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Research Paper

GENETIC AND ENVIRONMENTAL FACTORS AFFECTING FRIESIANN COWS REPRODUCTIVE PERFORMANCE UNDER DRYLAND CONDITIONS

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Data was obtained from the dairy herd of the Arab Company for Agricultural Production and Processing (ACAPP) in a semi arid area 40 km south of Khartoum. The data used was of the first five lactations in 4784 records of 2998 cows covering the period from 1982 to 1998. Harvey's computer program (1990) was used for data analysis. The analysis of variance showed that sires had a significant effect on age at first calving, Number of Services Per Conception (NSPC), breeding efficiency, calving interval and open period. Age at first calving was significantly ($p<0.01$) affected by year seasons of birth. The year-seasons of calving had a highly significant effect ($p<0.01$) on calving interval, open period and breeding efficiency. The effect of parity number on calving interval and breeding efficiencywassignificant, while it was not significant on open period and NSPC. The least squares means of age at first calving, calving interval, open period, NSPCand breeding efficiency were 28.98±0.35 months, 14.74±0.131 months, 131.7±2.08 days, 2.36±0.21 and 80.797±0.614% respectively. Heritabilites for age at first calving, calving interval, open period, NSPC and breeding efficiency were 0.092±0.021, 0.008±0.005, 0.004±0.005, 0.100±0.017 and 0.057±0.011 respectively. There were negative genetic correlations between breeding efficiency and both of age at first calving (-1.000±0.370) and NSPC (-0.956±0.121). There were also negative genetic correlations between calving interval and both of open period (-0.406±0.541) and NSPC (0.705±0.286). There were positive genetic correlations between breeding efficiency and both of calving interval (0.637±0.3080), and open period (0.706±0.551). Open period and NSPC (0.791±0.550). Reproductive performance of Holstein Friesian under dryland conditions was below what was expected. However, their performance was better than that of local types but not better than estimates reported for crossbreds.

Keywords: Tropics, Holstein cattle, Reproduction performance

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INTRODUCTION

The indigenous cattle of the Sudan belong to the species *Bos indicus* and are well adapted to tropical environments. They possess a high degree of heat tolerance, some resistance/ tolerance to tick borne and to other diseases occurring in the tropics, and have a low maintenance requirement. However, their potential for milk production is low and despite the huge cattle numbers in Sudan, there is a deficit in the supply of milk due to the poor genetic potential of indigenous cattle coupled with a low input system of management. To encourage milk production in Sudan the modern livestock sector has embarked on importation of exotic cattle breeds (Mainly Holstein Friesian) with the objective of using them in cross breeding programmes to upgrade indigenous cattle or use them as pure breeds.

The predominantly specialized dairy breeds of the temperate countries which belong to the *Bos taurus* species have high milk yield potential but lack heat tolerance and disease resistance. Darwash *et al*. (1997) reported that Holstein – Friesian has superior genetic merit for milk yield, but it may also carry the undesirable genes for subfertility and it lacks adaptation to tropical environments.

Because of the importance of genetic and non genetic factors that influence the production of exotic cattle breeds in tropical environments, this study was initiated with a view to establishing base line information relevant to the tropical environment of Sudan. The objectives of this study were to estimate some genetic and phenotypic parameters of reproductive performance of imported Holstein Friesian. The traits investigated were the age at first calving, calving interval, open period, number of services per conception, breeding efficiency and their heritabilities and correlations among them were estimated.

MATERIALS AND METHODS

Data Collection and Manipulation

The data was obtained from records of a Holstein-Friesian herd that belongs to the Arab Company for Agriculture and Animal production and Processing (ACAPP). The number of records studied was 4784 from 2998 pure Holstein Friesian cows. The records covered a period of nineteen years (1982-1998) and extended from the first to fifth lactation. The numbers of records used in actual analyses varied among traits according to availability of information andmodel requirements.

Statistical Analyses

Least squares means, standard errors, heritabilites and correlationsamong the reproductive traits were computed. The data were analyzed using Harvey's (1990) Least Squares and Maximum likelihood programme.

