control structure and development of the population. If we assume that males of age i and females of age j are culled by C_m^i and C_f^j respctively, then we get

$$C' = (C_m^1\, C_m^2 \cdots C_m^i \cdots C_m^m\, C_f^1\, C_f^2 \cdots C_f^j \cdots C_f^f),$$

where superscripts m and f represent maximum in herd time (years) of male and female individuals. Generally, conservation population should be kept in stable size and structure. Letting $N_{t+1} = N_t$, we get

$$N = LN - C.$$

The 3 mating methods are random mating, age—mating (AM, assortative mating with respect to age) and parentage—mating (PM, mating scheme is determined with the objective function of average coancestry of all possible mating pairs to be minimized).

The 5 single trait selection methods are random selection (RM), family—selection (FS, truncation selection on the average of paternal and maternal family sizes), age—selection (AS, truncation selection on average age of parents), inbreeding—selection (IS, truncation selection on indivdual's inbreeding coefficient) and parentage—selection (PS, truncation selection on the average coancestry of an individual with the others in the population).

From the last 4 selection methods, 6 two—trait selection index (FAS, FIS, FPS, AIS, APS, IPS) and 1 three—trait selection index (AIPS) can be constructed, each trait in every index being weighed by the inverse of its population mean. So a total number of 36 mating systems are obtained considering the 5 simple selections and the 7 index selections combined with the 3 mating methods.

In the simulation model, the population is assumed to be composed of 30 breeding sires and 100 cows; the size and structure and demographic parameters are kept stable. Inbreeding coefficient of and coancestry between individuals of generation zero are zero. For each mating system, a simulation is run for 200 years and 5 replicates to simulate the changes of inbreeding coefficient, which is calculated iteratively from coancestry (Falconer, 1981).

RESULTS AND DISCUSSION

1. Selections under random mating

The effect on inbreeding of the 12 selection schemes under random mating is shown in Table 1. Compared with RS, all the four simple selections have certain effect in controlling inbreeding. The average inbreeding coefficient of population conserved for 200 years (denoted as F_{200}) under IS and PS is decreased by 31% and 37% respectively compared with RS. Among the 6 two—trait indexes, the 3 indexes containing family selection (FAS, FIS, FPS) are lest effective. For all the conservation period of 200 years, the three—trait index (AIPS) has the largest effect; F_{200} is decreased by 43% compared with RS.

Based on a derivation of Latter (1959), Hill (1972) has given a formula for a population with separate sex for constant size and structure.

$$1/Ne = [2+\sigma^2_{mm}+(2M/F)Cov(mm,mf)+(M/F)^2\sigma^2_{mf}]/(16ML)$$
$$+[2+\sigma^2_{ff}+(2F/M)Cov(fm,ff)+(F/M)^2\sigma^2_{fm}]/(16FL)$$

where M and F are the numbers of male and female that reach adult age each year, L is generation interval. This formula is very useful to study the effects of generation interval, variances and covariances of family size in ideal populations with overlapping generations. We know, however, effective size can only be used to predict inbreeding when a steady state of the rate of inbreeding is reached. For the first generations, the changes in inbreeding are somewhat erratic and large bias may result in the prediction by effective size. It is clear from Table 1 that FS decreases the variances and covariance of family size for male parent; it, however, also decreases generation interval compared with RS. The effect of AS is just opposite to that of FS. Among the 7 index selections, schemes combining AS with IS or PS (schemes AIS, APS and AIPS) have the largest effect in controlling inbreeding, which is realized through prolonged generation interval with little changes in variance and covariance terms (compared with RS).

