Theor. Appl. Genet. 54, 69-74 (1979)

Genetic Divergence in Various Sahiwal x Holstein Crossbred Grades

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Summary. The degree of genetic divergence using Mahalanobis's D^2 statistic and the clustering pattern using canonical variate analysis between Sahiwal and its 39 Friesian grades were studied for 9 characters of economic importance. The records were adjusted for the significant effects due to farms, periods and seasons. Forty grades were grouped into 11 clusters. The results have shown that in cattle when two breeds of diverse origin, one of superior merit and the other relatively inferior, are crossed in a scheme of forward crossing, there is no linear increase in production level above 50% with the increase in genes of the superior parent. It can not be assumed that grading up to a total replacement of genes will lead to higher levels of production at least in cattle. In order to stabilize a breed type from such a crossbred population a breeding plan has been proposed.

Key words: Divergence – Grades – Forward crossing – Canonical root

Introduction

Most crossbreeding experiments in the tropics are comprised of crossing indigenous cattle with the better developed dairy breeds of European origin. The F_1's thus generated would have half the number of genes coming from the better parent and the second half coming from the indigenous parent. The fact of the case is that this cross involves two segregating populations where males from one population having higher gene frequency for production are being crossed with females having low gene frequency for that trait. A crossbred population when further mated would then show segregation and linkage between blocks of genes affecting production traits which would then generate a series of genotypes with different proportions of inheritance from either parent population. The situation becomes more complex when backcrossing with the better parent is continued in order to generate genotypes with a higher proportion of exotic inheritance namely 3/4, 7/8, 15/16, 31/32 and 63/64. In fact, the very validity of calling a certain grade 3/8, 1/2, 5/8 or 3/4 etc. is questioned because individuals within that grade may not in reality have that level of exotic inheritance.

In a somewhat planned crossbreeding experiment conducted with cattle (*Bos taurus* ♂ × *Bos indicus* ♀) at Military dairy farms in India, it has been generally observed that with an increase in exotic inheritance, the advance made in production in later crosses has fallen short of theoretical expectations (Bhat and Khanna 1970; Taneja 1973). This led to backcrossing with the indigenous parent. As a result of forward and backward crossing, a series of different genotypes having varying levels of exotic inheritance were generated. Therefore, the problem is to identify each grade with respect to another, assuming that these two are from different populations. Should it turn out that they are not really identical, it might illucidate the reasons for differences, if any, in the phenotypic expression of economic traits and their genetic basis.

It is, therefore, proposed here to estimate the genetic distance between these grades and to study their clustering pattern, based on traits of growth, reproduction and production using multivariate analysis approach. On the basis of clustering patterns one could pool such grades which do not show genetic differences. This, in fact, would be a valid classification.

Materials and Methods

The data for the present study were taken from breeding records of animals maintained at 8 Military Dairy Farms: Ambala, Bareilly, Dehra Dun, Jabalpur, Jullundur, Lucknow, Meerut and Mhow. The breeding policy in operation prior to 1952 was that of criss-cross breeding. Since 1953 a policy of backcrossing with Sahiwal bulls was introduced with a view to reduce the exotic inheritance

0040-5752/79/0054/0069/$ 1.20

gradually. As a result of forward and backward crossing, grades with 1/64 to 63/64 Holstein inheritance have been produced (Fig. 1). These crossbred grades have been produced by Sahiwal and Holstein sires. Animals with 32/64 and above Holstein inheritance were Holstein sired and those having less than 32/64 Holstein inheritance were Sahiwal sired.

The data were spread over a period of 30 years (1939-68). For the purposes of analysis the entire period of 30 years was divided into 5 periods, comprised 6 years each, where differences would be sizable enough to be detected. Four seasons of freshening based on climate were delineated as follows:

1. May through July – Summer
2. August through October – Autumn
3. November through January – Winter
4. February through April – Spring

Body weights of calves were recorded weekly up to one year of age and at monthly intervals thereafter. Records on weights were available up to maturity in females. The males were discarded 15 days after birth. Therefore, no records on body weights were available on males.

