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Genetic control of milk yield from lactations of different duration in Nili-Ravi buffaloes

Abstract

Data on 2704 lactations of 1093 Nili-Ravi buffaloes were used to see the genetic control of milk yield projected for lactation length using information on last recorded yield and average daily yield of the recorded lactation. Year and season of calving and their interaction significantly affected actual and predicted milk yield. Winter calvers had a higher mean (1364.5±31.63 kg) as compared to summer calvers (1299.4±30.28 kg). The milk yield adjusted to 308-days increased from first parity (1731.8±78.86 kg) to third parity (1919.6±64.56 kg) where after it declined gradually. Age at calving with in parity affected lactation milk yield significantly (P<.01). Lactation length had a significant effect on actual and adjusted lactation yields but the effect was much smaller in projected lactations. Repeatability of actual lactation milk yield was 0.46±0.02. Heritability of actual lactation milk yield from paternal half-sib correlation method was 0.244±0.057. Lactations adjusted to 308 days by simple linear regression had a similar heritability (0.243±0.057) but lactations adjusted using last record-day information had slightly better heritability estimate (0.295±0.063 to 0.314±0.065). Estimate improved as data set was restricted to include more completed. Results from Animal Model analysis indicated that overall heritability value for actual lactation milk yield was 9.1% while for 308-day lactation milk yield (adjusted by using last record-day and or average daily milk yield information), value was 10.7 to 12.0%. Extension of all lactation records with less than 305-days length to standard such as 305-days using last record-day and average daily milk yield information is suggested.

Key Words: Nili-Ravi, buffalo, milk yield, heritability, lactation length

Zusammenfassung

Titel der Arbeit: **Genetische Kontrolle der Milchleistung bei unterschiedlicher Laktationslänge untersucht an Nili-Ravi Büffeln**
Die Daten der 2704 Laktationen von 1093 Nili-Rahi Büffelkühen wurden für eine genetische Kontrolle des Milchertrages bei unterschiedlicher Laktationslänge unter Verwendung der Gesamtlaktationsleistung, der letzten erfassten sowie der durchschnittlichen täglichen Milchleistung genutzt. Jahr und Saison der Kalbung und ihre Interaktion beeinflussten signifikant den tatsächlichen und zu erwartenden Milchertrag. Dieser lag bei Winter- im Vergleich zur Sommerkalbung höher (Wi. 1364,5±31,6 kg; So 1299,4±30,3 kg). Der Milchertrag bei 308 Laktationstagen stieg von der ersten (1731,8±7887 kg) zur dritten Laktation (1919,6±64,6 kg) an, um dann allmählich abzunehmen. Das Alter bei der Kalbung innerhalb der einzelnen Laktationen beeinflusste den Milchertrag signifikant (P<0,01). Auch die Laktationslänge hatte einen signifikanten Einfluss auf den tatsächlichen und den zu erwartenden Milchertrag. Dieser Einfluss verringerte sich jedoch mit steigender Laktationszahl. Die Wiederholbarkeitsschätzung des aktuellen Milchertrages ergab bei kürzester Laktationslänge den geringsten Wert von 0,46±0,02 und der Heritabilitätskoeffizient zu diesem Zeitpunkt, ermittelt nach der väterlichen Halbgeschwisterkorrelation, lag bei 0,244±0,057 und erhöhte sich bis zum 308. Laktationstag. Der Heritabilitätskoeffizient für die Laktationsleistung bezogen auf 308 Laktationstage ergab mittels einfacher linearer Regression einen geringeren Wert von 0,243±0,057 bezogen auf die kürzeste Laktationslänge, aber bezogen auf das letzte Prüfergebnis wurden vergleichsweise leicht verbesserte Schätzwerte von 0,295±0,063 bzw. 0,314±0,065 ermittelt, Die Ergebnisse der Analyse mittels Tiermodell zeigten, dass die gesamten Schätzwerte des tatsächlichen Milchertrages bei 9,1 % lagen, während diejenigen für die 308 Laktationstage, verglichen mit dem letzten Kontrollergebnis oder dem durchschnittlichen täglichen Milchertrag 10,7 bis 12,0 % betrugen.

