ILCA Research Report

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ARSI RURAL DEVELOPMENT UNIT (ASELA), and
INTERNATIONAL LIVESTOCK CENTRE FOR AFRICA
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ABSTRACT

Analyses were carried out on a range of performance traits and productivity estimates for indigenous Arsi and Zebu cattle and eight different grades of these crossed with Jersey and Friesian, maintained for milk production. Data covered the period 1968 to 1981, and the animals were kept at Asela station and on surrounding smallholder farms in the Arsi Region of Ethiopia. Major points to emerge concerning overall productivity were the clear superiority of all crossbreds over the indigenous breed groups; the similarity in performance of the 75% *Bos taurus* and the 50% *Bos taurus*; the similarity in performance between indigenous Arsi and Zebu; and the major advantages of calving in the wet season compared with the rest of the year. Production levels on smallholder farms were similar to those on Asela station and, based on annual milk yield, the rankings of the four crossbred groups kept on smallholder farms were the same as their rankings on Asela station.

KEY WORDS

/Breeding/ /dairy cattle/ /crossbreeding/ /productivity indices/ /smallholder/ /Ethiopia/ /Jersey/ /Friesian/ /Zebu/ /Arsi cattle/

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PREFACE

Development of the dairy industry in most African countries is crucially dependent on production by smallholders, each owning a small number of cows. Experience throughout the world has shown that the choice of breed for these small-scale enterprises is a key determinant of both biological efficiency and profitability. Small-scale dairy development in Ethiopia is comparatively recent: the number of specialist dairy enterprises is small and these are largely concentrated around the major cities. In a few rural areas like the Arsi Region, where integrated agricultural development projects have been implemented through individuals, producer cooperatives and peasant associations, there is great potential for dairy development.

The most intensive small-scale dairy development in Ethiopia was initiated by the Chilalo Agricultural Development Unit (CADU) in 1967 and since 1976 has been operating under the Arsi Rural Development Unit (ARDU). A major livestock activity of both CADU and ARDU has been the production of crossbred dairy heifers for distribution to farmers in order to establish dairy production enterprises. Services provided by ARDU to various farmers' groups include preparation and distribution of semen, disease control, forage crop introduction and milk recording, while a dairy research programme has been carried out at Asela station in the same region. Crossbreeding data on dairy production collected from Asela research station and from smallholder farms by ARDU provide the information for decisions on breed types to be used.

Three recent papers in *World Animal Review* have reported on aspects of production data collected from 1969 to 1974. The present ILCA/ARDU study is a detailed analysis of data collected by ARDU from 1968 to 1981 with the objective of evaluating the comparative efficiencies of various breed groups of indigenous and crossbred cattle and their suitability for dairy production under smallholder conditions. The major part of the report deals with the general performance of indigenous and crossbred cattle at Asela station. Particular emphasis is laid on the evaluation of dairy productivity indices to allow efficient comparisons of breed groups. A short section towards the end of the report analyses productivity data from smallholder dairy farms during the consolidation phase of CADU's activities (1969-1975), while the final section examines the applicability of the results from Asela station to practical farming conditions. The effects of upgrading indigenous cattle to *Bos taurus*, the implications of larger body size of crossbreds in relation to feed requirements and availability, and the multi-purpose aspects of the dairy industry in Ethiopia are discussed.

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CONTENTS

BACKGROUND

INTRODUCTION

Asela station was established in 1967/68 in the Chilalo District of the Arsi Region of Ethiopia (Figure 1). It was designed as a component of the Chilalo Agricultural Development Unit (CADU), an integrated project established jointly by the Ethiopian and Swedish Governments. The activities of CADU have been expanded since 1975 and are currently part of the Arsi Rural Development Unit (ARDU). The investigations analysed and reported here were set up with the objectives of:

1. Comparing the important performance traits of indigenous, crossbred and high grade dairy cattle on the station.
2. Measuring the environmental influences (years, seasons, etc) on dairy production traits.
3. Deriving relevant dairy productivity indices for the various breed types.
4. Assessing the initial performance of these crossbred cattle under smallholder dairy farming conditions in the surrounding areas.