Statistical Models

Model (1)

Analysis of age at first calving:

$$Y_{ij} = \mu + S_i + A_j + E_{ij} \qquad \ldots(1)$$

where

Y_{ij} = The i, jth observation on age at first calving

μ = The overall mean.

A_j = The jth year-season of calving (j = 1-10)

S_i = The random effect of the ith sire (i = 1-80)

E_{ij} = Residual error

Model (2)

The following model was used to analyze calving interval, open period and breeding efficiency:

$Y_{ijk} = \mu + A_i + S_j + H_k + E_{ijk}$ …(2)

where

Y_{ijk} = The ijth observation calving interval

μ = The overall mean.

A_i = The ith year-season of calving effect (i = 1-12)

S_j = The jth sire effect (j = 1-80).

H_k = The kth parity number effect (k = 1-5)

E_{ijk} = The residual error.

Model (3)

This model was used to analyze number of service per conception:

$Y_{jk} = \mu + S_j + H_k + E_{jk}$ …(3)

where

Y_{jk} = The jkth observation on the trait in question.

μ = The overall mean.

S_j = Effect of jth sire (j = 1-80)

H_k = Effect of kth parity number (k = 1-5)

E_{jk} = The residual error

Heritability Estimates

The heritabilities were estimated by paternal half-sib analysis as described by (Becker,1975).

$h^2_{phs} = 4\sigma^2_s/(\sigma^2_s + \sigma^2_w)$

where

h^2_{phs} = The estimate of heritability based on paternal half sibs.

σ^2_s = The genetic variance between sires.

$\sigma^2 w$ = The variance within sires.

Correlations

The phenotypic and genetic correlations among studied traits were estimated by paternalhalf-analysis and covariance (Becker, 1975).

The Genetic Correlation

$r_G = cov_s/\sqrt{(\sigma^2 s(x).\sigma^2_s(y))}$

The Environmental Correlation

$r_E = cov_w - 2cov_s/\sqrt{(\sigma^2 w(x) - 2\sigma^2_s(x))}.\sqrt{(\sigma^2 w(y) - 2\sigma^2_s(y))}$

where: x and y stand for the two traits whose correlation is being calculated

Breeding Efficiency

The breeding efficiency for each cow was calculated using the following formula:

BE = [396*(N-1)+960]/(age in days at each successive calving)

where

BE is breeding efficiency;

(N-1) is the number of calving interval in N generations

'396' is the upper limit of desirable calving interval in days

RESULTS AND DISCUSSION

Age at First Calving

Age at first calving is defined as the period from date of birth to date of first successful calving. It is considered an important economic characteristic that determines the reproductive and productive performance of dairycattle. In this study the overall mean of age at first calving was 28.98±0.35 based on 1699 records (Table 1). The latest age at first calving was recorded for cows born in the period 1986-1989. Khalafalla (1977) reported that first calving for temperate breeds occurred at 24-30 months of age compared to tropical African zebu which are late maturing animals calving at 36-48 months. This result is similar to an estimate of 27.7±3.4 for age at first calving of Holstein Friesiansin Mexico obtained by Lemus-Flores *et al*. (2002) and an estimate of 29.76±0.40 obtained by Abdel Gader (2004) in Sudan. However, it is higher than the value of 25.2±2.3 reported by Ageeb and Hayes (2000) in Sudan.It is lower than the estimatesof36.57±8.8 and 32.6±0.45 reported for Holstein Friesians by Elkhalil (2001) in Libya and Chagunda *et al.* (2004) in Malawi, respectively.

Compared with values of age at first calving among Friesian x indigenous cattle crossbreds in the tropics, this result is much lower than those results obtained by both Hamza (2001) (43.78±1.19) of Sudan for Kenana and Butana crosses with Friesian and Teirab *et al*. (2006) (47.53±2.24) in records of Friesian x Zebu.