Schlüsselwörter: Nili-Ravi, Büffel, Milchertrag, Heritabilität, Laktationslänge

1.   Introduction

Inclusion of incomplete lactations along with completed lactations helps reduce the bias in ranking of bulls for breeding values. Early estimates of sires' breeding values by extending incomplete lactations can also help to reduce the generation interval. The projected records can also be used to estimate cows' producing abilities while their lactations are still in progress and facilitate the farmers for early culling decisions. Duration of lactation length is the main criteria to declare any record complete or incomplete as information on reasons of drying is usually not available.

One option to resolve the issue of extending records is to use completed records which means loosing more than 50% of the data if standard lactation is of 10 months which is not judicious utilization of resources and cause bias in ranking in breeding values for milk yield. The other option is to consider lactations of shorter duration as the ability of the buffalo and not project such lactations declaring them as completed lactations. Previously such suggestions have been made both for cows (VAN VLECK and HENDERSON, 1961) and buffaloes (KHAN, 1986). The problem with such a decision is that which lactation should be declared shorter i.e., a lactation of 60 days or a lactation of 285 days. Different cut offs are available in the literature ranging from 28 to 285 days and the issue has previously been discussed (KHAN, 1996). Another solution is to project all records, complete or incomplete. This is being followed in US production system. NORMAN et al. (1985) has suggested this strategy for Holsteins due to better genetic parameters of projected records and also because credit given to a cow of completed lactations is very little when projection is based on last record-day yield as prediction is made only for unknown part of the lactation.

For buffaloes, procedures to project incomplete lactations using last record-day information have been developed but credit given to a buffalo for unknown lactation period depended only on the lactation length and last recorded milk yield. The procedure was more accurate than the other methods of projection yet, it did not differentiate between high and low producing buffaloes with similar last recorded milk yield. KHAN et al. (2005) presented an improvement of the last record-day procedure by including the average milk yield of the recorded lactation period. The method had a lesser bias, improved accuracy and credit given to a lactation of certain duration was more reasonable than if last record-day information was used as the only predictor. The impact of this improved prediction method on genetic control of projected milk yield is presented in the present study.

2.   Materials and Methods

Milk yield records of 993 Nili-Ravi buffaloes, maintained at Livestock Experiment Station, Bahadurnagar, Okara were used for the present study. A total of 2704 lactations were available with lactation length of at least 60 days. If milk yield was missing for any week, it was estimated by averaging previous and next available weekly record. However, if milk yield information was missing for more than 56 days consecutively, such records were excluded. Errors in data entry were minimized by deleting outliers and allowing a maximum of 100% increase/decrease between two consecutive weeks. Season of calving was defined as summer (for buffaloes calving from April to September) and Winter (for buffaloes calving from October to March).

Adjustment procedures
Five types of adjustments for adjusting shorter lactations to 308-day yield were considered.

1. Milk yield adjusted by using a simple regression equation proposed by KHAN (1986). The adjusted milk yield using this simple linear regression was named as MYSRF.

2. Milk yield adjusted by using factors calculated on the basis of last record-day procedures (KHAN and IQBAL, 1996). All lactations of ≥308 day duration were used for the calculation of equations to predict future milk yield and the adjusted lactation milk yield was called MYATYP. In this adjustment procedure 308-day milk yield was estimated using last record-day yield information (milk yield of morning and evening milkings added together on the last record). The 308-day milk yield was estimated as follows:

$$\hat{Y}_{308} = Y_t + \hat{Y}_f (308 - DIM)$$

Where $\hat{Y}_{308}$ is extended 308-day milk yield for lactation of any length; Y_t is total milk yield produced before the termination of lactation or milk yield of recorded lactation, DIM is days in milk and $\hat{Y}_f$ is Predicted daily milk yield for unknown part of lactation was estimated as follows:

$$\hat{Y}_f = a + b X_i$$

Where, $\hat{Y}_f$ is predicted future daily yield at any lactation length, a is the intercept, b is the regression coefficient, X_i is the available milk yield on the last record-day at any lactation length

3. Milk yield adjusted by using factors calculated on the basis of last record-day procedure, similar to 2) above but excluding lactations that were atypical.
To determine whether a lactation is typical or atypical, a gamma-type function Wood (1967) was used as follows:

$$Y = a\, b^n\, e^{-cn}$$

Where, Y is daily milk yield (kg), recorded at a weekly interval, n is week of lactation length (1 to 44) and a,b,c represent coefficients representing intercept, rate of increase towards peak and rate of decline from the peak.
The logarithmic form of the model given below was applied to individual lactations.

$$\ln(Y) = \ln(a) + b \ln(n) - c\, n$$

Lactations were considered atypical if b in the above model was negative (i.e., a decline in milk yield after calving, instead of an increase) or if c in the above model was positive (i.e., an increase after the peak instead of a decline). There were 253 such lactations leaving 2451 lactations to be used for the development of regression equations. The factors developed were used to estimate 308-day milk yield and the estimated lactation milk yield variable was named as MYTP1.