Preliminary results from the breeding work at Asela station and with nearby smallholders have been reported by Brannang et al (1980), Schaar et al (1981), and Swensson et al (1981). However, detailed assessment of the overall productivity of crossbred and high grade animals under station and smallholder dairy farming conditions has hitherto not been made.

The Arsi Region covers 24 500 km², or 2% of the total area of Ethiopia. Cultivated land comprises 20.4%, forest land 3.9%, pasture land 9.8%, and fallow and waste land 65.9% of the region. The region varies in altitude and the cropping patterns include both highland and lowland crops. The major crops are barley, wheat, pulses and oil crops, teff, maize and sorghum, in that order. The human population is estimated at 1.34 million, and at 54 per km² is relatively high compared with other Ethiopian regions. Livestock are a major agricultural resource, there being 1.5 million cattle, 0.97 million sheep and goats, and 0.32 million draught animals.

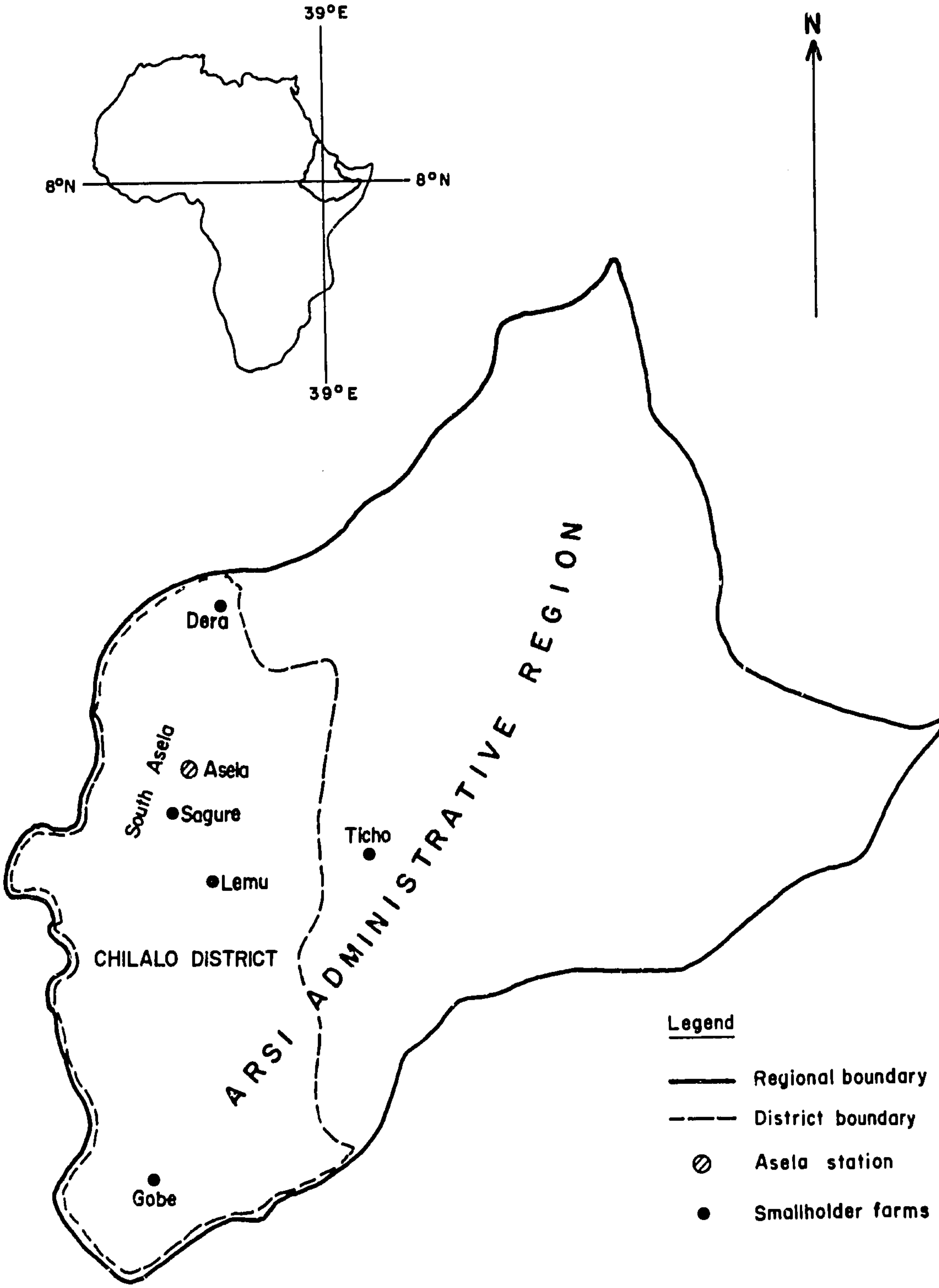
ASELA STATION

Asela is situated about 180 km southeast of Addis Ababa in a highland plateau region rising to a height of 2000 - 3000 m. Both Arsi Region and Asela station are characterized by mild subtropical weather with maximum and minimum temperatures ranging from 18° to 28°C and 5° to 10°C respectively. The station experiences bimodal rainfall, with an annual average precipitation of 1300 to 1350 mm. Short rains occur during March and April, followed by long rains during July to September. The long dry season lasts from November to February, and a short dry spell is experienced in May and June. The average distribution of rainfall at Asela station is illustrated in Figure 2. Precipitation and altitude rather than temperature are generally considered to be the most important factors determining vegetation conditions. The vegetation consists of annual legumes and perennial grass species. The natural pastures include *Chloris gayana, Setaria sphacelata, Panicum coloratum* and a number of useful legumes such as *Trifolium semipilosum, Glycine wightii* and *Trifolium burchellianum.* Asela station, and Chilalo District in general, are characterized by a rather mild climate with few livestock production problems from external parasites such as ticks and flies. In this area, formerly recognized as cattle country, farming activities are gradually switching to cropping.

CATTLE