Table 1. Simulation results of inbreeding coefficient, generation interval and variances and covariance of family size for random bred populations under various selection schemes

Selec. scheme	Inb. coe. × 10000 in year 50	100	150	200	GI** (year)	Variance and covariance of family size σ^2_{mm}	σ^2_{mf}	Cov(mm,mf)	σ^2_{fm}	σ^2_{ff}	Cov(fm,ff)*
RS	381	940	1408	1892	6.97	1.15	3.63	0.52	0.44	1.23	0.10
FS	305	826	1219	1644	6.34	0.64	1.31	0.52	0.37	0.96	0.06
AS	340	890	1289	1690	8.44	1.99	6.23	1.91	0.43	1.27	0.11
IS	191	580	972	1350	7.67	1.42	4.16	0.85	0.52	1.47	0.22
PS	274	582	933	1194	6.99	0.57	2.14	0.52	0.41	1.30	0.10
FAS	257	627	950	1289	7.24	0.57	1.15	0.19	0.38	1.06	0.01
FIS	195	613	1030	1408	6.33	0.45	0.94	0.29	0.39	0.99	0.02
FPS	302	718	1084	1502	6.23	0.36	0.80	0.25	0.39	0.98	0.02
AIS	104	460	795	1122	9.13	1.34	4.33	1.46	0.51	1.53	0.23
APS	228	515	789	1109	9.41	1.26	4.20	1.43	0.53	1.52	0.23
IPS	111	458	797	1110	7.49	1.12	3.02	0.62	0.48	1.40	0.17
AIPS	93	441	756	1072	9.03	1.28	4.17	1.23	0.53	1.55	0.25

* σ^2_{mm}, σ^2_{mf} and Cov (mm,mf) represent variances and covariance in the numbers of male and female progeny for male parent; σ^2_{fm} σ^2_{ff} and Cov (fm,ff) are corresponding quantities for female parent.

* * GI: Generation interval.

2. Selections under age—mating

The results are shown in Table 2. Under age—mating, AS increases generation interval by 4 years compared with RS. Thus the conservation period of 200 years is equivalent to about 18 generations for AS, 10 generations less than that for RS. Thus, in spite of the concominant increament in variances and covariance of family size for male parent, the selection scheme is the most efficient one of the four simple selection methods. F_{200} is decreased by 37% for AS compared with RS. It can be predicted that the longer the conservation period, the larger the effect of AS. The effects of FS are just opposite to those of AS shown above. For short period, IS has the largest inbreeding control effect. However, it will be surpassed by AS in later stages.

Generation interval is decreased evidently by AS and indexes containing AS. Thus inbreeding coefficient under these schemes are even higher than that under RS. The efficient selection schemes under age—mating are AIS, APS and IPS. F_{200} is decreased by 48%, 47% and 40% respectively by the 3 index selections compared with RS. Regardless of the conservation period, AIS always has the largest inbreeding control effect.

Table 2. Simulation results of inbreeding coefficient, generation interval and variances and covariance of family size in populations under age—mating and various selection schemes

Selec. scheme	Inb. coe. × 10000 in year 50	100	150	200	GI (year)	Variance and covariance of family size σ^2_{mm}	σ^2_{mf}	Cov(mm, mf)	σ^2_{fm}	σ^2_{ff}	Cov(fm, ff)
RS	360	884	1395	1820	7.20	1.17	3.58	0.35	0.47	1.25	0.18
FS	702	1300	2010	2600	4.50	0.58	1.27	0.49	0.31	0.67	0.15
AS	260	525	864	1146	11.00	2.17	6.79	2.09	0.63	1.74	0.41
IS	130	468	858	1208	8.75	1.62	4.70	1.26	0.56	1.44	0.25
PS	263	643	949	1323	6.59	0.97	2.64	0.69	0.40	1.08	0.02
FAS	357	810	1220	1647	5.96	0.50	1.44	0.14	0.32	0.72	0.14
FIS	357	1047	1788	2466	4.57	0.42	1.04	0.20	0.33	0.68	0.13
FPS	610	1333	2031	2698	4.29	0.31	0.80	0.21	0.32	0.67	0.14
AIS	78	388	676	949	10.59	1.65	5.36	2.2	0.56	1.81	0.35
APS	173	419	675	968	10.50	1.58	5.77	2.23	0.53	1.76	0.35
IPS	110	453	781	1096	7.88	1.44	3.91	1.02	0.49	1.41	0.20
AIPS	273	700	1046	1381	8.30	1.77	9.25	2.87	0.63	1.73	0.38

3. Selections under parentage—mating

No large difference is found in the effects on inbreeding of various selection schemes under parentage—mating (data ommited). F_{20} for all the 12 selection schemes are in the range of 0.13—0.19.

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