4. To utilize short lactations (< 308 days) a ratio of the milk yield to be estimated and last record-day yield was obtained [ratio = (308-day milk yield - milk yield for recorded lactation) / last record-day milk yield] from the 308-day complete lactations and 308-day yield was estimated for the short lactations. This made it possible to estimate future daily yield and the regression equations could be developed from all the data set to predict future daily yield and then the 308-day yield. The predicted 308-day yields were called MYTP2.

5. To account for variation in the behavior of lactation curves for low and high producing animals with a similar last record-day yield, regression equation to predict future daily milk yield was modified. Future daily yield for the short lactations was not only predicted from the last record-day yield available (KHAN and IQBAL, 1996; AKRAM, 1997) but average daily yield of the known part of the lactation was also utilized. The regression equation was as follows:

$$\hat{Y}_f = a + b_1 X_1 + b_2 X_2$$

Where $\hat{Y}_f$ is predicted future daily yield at a certain lactation length, a is the intercept, b_1 and b_2 are regression coefficients and X_1 is available milk yield on the last record-day at a certain lactation length and X_2 average daily milk yield of known part of the lactation at a certain lactation length. The 308-day milk yield was then predicted as described above and the predicted 308-day milk yield was named as MYTP3.

Heritability estimation

Heritability of un-extended (MYTOT) and extended milk yield (MYSRF, MYTP1, MYTP2, MYTP3) was estimated by paternal half-sib correlation assuming the following model.

$$Y_{ijkl} = \mu + Sire_i + YS_j + Age_k + e_{ijkl}$$

Where

Y_{ijkl} Milk yield up to 308-days of lactation (extended or un-extended)

μ Population mean

$Sire_i$ Random sire effect

YS_j Fixed effect of year and season combination of calving (1 to 54)

Age_k Fixed effect of age defined within parity, 35 age classes defined within parity (KHAN and IQBAL, 1996)

e_{ijkl} Random error

The ratio of sire variance to total variance from the above model was multiplied by 4 for heritability estimation. For the individual lactations, model was similar to the above except that age classes were limited for that particular parity. Data sets used for the estimation of heritability and repeatability of lactation milk yield by including records of various lactation lengths were the same except that cows were the random source of variation in the repeatability model and adjacent years were pooled into periods, called year groups.

Additive and permanent environmental variances were also calculated fitting an individual Animal Model for the four variables of 308-day milk yield and lactation length. The model was as follows:

$$Y_{ijk} = YS_i + Anim_j + Perm_j + b_1 Age + b_2 Age^2 + e_{ijk}$$

Where

YS_i Combined effect of year and season of calving

$Anim_j$ Random animal genetic effect

$Perm_j$ Random permanent environmental effect

b_1 and b_2 Regression coefficients

Age   Age at calving (in months)

e_{ijk} Random temporary environment effect (residual effect).

For linear models and regression analysis SAS® (1990) was used while for heritability and repeatability estimation, LSMLMW (HARVEY, 1990) was used. Calculation of additive genetic and permanent environmental variance through Animal Model was accomplished by Derivative Free Restricted Maximum Likelihood (DFREML) software (MEYER, 1997).

3.   Results and discussion

Basic statistics

Frequency distribution of lactations according to lactation length (or days in milk) indicated that out of 2704 lactations having more than 56 days of duration, 59.2% had shorter lactation than 308 days of duration (Table 1). If minimum was increased from 56 to 112 days, this included 3.0% of all the lactations. Buffaloes with lactations of more than 182 days duration were 89.2% of the data set. It may be mentioned that lactations with lactation length (LL) of less than 56 days were not included in the data set and the values do not represent population averages. Such lactations were less than 5% of the total lactations included the study period. Expected shorter lactations had lower milk yield as compared to the complete or longer lactations. Milk yield averaged 1984.4 kg with a standard deviation of 773.43 kg when information up to 308 days was used. Lactation length for these records averaged 266.6 days with a standard deviation of 55.15 days. Actual average lactation length of these records was 289.6±82.12 days. Very short lactations (56-77 days in milk) had average milk yield of 347.1 kg with a standard deviation of 148.53 kg.