The lactation yield was defined as the milk yielded by the cow in 300 days or less. Those animals yielding less than 400 kg. of milk in a lactation period were excluded from the study pertaining to milk yield. Herds were kept on uniform rations and managerial regimes as laid down by the authorities of Military farms and hence there should be little variation in the records due to these causes. In the present study, 9 traits of growth, reproduction and production were used; weight at 52 weeks, weight at 24 months, weight at first calving, age at first calving, first service period, first lactation yield, first lactation length, first dry period and first calving interval.

A four-way fixed effects model with grades, farms, periods and seasons was used for analysis following the procedure given by Harvey (1966). Using least-square constants, the records were adjusted for significant effects due to farms, periods and seasons. The adjusted records were used to estimate genetic divergence among the grades.

For simultaneous test of significance of the differences in the mean values of 9 traits for Sahiwal and 39 Holstein crossbred grades, Wilk's criterion as described by Rao (1952) was used. mathematically,

$$\lambda = \frac{|E|}{|E+G|}$$

where

λ = Wilk's criteria
$|E|$ = determinant of error variance and covariance matrix
$|E+G|$ = determinant of (error + grade) variance and covariance matrix.

The significance test was made as shown below:

$$V = -m \log_e \lambda = \frac{-(2n-p-q-1)\log_e \lambda}{2}$$

Where V is taken as χ^2 value to test the significance with pq degrees of freedom and

n = degrees of freedom for (grade + error)
p = traits under study
q = number of grades – 1

The D^2 value between two populations could be estimated as described by Rao (1952).

$$D^2_G = \sum_i \sum_j \lambda^{ij} d_i d_j$$

where λ^{ij} is the reciprocal matrix of λ_{ij}, the pooled common dispersion matrix, and d_i is the difference between the mean values of two populations for the i^{th} character. Since computations using this formula are laborious, transformation of the character means of the population to uncorrelated variables was done using the pivotal condensation method. D^2 values were calculated as the sum of the differences of grades over all the transformed variables. The programme used for calculation and testing of D^2 values was a modification of an earlier version written by Murty and Arunachalam (1967).

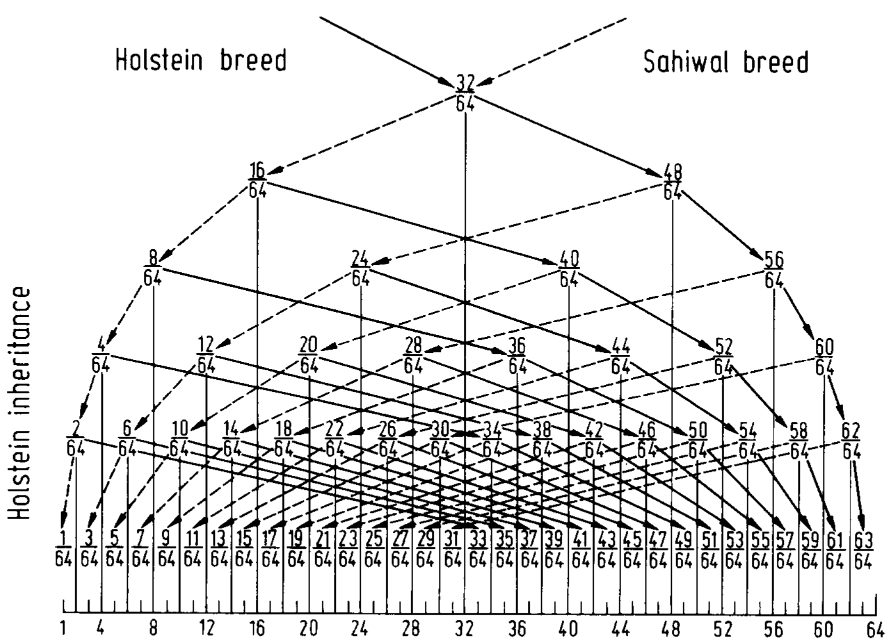

Fig. 1.