Sire and year season of birth of cows hadsignificant effects (p<0.01) on age at first calving (Table 2). This is similar to the findings of Elkhalil (2001) on Libyan Friesian cows, but at variance with the findings of Abdel Gader *et al*. (2004) who reported that age at first calving was not significantly (p>0.05) affected by sires but it

Table 1: Least-Squares Means and Standard Errors of Age at First Calving, Calving Interval, Service Period, NSPC and Reproductive Efficiency

Item	Age at First Calving		Calving Interval		Service Period		NSPC		Breeding Efficiency	
	N	L.S.M±SE	N	L.S.M±SE	N	L.S.M±SE	N	L.S.M±SE	N	L.S.M±SE
Overall mean	1699	28.98±0.35	1232	14.74±0.13	2749	131.70±2.08	3838	2.36±0.21	4784	80.797±0.614
Parities										
First parity	-	-	982	14.71±0.16	135	123.39±3.76	19	2.42±0.7	1669	74.757±0.666
Second parity	-	-	629	14.17±0.16	294	127.31±4.01	1494	2.39±0.21	1279	77.687±0.666
Third parity	-	-	358	14.54±0.17	592	126.29±4.23	1149	2.27±0.21	920	80.590±0.680
Fourth parity	-	-	147	14.35±0.20	840	118.73±3.83	**757**	2.31±0.21	589	83.865±0.710
Fifth parity	-	-	982	14.60±0.29	951	145.83±4.32	419	2.41±0.21	327	87.086±0.808
Calving Year – Season										
Winter, 1982-1985	292	27.31±0.48	801	14.13±0.22	669	129.06±3.86	-	-	920	91.991±0.777
Dry summer, 1982-1985	68	29.25±0.63	450	14.17±0.24	389	118.01±3.95	-	-	530	90.290±0.810
Wet summer, 1982-1985	281	28.99±0.48	355	13.10±0.25	294	150.19±5.35	-	-	391	87.498±0.840
Winter, 1986-1989	201	29.96±0.49	312	14.02±0.23	265	134.58±3.85	-	-	493	85.130±0.760
Dry summer, 1986-1989	176	29.48±0.51	216	14.24±0.26	203	126.41±12.87	-	-	420	85.591±0.791
Wet summer, 1986-1989	114	29.87±0.55	304	14.31±0.23	274	163.41±12.87	-	-	568	83.702±0.738
Winter, 1990-1994	183	28.55±0.52	325	14.26 ± 0.22	230	117.05±9.81	-	-	489	78.102±0.752
Dry summer, 1990-1994	143	28.78±0.50	174	15.66 ± 0.28	105	150.42±2.73	-	-	277	78.875 ±0.847
Wet summer, 1990-1994	222	28.75±0.50	314	14.14± 0.22	251	125.79±2.66	-	-	504	77.721±0.750
Winter, 1995-1998	19	28.12±1.69	26	15.05±0.67	18	131.76±2.87	-	-	61	71.554±1.427
Dry summer, 1995-1998	-	-	35	16.62±0.58	19	132.59±3.41	-	-	56	71.316±1.463
Wet summer, 1995-1998	-	-	36	13.11±0.57	32	137.90±4.85	-	-	75	70.793±1.329
Coefficient of variation	-	14%	-	22%	-	39%	-	19%	-	12%

Note: L.S.M = least squares mean; S.E = standard error.

was significantly affected by year seasons of birth. The results of the present study indicate that there are differences between sires in the rate of maturity of their daughters. This means that selection pressure can be applied for early maturity. However, there is need to investigate how current selection practices for high producing sires impact maturity rates.

Calving Interval

Calving interval is the period between two consecutive calvings and is considered as a measure of breeding efficiency. The overall mean of calving interval was 14.74±0.13 based on 1232 records (Table 1). The longest calving interval was that of cows which calved in the dry summer of 1995-1998 (16.62±0.58 months). The analysis of variance of calving interval (Table 2) shows that the effects of sires on calving interval were significant (p< 0.05). The year-seasons of calving and the parity number had a highly significant (p<0.01) effect on calving interval. Similar estimates were arrived at by Abdel Gader *et al*. (2004) who analyzed data of 1049 records from the dairy herd of (ACAPP) in Sudan and found that the least squares means for calving interval increased from 14.10 after the first parity to 14.86 in the third parity and the longest calving interval was recorded for cows calving in the dry summer. Salhab *et al*. (1997) and El Khalil (2001) reported estimates of 14.2 and 13.54 months, respectively for Friesian cattle in Libya and they found that parity and calving year but not calving season significantly (p<0.01) affected calving interval. Chagunda *et al*. (2004) gave estimates of 13.57 and14.87 months in two Friesian herds in Malawi and the calving interval was significantly (p<0.05) affected by parity. Theestimate found in the present study is higher than that of Lemus-Flores (2002) (12.9±2.03) in Mexico Holstein Friesian; Goodchild *et al*. (1984) (378±59 days) in Friesian x Sahiwal crosses in a tropical location; and Agyemang and Nkhonjera (1986) (407±90 days) in crossbred cattle in Malawi.