Table 1
Frequency distribution of lactations by lactation length and averages (±SD) of milk yield and lactation length (Beschreibung der unterschiedlichen Laktationslänge und des jeweiligen Milchertrages)

Lactation length (days)	N	%	Lactation length	Milk yield
56-77	30	1.1	75.0±12.00	347.1±148.53
84-105	51	1.9	106.1±24.82	549.1±186.50
112-133	56	2.1	133.0±25.40	704.0±174.89
140-161	79	2.9	160.6±19.41	858.0±287.64
168-189	98	3.6	184.6±14.21	1066.3±308.29
196-217	207	7.6	213.0±11.12	1326.7±355.36
224-245	270	10.0	239.5±14.39	1694.6±471.03
252-273	422	15.6	267.8±09.26	1954.2±503.18
280-301	389	14.4	294.4±08.30	2198.2±622.37
≥ 308	1102	40.8	307.0±08.07	2453.5±618.78
OVERALL	2704	100.0	266.6±55.15	1984.4±773.43

Actual vs Predicted milk yield

Regression equations were developed for adjusting lactations to a standard lactation length of 308-days using the last record-day information. Predicted yields were calculated both from the regression equations when atypical lactations were in the data set (MYATYP) and when such lactations were excluded (MYTP1). Milk yield using the correction factors developed by KHAN (1986) and currently being used were also predicted (MYSRF). Actual lactation milk yield (MYTOT) and extended lactation milk yield (MYSRF, MYATYP, MYTP1, MYTP2 and MYTP3) along with standard deviations using different procedures of adjusting for 308-days yield are presented in Table 2. The actual lactation milk yield was 1984.4 kg for an average lactation length

of 266.6 days (yield beyond 308-days excluded). The difference of actual and predicted gradually reduced with increase in lactation length. When extrapolation was made using last record-day information (i.e. predicting yield of unknown part of the lactation period only (MYATYP, MYTP1), predicted yield had lesser variation however, as compared to when a linear regression was used (651.99 to 655.62 kg standard deviation as compared to 772.52 kg). Predicted milk yield was generally higher (except for 56-77 days of lactation length) when prediction equations included all the records (MYATYP) as compared to using typical lactations only (MYTP1). Difference between MYATYP and MYTP1 however, was small and reduced to almost zero for lactations with lactation length nearer to 308 days. The variable MYATYP was thus dropped from further analysis.

When shorter lactations were included in the development of prediction equations (MYTP2, MYTP3), predicted milk yield was lower as compared to predicted milk yield from equations using lactations with ≥308 days of duration (MYTP1). This was especially true for shorter lactation length groups. Predicted milk yield for 56-77 days lactation length group was 1417.1, 1137.4 and 1099.1 kg for MYTP1, MYTP2 and MYTP3, respectively (Table 2). The difference among the three variables however, reduced for higher lactation length groups. The standard deviation of bias and correlation between actual and predicted lactation milk yield indicated that inclusion of average daily milk yield as a predictor along with the last record-day milk yield was a better choice when all lactation records were used (MYTP2 vs. MYTP3). It decreased standard deviation of bias and improved the correlation between actual and predicted milk yield. Lower values of bias and better correlation between actual and predicted milk yield for MYTP1 were due to the analysis of completed lactations only.

Table 2

Average ± standard deviation of milk yield for different lactation length classes (Mittelwert und Standardabweichung der Milchleistung der unterschiedlichen Laktationslängengruppen)