Significance of D^2 values was tested using the statistic

$$\frac{N_1 N_2 (N_1 + N_2 - p - 1) D^2}{p (N_1 + N_2)(N_1 + N_2 - 2)}$$

which follows 'F' distribution with (p, $N_1 + N_2 - p - 1$) degrees of freedom. N_1 and N_2 are the sample sizes for the two grades, each characterised by p characters.

Group Constellations

Grades were grouped into a number of clusters following canonical variate analysis as suggested by Rao (1952). Mean values of canonical variates for different grades were calculated using a programme written by Arunachalam (1967). The grades were represented graphically in a two dimensional model with two canonical variates as coordinates which generally give an accurate picture of the configuration of various grades. Inter- and intra-cluster values were calculated treating D^2 as the square of generalised distance.

Results and Discussion

In order to get an accurate idea about the differences or similarities between various grades based on 9 traits under study, a multivariate analysis was run to estimate the genetic distance between 40 grades. For this purpose, variance-covariance matrix was developed. The common dispersion matrix was used for simultaneous test of significance of differences in the mean values of characters for the 40 grades. The test of significance of differences in the mean values of traits using Wilk's criterion showed highly significant grade differences for all the 9 traits taken together as one combination. This was quite expected as the grade effect for all these traits except first service period and first calving interval was significant (Taneja 1973). The χ^2 value obtained was 1185.70 against 351 degrees of freedom.

To convert the mean values of characters of each grade into uncorrelated mean values for each variable, coefficients of X(characters) in the uncorrelated linear function of Y (variables) were calculated by the pivotal condensation method for 9 × 9 common dispersion matrix. Using the relations between Y's and X's, the original mean values of 40 grades for 9 characters were transformed into mean values of a set of uncorrelated variables. These uncorrelated mean values were used for the calculation of D^2 values. Sums of squares of grade differences for all the variables were estimated as D^2. The actual values of D^2 corresponding to 780 grade combinations taking two grades at a time were computed and tested for significance. Out of these 780 comparisons of grades, significant D^2 values were observed for 257 comparisons.

The relative contribution of each character to the total D^2 between each pair of grades was ranked based on the magnitude of D^2 due to each character. The total contribution of these characters to divergence was also estimated. The results are presented in Table 1.

It can be seen from Table 1 that the percentage contribution ranged between 7.22 (first lactation yield), the lowest, to 13.42 (first dry period), the highest. 32.76 per cent of the total variability was accounted for by 3 traits of growth, 48.15 per cent by 4 traits of reproduction and 19.09 per cent by 2 traits of production. The results in general indicated that the differences in the relative contributions of each character to total divergence were not very large.

After calculation of uncorrelated mean values, mean values of the first two canonical variates were estimated. The results are given in Table 2.

It can be seen from Table 2 that the contribution of λ_1 and λ_2 was 19.84 and 5.46, respectively. These 2 roots contributed a total of 25.30 which was 67.50% of the total variability. The sum of all the canonical roots was 37.43.

Mahalanobis et al. (1949) had shown that the configuration of various clusters represented by a three dimensional configuration based on more than two roots did not give the same configuration as was obtained by the group constellation method. However, if at first only two dimensional vectors were considered, it gave the same configuration as by group constellation. Thus, the mean values of the first two canonical variates were used for plotting the grades. Graphical representation of λ_1 and λ_2 for grades has been made in Fig. 2. Clusters were made on the basis of closeness of distance. Forty grades were grouped into 11 clusters such that the grades within the clusters were having smaller D^2 among themselves than those from grades belonging to the different clusters. The results of clustering pattern of 40 grades are detailed in Table 3.

The intra- and inter-cluster average D^2 and $\sqrt{D^2}$ values were calculated and are given in Table 4.