Table 2: Analysis of Variance of Age at First Calving, Calving Interval, Service Period, NSPC and Reproductive Efficiency

Source	Trait	D.F.	M.S	Prob	F
Sire	Age at first calving	79	54.6	3.85	0
	Services period	79	2995.6	1.12	0.02139
	(NSPC)	79	11.29	6.24	0
	Calving interval	79	14.02	1.34	0.0259
	Breeding efficiency	79	374.48	2.47	0
Year-season effect	Age at first calving	9	95.11	6.7	0
	Services period	11	17950.28	6.74	0
	(NSPC)	-	-	-	-
	Calving interval	11	49.07	4.68	0
	Breeding efficiency	3	46208.16	305.14	0
Parity number	Age at first calving	-	-	-	-
	Services period	4	6022.71	2.26	0.0602
	(NSPC)	4	3.06	1.69	0.1499
	Calving interval	4	39.24	3.74	0.0048
	Breeding efficiency	8	2038.91	13.46	0
Remainder	Age at first calving	1610	14.18		
	Services period	2654	2663.02		
	(NSPC)	3754	1.81		
	Calving interval	3253	10.48		
	Breeding efficiency	2461	151.43		

Note: D.F = degrees of freedom; M.S = mean squares; F = F-ratio; Prob = Probability.

Open Period

The postpartum anoestrous and service periods together are called the days open (Peters, 1984). The overall mean of open period in this study was 131.7±2.08 (Table 1). This finding is close to those obtained by Juma and Al Tikriti (1990) who analyzed data on 272 Brown Swiss and 273 Friesian cows in Iraq and found that the service periods in the two breeds were 138.19±0.04 and 145.54±2.85, respectively. Zaid (1995) found open period estimates of 94.8±2.3 and 145.2±3.5 daysin first lactation records of 566 and 467 imported and homebred cows,respectively in Libya. Lemus *et al*. (2002) in Mexicoanalyzed 8650 records of Holstein Friesian and reported that the overall mean of service period was 115±64 and found that the white colour of the coat affected open period in the temperate dry and warm humid climates of Mexico. The estimate obtained here is lower than that reported by Abuzaid (1999) who studied imported and locally born Friesians in the Sudan and reported that open period was 197.3±120.3 and 217.0±160.5 days, respectively. It is also lower than the finding of Ageeb and Hayes (2000) who analyzed data of 1274 purebred Holstein Friesian in Sudan and found an estimate of 208.9 days. The duration of open period is influenced by nutrition, season, milk yield, parity (Wiltbank *et al.*, 1962), suckling and uterine involution (Buck *et al*. 1975). Abdel Gader *et al*. (2004) analyzed 1049 records from the dairy herd of the (ACAPP) in Sudan and found that the least squares mean of days open was 167.79±7.08 days. In Ethiopia, Kassa and Tegegne (1998) in a study of zebu and Friesian x zebu crossbred cows reported that the overall mean interval from calving to conception was influenced by genotype ($p<0.05$) and was shorter in crossbreds (148.4±11.7 days) than in zebu cows (183.2±11.7 days).

The effects of sires on open period were significant ($p<0.05$). The effect of year-season of calving had a highly significant ($p<0.01$) effect on open periodbut parities did not have a significant effect ($p>0.05$) (Table 2). This finding is in disagreement with that of Chagunda *et al*. (2004) in Malawi who studied three herds of Holstein Friesian cows and reported that the number of days open was not affected by year seasons of calving ($p>0.05$) but washighly significantly affected by parity ($p<0.05$). AlsoAbdel Gader *et al*. (2004) mentioned that the number of days open increased significantly as parities advanced from 141.42±8.81 in the first parity to 194.70±15.10 in the fourth parity.