Lactation length (days)	MYTOT[1]	Milk yield adjusted for lactation length				
		MYSRF[2]	MYATYP[3]	MYTP1[4]	MYTP2[5]	MYTP3[6]
56-77	347±148.5	347±148.5	1413±433.2	1417±438.9	1137±458.7	1099±455.7
84-105	549±186.5	549±186.5	1458±437.4	1436±442.8	1197±462.8	1190±444.8
112-133	704±174.9	704±174.9	1407±275.4	1377±280.7	1171±291.0	1178±292.6
140-161	858±287.6	858±287.6	1407±378.1	1371±384.9	1226±394.0	1225±408.8
168-189	1066±308.3	1178±405.1	1497±370.7	1478±373.9	1380±376.0	1390±390.2
196-217	1327±355.4	1825±481.5	1673±395.7	1664±396.5	1594±399.1	1596±412.4
224-245	1695±471.0	2147±688.3	1948±499.5	1943±500.0	1904±501.6	1907±510.4
252-273	1954±503.2	2205±559.2	2099±509.7	2097±509.8	2079±510.9	2083±516.6
280-301	2198±622.4	2282±640.1	2254±624.7	2253±624.8	2249±626.1	2252±628.7
≥ 308	2454±618.8	2454±618.8	2454±618.8	2454±618.8	2453±618.6	2453±618.5
Overall	1984±773.4	2123±772.5	2140±652.0	2138±655.6	2105±522.1	2107±688.1

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; all lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[6]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.

Environmental factors and phenotypic trends
F-values from analysis of variance for various factors affecting lactation milk yield are presented in Table 3. Milk yield traits were significantly affected by variation due to cows. Actual lactation milk yield (MYTOT) and adjusted milk yield (MYSRF and MYTP1, MYTP2, MYTP3) were 44.2, 40.3, 43.0, 43.0 and 43.1 % repeatable. Year of calving groups also significantly affected these yield traits as did the season of calving and interaction between the two.

Table 3
F-values from analysis of variance for various factors affecting lactation milk yield (F-Werte der Varianzanalyse für die Milchleistung beeinflussenden Varianzfaktoren)

Source	df	MYTOT[1]	Milk yield adjusted for lactation length			
			MYSRF[2]	MYTP1[3]	MYTP2[4]	MYTP3[5]
Cow (random)	992	3.08**	2.77**	2.98**	2.98**	2.99**
Year group	13	31.31**	23.77**	29.58**	29.50**	29.79**
Season of calving	1	9.92**	7.24**	8.39**	9.62**	10.74**
Year group*Season	13	2.70**	2.59**	2.91**	2.99**	3.02**
Days in milk (grouped over weeks)	36	50.16**	35.81**	13.80**	19.62**	19.52**
Age within parity	34	4.44**	4.33**	4.03**	3.98**	3.96**
Error	1614					

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.
** Significant (P < .01)

The overall mean (±SE) for the three milk yield variables were 1332.0±29.19, 1484.1±31.10, 1810.22 ±29.99, 1692.0±30.06 and 1690.4±30.20 kg, respectively. Actual lactation milk yield and 308-day adjusted milk yield generally decreased across the years. Maximum values for MYTOT, MYSRF and MYTP1 were 1957.0±159.90, 2041.5±180.25, 2410.5±167.26, 2297.3±165.89 and 2309.4±166.35 kg, respectively for 1970-71, where after it decreased to the lowest values in 1980-81. Then there was a slightly increasing trend but values with an overall negative trend across the years. The lowest values for 1980-81 can be attributed to heavy rain falls, resulting in forage shortage in these years (DAHLIN, 1998). The overall mean is lower than the earlier reports (KHAN, 1996; KHAN and IQBAL, 1996) because of inclusion of shorter lactations in the present study. The adjusted milk was higher as compared to the actual milk yield because of adjustment to a higher base (308-days) as compared to the average (266 days) as mentioned earlier. Huge difference between the MYSRF and MYTP1 was because in MYSRF extrapolation of records for less than 180 days was not possible for shorter lactations and milk yield was assumed as the production potential of the animals (KHAN, 1986). Values for MYTP2 and MYTP3 were lower than MYTP1 because shorter lactations had been included in the development of regression equations.
Winter calvers had a significantly higher actual milk yield (1364.5±31.63 kg) as compared to summer calvers (1299.4±30.28 kg). Seasonal affects were however, not consistent across the years, resulting in a significant year by season interaction for all the lactation milk yield variables. Age within parity significantly (P<.01) affected milk yield. There was no clear trend for age groups within parities. For second parity buffaloes however, younger calvers had lower milk yield as compared to the older

buffaloes but buffaloes calving at a very old age again had a lower estimate for actual (MYTOT) and adjusted milk yield (MYSRF, MYTP1, MYTP2 and MYTP3). It increased towards third parity (1438.2±61.93) being maximum there and then followed a gradual decline. Trend was similar when milk yields had previously been adjusted for a lactation length (MYSRF, MYTP1, MYTP2 and MYTP3) and highest estimates were observed for MYTP1 as discussed previously.