Table 1. Relative contribution of each character to total divergence as depicted by rank totals

Sl. no.	Character	Rank total	Contribution (%)
1.	Weight at 52 weeks	3218	9.17
2.	Weight at 24 months	4010	11.42
3.	Weight at first calving	4271	12.17
4.	Age at first calving	3685	10.50
5.	First service period	4101	11.69
6.	First lactation yield	2534	7.22
7.	First lactation length	4166	11.87
8.	First dry period	4711	13.42
9.	First calving interval	4401	12.54
		35100	100.00

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No intra-cluster value could be estimated for the 2 clusters which had one grade each. Intra-cluster values were low and ranged between 0.45 (cluster VII) to 1.18 (cluster X). The inter-cluster distance was minimum (0.63) between cluster IV and cluster VI, suggesting close relationship. On the other hand, maximum distance (16.27) was observed between cluster I and cluster XI, indicating wide diversity between these 2 clusters.

It can be seen from Table 4 that cluster I consisted of Sahiwal and 3 other grades of low Holstein inheritance. 63/64 H grade was quite distinct and formed a separate cluster. The results in general indicated that the distance

Table 2. Mean value of first two canonical variates for 40 grades

Sl. no.	Grade	Z(1)	Z(2)	Sl. no.	Grade	Z(1)	Z(2)
1.	0H	2.00	5.16	21.	26H	3.05	4.99
2.	4H	2.29	5.33	22.	28H	3.55	5.57
3.	5H	2.08	4.99	23.	30H	3.33	5.40
4.	6H	2.14	5.00	24.	32H	4.01	5.00
5.	7H	2.60	4.86	25.	36H	3.06	4.65
6.	8H	2.62	5.19	26.	37H	3.67	4.57
7.	10H	2.38	4.86	27.	38H	4.01	4.66
8.	11H	2.28	5.08	28.	39H	3.64	4.53
9.	12H	2.50	5.11	29.	40H	3.44	4.58
10.	13H	2.35	4.86	30.	42H	3.61	4.67
11.	14H	2.46	5.05	31.	43H	3.15	4.28
12.	15H	2.26	5.45	32.	44H	3.48	4.75
13.	16H	2.76	5.13	33.	46H	3.40	4.91
14.	18H	2.84	5.59	34.	47H	3.33	4.42
15.	19H	2.91	5.18	35.	48H	3.12	4.87
16.	20H	2.88	5.27	36.	52H	3.47	4.50
17.	21H	2.91	5.15	37.	54H	2.77	5.20
18.	22H	2.94	5.25	38.	55H	3.49	4.18
19.	23H	3.25	5.30	39.	60H	2.79	4.95
20.	24H	2.93	5.33	40.	63H	5.99	5.97

$\lambda_1 = 19.84$; $\lambda_2 = 5.46$; $\lambda_3 = 3.25$; $\lambda_4 = 2.47$

Sum of other canonical roots = 6.39
Sum of all canonical roots = 37.43
Contribution of canonical root 1 = 52.9%
Contribution of canonical root 2 = 14.6%
Contribution of canonical root 3 = 8.6%
Contribution of canonical root 4 = 6.6%

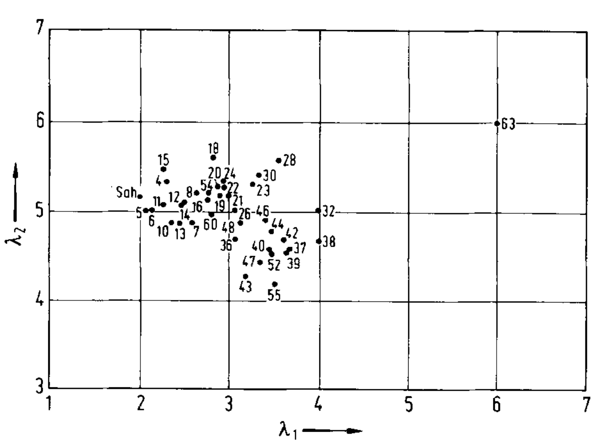

Fig. 2.