Number of Services per Conception (NSPC)

This is the number of services required by a female to conceive and is calculated as a measure of its breeding efficiency (Sastery and Thomas, 1979). In the present study the overall mean of number of services per conception based on 3838 records was 2.36±0.21 (Table 1). Lemus-Flores *et al*. (2002) in Mexico analyzed 8650 records of Holstein Friesian cows and reported that theoverall mean number of services per conception was 2.08±1.3. In the present study the lowest number of services per conception was obtained in the third parity (2.27± 0.21) and the highest number was found in the fifth parity (2.41± 0.21). The number of services per conception in the first parity was 2.42±0.37. However, it was based on 19 records only. This estimate is close to the estimates of Mangoukar *et al*. (1986) who reported 2.99 inseminations per conception for purebred Holstein-Friesians in India, and Goodchild *et al*. (1984) in Australia who reported an estimate of 2.1±1.5 from records of 350 Friesian x Sahiwal cows and heifers. However, the estimate in the present study is much lower than that obtained by Ageeb and Hayes (2000) in Sudan who analyzed data of 1274 of purebred Holstein Friesians and reported that the overall mean number of services per conception was 4.2, but higher than the estimates obtained by Bashir (1990) who analyzed data from 40 imported and 40 locally born Friesians and reported that the overall means of NPSC were

1.13 and 1.23, respectively. Mohudein (1994) reported that the overall mean NPSC was 1.5±2.9 in 155 records of Holstein-Friesian heifers in Sudan.

In the present study the effect of sireson number of services per conception was highly significant ($p<0.01$) while the effect of parity number was not significant ($p>0.05$) (Table 2). This is at variance with the results of Mangoukar *et al*. (1986) in India and Juma *et al*. (1998) in Iraq who found the same result with regard to the effect of parity but different results with regard to the sireaffect. Ageeb and Hayes (2000) found that year and month of calving had significant effects ($p>0.01$) on NSPC.

Breeding Efficiency

Fertility in cattle is affected by genetic and environmental factors which influence the reproductive processat ovulation, fertilization, implantation or during gestation.

The overall mean of breeding efficiency (Table 1) was 80.797±0.614 based on 4784 records. The highest estimate of breeding efficiency was 91.991±0.777, obtained in the winter of the period (1982-1985) and the lowest number was 70.793±1.329, found in the wet summer of the period (1995-1998). The results showed that the estimates of breeding efficiency increased from the first parity to the fifth parity. The effects of sires, year-season of calving and parity number on breeding efficiencywere all highly significant ($p<0.01$) (Table 2).

The estimate of breeding efficiency found in the present study is lower than the estimates found by Tadesse and Dessie (2003) in cows of ½ Baraca x ½ Friesian, ½ Boran x ½ Friesian (92.45% and 98.99% respectively). Pandi *et al*. (1999) in India using Friesian x (Jersey x Gir) records estimated breeding efficiency at 90.07%. The present estimate is higher than those obtained by Goshu (2005) in Ethiopia from cows of Friesian x Boran breeding (66.3±0.49%) and Sharma and Singh (1999) (64.8±0.7%) in 5/8 Friesian-3/8 Sahiwal cows.

Genetic Parameters

The heritability estimates were 0.092±0.021, 0.008±0.005, 0.004±0.005, 0.100±0.017 and 0.057±0.011 for age at first calving, calving interval, service period, number of services per conception and breeding efficiency. They were all generally low and did not exceed 10%. Generally, reproductive traits are less heritable than productive traits (Cassandro, 2014). In practice, this mean that larger numbers of records are required in order to obtain reliable proofs for bulls compared to those required for production traits.