Weeks in milk had a significant effect on lactation milk yield yet, as evident from the F-values (Table 3), the effect reduced to a greater extent when lactations had been adjusted for lactation length. For adjusted lactation milk yields, adjusted lactation yields from last record-day information (using complete lactations of 308-day duration) had lower F-values (13.80) as compared to the adjustments by simple linear regression procedure where F-value for this effect was 35.81. F-values for MYTP2 and MYTP3 were 19.62 and 19.52, respectively. As mentioned previously, there was over adjustment using simple linear regression procedure as compared to the adjustments from last record-day information. A dip in the milk yield at 11th week of lactation was due to very few observations for shorter lactations and some influential observations. Among the last record-day adjustment procedures, MYTP1 had higher values as compared to MYTP2 and MYTP3.

Lactation milk yield is most commonly reported performance trait for buffaloes. Lactation milk yield has been quite variable among and even within breeds. Simple lactation averages do not tell much about this trait unless other traits controlling most of variation in it are reported. CADY et al. (1983) reported that adjusted milk yield (for environmental effects) was 1883±60 kg for a lactation length of 282 days in Nili-Ravi buffaloes. Milk yield adjusted to 305-days of length and age at calving to 60 months have been reported to be 2022±14.8 kg. First parity buffaloes had an average of 1922±21.9 kg while average milk yield for later parity buffaloes was 2078±19.5 kg (KHAN, 1996). Average milk yield for Italian buffaloes have been reported to be 1963 kg with standard deviation of 614 kg and an average lactation duration of 268±67 days (PILLA and MOIOLI, 1992).

Genetic parameters

Heritability estimates of milk yield using paternal half-sib correlation method are presented in Table 4. For 2235 observations having sire identification, and lactation length of ≥ 56 days, heritability for actual milk yield (MYTOT) averaged 0.244±0.057. For lactation records adjusted by linear regression procedure (MYSRF) heritability estimate was similar (0.243±0.057). For lactation yields adjusted by using last record-day information (using completed lactations, MYTP1) however, heritability of milk yield was 0.314±0.065. When shorter lactations were used in the development of regression equations (MYTP2 and MYTP3) heritability estimates were 0.299±0.063 and 0.295±0.063, respectively. When data set was restricted by lactation length i.e. more completed lactations, heritability generally increased indicating that environmental portion of the variance decreased. For the data set having ≥280 days of lactation length, milk yield was 34-35% heritable. The actual 308 days lactation milk yield had a heritability of 26.2%. For MYTP3, where lactation milk yield adjustments were more precise as compared to the MYTP1 and MYTP2, heritability estimates were slightly lower (but statistically similar) than MYTP1 for

data sets having shorter lactations. Unadjusted milk yield (MYTOT) always had higher environmental and lower additive genetic variance.

Table 4
Heritability estimates of milk yield for different lactation length groups (Heritabilitätsschätzwerte der Milchleistung für die unterschiedlichen Laktationslängengruppen)

Lactation length (days)	Obs.	MYTOT[1]	Milk yield adjusted for lactation length			
			MYSRF[2]	MYTP1[3]	MYTP2[4]	MYTP3[5]
≥ 56	2235	0.244±0.057	0.243±0.057	0.314±0.065	0.299±0.063	0.295±0.063
≥ 84	2203	0.277±0.061	0.276±0.061	0.321±0.066	0.310±0.065	0.309±0.065
≥ 112	2159	0.276±0.061	0.282±0.062	0.323±0.066	0.309±0.065	0.309±0.065
≥ 140	2109	0.282±0.063	0.297±0.064	0.325±0.067	0.312±0.066	0.311±0.066
≥ 168	2046	0.286±0.064	0.312±0.067	0.325±0.068	0.313±0.067	0.313±0.067
≥ 196	1965	0.290±0.066	0.321±0.069	0.327±0.070	0.315±0.068	0.314±0.068
≥ 224	1807	0.316±0.071	0.347±0.074	0.351±0.075	0.345±0.074	0.345±0.074
≥ 252	1608	0.296±0.073	0.338±0.078	0.326±0.076	0.325±0.076	0.325±0.076
≥ 280	1286	0.336±0.087	0.341±0.088	0.342±0.088	0.354±0.089	0.354±0.089
≥ 308	964	0.262±0.096	0.262±0.096	0.262±0.096	0.262±0.096	0.262±0.096

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.