Table 3. Clustering pattern of 40 grades

Sl. no.	Cluster	Grades
1.	I	Sahiwal 5/64H, 6/64H, 11/64H
2.	II	4/64H, 15/64H
3.	III	7/64H, 10/64H, 12/64H, 13/64H, 14/64H
4.	IV	8/64H, 16/64H, 19/64H, 20/64H, 21/64H, 22/64H, 24/64H, 54/64H, 60/64H
5.	V	18/64H
6.	VI	26/64H, 36/64H, 48/64H
7.	VII	23/64H, 28/64H, 30/64H
8.	VIII	37/64H, 39/64H, 40/64H, 42/64H, 44/64H, 46/64H, 47/64H, 52/64H
9.	IX	43/64H, 55/64H
10.	X	32/64H, 38/64H
11.	XI	63/64H

Table 4. Intra-cluster and inter-cluster average D^2 and D values in 40 grades

Cluster	I	II	III	IV	V	VI	VII	VIII	IX	X	XI
I	1.04 (1.02)	0.77 (0.88)	1.03 (1.02)	1.34 (1.16)	1.82 (1.35)	1.73 (1.31)	2.52 (1.59)	2.80 (1.67)	2.93 (1.71)	4.44 (2.11)	16.27 (4.03)
II		0.76 (0.87)	0.81 (0.90)	1.09 (1.04)	1.46 (1.21)	1.66 (1.29)	1.97 (1.40)	2.74 (1.66)	3.05 (1.75)	4.08 (2.02)	14.38 (3.79)
III			0.88 (0.95)	0.92 (0.96)	1.71 (1.31)	1.08 (1.04)	1.76 (1.33)	1.90 (1.38)	1.99 (1.41)	3.37 (1.83)	13.99 (3.74)
IV				0.55 (0.74)	1.13 (1.06)	0.63 (0.79)	0.82 (0.91)	1.38 (1.18)	1.58 (1.26)	2.10 (1.45)	11.05 (3.32)
V					–	1.76 (1.33)	1.64 (1.28)	2.27 (1.51)	3.06 (1.75)	2.93 (1.73)	10.74 (3.28)
VI						0.53 (0.73)	0.79 (0.89)	0.83 (0.91)	0.88 (0.94)	1.33 (1.15)	10.29 (3.21)
VII							0.45 (0.67)	1.31 (1.14)	1.85 (1.36)	1.32 (1.15)	7.70 (2.78)
VIII								0.62 (0.79)	0.86 (0.93)	0.71 (0.84)	8.11 (2.85)
IX									0.59 (0.77)	1.43 (1.19)	10.59 (3.25)
X										1.18 (1.09)	5.69 (2.38)
XI											

$\sqrt{D^2}$ = D is given in parenthesis

between Sahiwal and 63/64H grade was the maximum. All other grades both with Holstein inheritance more or less than 50 per cent were lying between Sahiwal and 32/64 H grade, barring 38/64H grade which also clustered with 32/64H grade. From the clustering pattern based on 9 characters of these grades, it can be concluded that Sahiwal was lowest in performance while 63/64H grade was distinctly better than other crossbred grades. 32/64H and 38/64H grades were next in order of merit. A similar picture was available from the study of least square constants for these grades for different characters (Taneja 1973).

The results of this investigation reveal that in cattle when two breeds of diverse origin, different in their production levels, one of superior merit and the other relatively inferior, are crossed in a scheme of forward crossing (Fig. 1), there is no linear increase in production level with the increase in the level of inheritance of the superior parent. The genetic reasons for this are not obvious. In view of this it can not be assumed that by grading up a total replacement of genes can be obtained, at least not in cattle.

Based on these results, the following breeding plan is proposed to stabilize various breed types. The cluster I should be inter-bred using Sahiwal bulls. The genetic groups in clusters II-X should form the diverse crossbred foundation and be bred to bulls with 50% temperate inheritance and subjected to intense selection and inter-se-mating. The cluster XI could safely be bred to Holstein.

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Received August 9, 1978
Communicated by L.D. Van Vleck and B.R. Murty

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