The heritability of age at first calving in this study was 0.092±0.021 which is in good agreement with the findings of Abdel Gader *et al*. (2004) (0.098±0.104) in Sudanwho studied 337 Holstein Friesian cows and Teirab *et al.* (2006) (0.01±0.05) in Sudan using Friesian x Kenana records. This estimate is less than the ones obtained by El Khalil (2001) (0.41±0.08) in Libya, and Musa (2005) (0.19±0.07) in Sudan Butana cattle. The heritabilityof calving interval in this study was 0.008±0.005. This estimate is lower than the estimates obtained by El khalil (2001) (0.02±0.02) in Libya and Abdel Gader*etal* (2004) (0.047±0.046) in Sudan. In the present study the heritability of open period was 0.004±0.005. This finding is lower than estimates obtained by Tahir and Maarof (1990) of 0.09±0.09 in Friesian cattle in India, El-Said *et al*. (2001) (0.163±0.042) in Pakistan and Abdel Gader*et al*. (2004) (0.51±0.37) in Sudan. The heritability of number of services per conception of Holstein Friesian in the present study was 0.100±0.017. This is close to the estimate obtained by Juma *et al*. (1988) in Iraqwho analyzed 449 records of purebred Friesians and estimated the heritability of number of services per conception as 0.04±0.01.

Table 3: Heritabilities and Standard Errors of the Studied Reproductive Traits

Trait	Heritability Estimate
Age at first calving	0.092±0.021
Calving interval	0.008±0.005
Service period	0.004±0.005
Number of services per conception	0.100±0.017
Reproductive efficiency	0.057±0.011

Genetic, Phenotypic and Environmental Correlations

Negative genetic correlations were found between age at firstcalving and breeding efficiency (-1.000±0.370), calving interval and open period(0.406±0.541), calving interval and number of services per conception (-0.705±0.286) and number of services per conception andbreeding efficiency (-0.956±0.121). There were positive genetic correlations between calving interval and breeding efficiency (0.637±0.3080), open period and number of services per conception (0.791±0.550) and open period and breeding efficiency (0.706±0.551). Wollny *et al.* (1988) in Malawi found that the genetic correlation between age at first calving and calvinginterval was 0.22±0.21. There were positive phenotypic correlation estimates between age at first calving andcalving interval, age at first calving and open period. However, Ishag (2000) found apositive phenotypic correlation between age at first calving and calving interval in crossbred cows (Friesian x Kenana). El Khalil (2001) in Libya reported similar findingsfor age at first calving, calving interval and lactation length. In this study there werenegative phenotypic correlations between

Table 4: Genetic and Phenotypic Correlations of the Studied Reproductive Traits

Trait	Age at First Calving	Calving Interval	Open Period	(NSPC)
Calving interval	rg = NE			
	rp = 0.052			
	re = NE			
Open period	rg = NE	rg = -0.406±0.541		
	rp = 0.054	rp = 0.829		
	re = NE	re = 0.839		
NSPC	rg = NE	rg = -0.705±0.286	rg = -0.791±0.550	
	rp = NE	rp = -0.043	rp = -0.039	
	re = NE	re = 0.001	re = -0.014	
Breeding efficiency	rg = -1.000±0.370	rg = 0.637±0.308	rg = 0.706±0.551	rg = -0.956±0.121
	rp = -0.994	rp = -0.032	rp = -0.024	rp = -0.468
	re = -0.993	re = -0.078	re = -0.050	re = -0.399

Note: rg = Genetic correlation; rp = Phenotypic correlation; re = Environmental correlation; Ne = Not estimable.

calving interval and number of services per conception; calving interval and breeding efficiency; open period and number of services perconception; open period and breeding efficiency and number of services perconception and breeding efficiency. There were positive environmental correlations between calving interval and open period and calving intervaland number of services per conception, but negative environmental correlations between age at firstcalving and breeding efficiency; calving interval and breeding efficiency; number of services per conception and breeding efficiency; open period andbreeding efficiency and open period and calving interval.

CONCLUSION

There is a clear improvement in reproductive performance of Holsteins compared to local types. However, Holsteins' performance remains well below their performance in temperate countries. Under the tropical conditions of the Sudan there is need to address the problem of matching the proper genotype to the production system that is dominant in each part of the country. The level of foreign blood infused into local cattle must be suited to the low input production systems and the harsh environment prevalent in most parts of the country. It appears from the weight of evidence presented in this study and other similar studies in tropical countries that the local environment (i.e., high temperature, low feed quality and quantity, disease and parasitic loads challenge) can sustain composite genotypes better than pure exotic breeds.

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