Although, observations for the analysis of individual parities were limited, heritability increased with increase in parity (Table 5). Milk yield adjusted by using last record-day milk yield (MYTP1) had higher values for most of the parities. Variance for some of the parities could not be estimated due to confounding.

Table 5
Heritability estimates of milk yield for different parities (Heritabilitätsschätzwerte der Milchleistung bei unterschiedlicher Laktationsnummer)

Parity	Obs.	MYTOT[1]	Milk yield adjusted for lactation length			
			MYSRF[2]	MYTP1[3]	MYTP2[4]	MYTP3[5]
1	595	0.054±0.121	-	0.173±0.132	0.124±0.127	0.136±0.129
2	485	0.134±0.155	0.231±0.162	0.218±0.161	0.155±0.157	0.181±0.158
3	375	0.280±0.200	0.226±0.196	0.198±0.194	-	0.225±0.198
4	280	0.662±0.279	0.614±0.278	0.836±0.285	-	0.715±0.282
≥5	503	0.204±0.133	0.398±0.157	0.441±0.161	0.449±0.163	0.470±0.165

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.

Repeatability estimates had trend similar to the heritability estimates (Table 6). Actual lactation milk yield was less repeatable as compared to MYTP1. Extending records using last record-day procedures resulted in higher heritability and repeatability estimates as compared to actual milk yield (MYTOT) or milk yield extended by using simple regression procedure (MYSRF). Adjusted milk yield using last record-day information and information of average daily milk yield of the known part of the lactation curve (MYTP3) had repeatability of 49 to 54% when data sets of different lactation duration were included.

Table 6

Repeatability estimates of milk yield for different lactation length groups (Wiederholbarkeitsschätzung für Milchertrag bei unterschiedlichen Laktationslängengruppen)

Lactation length (days)	Obs.	MYTOT[1]	Milk yield adjusted for lactation length			
			MYSRF[2]	MYTP1[3]	MYTP2[4]	MYTP3[5]
≥ 56	2235	0.463±0.022	0.437±0.023	0.493±0.022	0.495±0.022	0.494±0.022
≥ 84	2203	0.471±0.022	0.439±0.023	0.492±0.022	0.494±0.022	0.492±0.022
≥ 112	2159	0.484±0.022	0.456±0.023	0.496±0.022	0.497±0.022	0.495±0.022
≥ 140	2109	0.485±0.023	0.461±0.023	0.501±0.022	0.501±0.022	0.500±0.022
≥ 168	2046	0.494±0.023	0.473±0.023	0.509±0.023	0.509±0.022	0.509±0.023
≥ 196	1965	0.500±0.023	0.488±0.024	0.516±0.023	0.515±0.023	0.516±0.023
≥ 224	1807	0.492±0.025	0.485±0.025	0.512±0.024	0.512±0.024	0.512±0.024
≥ 252	1608	0.517±0.026	0.535±0.025	0.529±0.025	0.533±0.025	0.530±0.025
≥ 280	1286	0.539±0.029	0.543±0.029	0.540±0.029	0.546±0.029	0.540±0.029
≥ 308	964	0.524±0.038	0.524±0.038	0.524±0.038	0.524±0.038	0.524±0.038

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.

Table 7

Data structure for Animal Model analysis of lactation milk yield and lactation length (Datenstruktur der Tiermodellanalyse für Milchertrag und Laktationsdauer)

Description	Number
No. of records	2235
No. of animals	1023
No. of "Base" animals	300
No. of animals with records	780
No. of animals with unknown/pruned sire	158
No. of animals with unknown/pruned dam	197
No. of sires with progeny records	78
No. of dams with progeny records	419
No. of grand-sires with progeny records	66
No. of grand-dams with progeny records	243

Results from Animal Model analysis (Table 7) to estimate heritability and repeatability are presented in Table 8. Estimates were much lower as compared to PHS method. Actual milk yield was only 9.1% heritable. MYSRF and MYTP1 had heritabilities of 8.1 and 12.0% respectively (Table 8).

Table 8
Estimates of genetic and phenotypic variances and genetic parameters under Animal Model (Schätzwerte der genetischen und phänotypischen Varianz sowie der genetischen Parameter mittels Tiermodell)

Description	MYTOT[1]	Milk yield adjusted for lactation length			
		MYSRF[2]	MYTP1[3]	MYTP2[4]	MYTP3[5]
Additive genetic σ^2	47555.7	42470.8	43330.6	43945.8	42392.6
Second animal σ^2	201231.2	190481.2	137793.6	155356.7	157300.4
Error σ^2	276014.2	288792.3	178972.7	196577.5	197084.6
Phenotypic σ^2	524801.5	521744.4	360097.0	395879.5	396777.6
Heritability	0.091±0.047	0.081±0.041	0.120±0.055	0.111±0.052	0.107±0.058
Repeatability	0.383±0.047	0.365±0.043	0.383±0.053	0.392±0.050	0.396±0.054

[1]Actual milk yield; [2] Prediction equations had lactation length (>180 days) only (KHAN, 1986).
[3]Prediction equations based on last record-day procedure; only typical lactations of ≥308 days duration were used in calculations.
[4]Prediction equations based on last record-day procedure; only typical lactations of ≥56 days duration were used in calculations.
[5]Prediction equations based on last record-day procedure but having daily milk yield also; only typical lactations of ≥56 days duration were used in calculations.

Repeatability estimates were in the range of 36.5 to 38.3%, with MYSRF having repeatability of 36.5% and the MYTOT and MYTP1 having estimate of 38.3%. CADY et al. (1983) reported that for lactations of >60 days length, within herd heritability was 25.4 % but reduced to 7.1% for records of 305-days duration. Repeatability of the milk yield (22.9 to 26.5 %) was higher for lactations of >60 days duration as compare to lactations of 305-days. METRY et al. (1994) reported that heritability of milk yield increased as the records of shorter duration were deleted, similar to the present study. NORMAN et al. (1985) used first and second lactation records of U.S dairy breeds and suggested extension of all lactation records (complete or incomplete) for evaluation of animals.

Results of the Animal Model suggested that milk yield was 10-12% heritable with a repeatability value between 35-40%. The conclusions of PHS analysis did not change regarding the extension of milk yield using last record-day milk yield or by simple linear regression procedure. The extended records had better genetic parameter estimates and although, information on the reasons of shorter lactations was very limited, lactation milk yields extended by last record-day procedure using especially the average daily milk yield for the known part of the lactation, improved adjustments and heritability and repeatability estimates.

The studies that have suggested the use of lactation length as the only trait for selection because when milk recording is difficult at field level (DAHLIN, 1998) are based on the completed lactations where lactation length was adjusted as a fixed effect to estimate genetic and environmental factors. The review of SYRSTAD (1993) for zebu cattle also concludes that either the shorter lactations should be used as such (un-extended) or a selection index having lactation length and milk yield be used. Present study does not agree with both of the mentioned studies because methods of extending shorter lactations from last record-day information can more precisely estimate credit given to an incomplete or completed lactations especially when average daily milk yield is included among the predictors. Standard lactation milk yield could be more precisely predicted and the genetic parameter estimates improved. A detailed study has previously explored the issue of the development of a selection index (KHAN, 1997) to have appropriate weightage to both milk yield and lactation length (SYRSTAD, 1993; DAHLIN, 1998). It was concluded that although, genetic correlation between the two trait is high (0.70) and inclusion of lactation length in a selection index with milk yield could improve the selection response slightly (104 vs 103 kg) absence of precise selection weights and complexity of multiple trait model did not justify the use of such a selection index for Nili-Ravi buffaloes. Test-day models are being developed for use in buffaloes like other species (HORSTICK and DISTL, 2002; AMIN, 2003; BÖMKES et al., 2004; HINRICHS et al., 2006) but data formats require drastic changes to incorporate these models for recording and selection of buffaloes, similar to those suggested (SWALVE, 1995) for cattle breeds.

Phenotypic trend in lactation milk yield was negative in the present study. Heritability estimates improved when lactations were adjusted to 308 days even if information on reasons for lactations to be shorter was not available / used. Data were limited for Animal Model analysis yet adjusted records had higher heritability and a similar repeatability estimates. Shorter lactations (completed or incomplete) should be projected to a standard such as 305-days by using last record-day yield and average

daily milk yield information to have better additive genetic variation and improved heritability and repeatability estimates and consequently faster improvement.

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