Crossbreeding with introduced breeds started at Asela in 1967/68 with the objective of producing

Figure 1. *Arsi Region and Chilalo District of Ethiopia.*



F_1 heifers consisting of ½ *Bos indicus* and ½ *Bos taurus* germplasm. The F_1 would later be upgraded to produce varying levels of *Bos taurus* inheritance (CADU, 1970). The original plan was to use germplasm from the Jersey and Friesian breeds on the local Arsi type. It was also intended that other local breed types, such as the Fogera, Barca and Boran, would be incorporated into the scheme. However, the use of Jersey semen from Kenya was discontinued in 1970, when it was found that the F_1 progeny had small teats which were inconvenient for milking. Farmers also preferred, and asked for, the larger sized F_1 Friesian crosses. The indigenous foundation cows were purchased from local markets. They included 200 Arsi, 22 Fogera, 16 Barca and 10 Boran cows. These together with some others kept at the nearby Gobe station provided the basic stock for crossbreeding. Due to the demand for crossbred cattle from farmers, 40 Friesian x Boran crosses were imported from Kenya to supplement the project. The Arsi, Boran, Fogera and Barca were later upgraded to the 50%, 75% and 87.5% Friesian levels. The Jersey-based F_1 crosses were upgraded to Friesian germplasm only.

HERD MANAGEMENT

Newly purchased local heifers were restricted in quarantine for a period of at least 3 weeks. They were checked for disease and were put on liberal feeding regimes based on pasture, hay and concentrates. After entering the breeding herd, animals continued to be grazed on pasture, and during the dry season hay or concentrates were fed. A number of short-term trials were carried out at various times on calf and cow feeding for growth and milk production. These provided guidelines for the proper management of dairy cattle under Ethiopian conditions, and the results were reported by Schaar et al (1981). The Arsi cows in these trials received concentrates for 4 months before parturition. After parturition they were supplemented at a rate of 0, 0.5 or 1.1 kg per kg of milk yield. The crossbred heifers received concentrates for 2 months before parturition and were then supplemented with 0, 0.25 or 0.5 kg per kg of milk. Different levels of concentrate feeding were discontinued after the first lactation. Thus, during the second and later lactations concentrates consisting of 48% Niger seed cake (residue of *Guizotia abyssinica* after oil extraction), 48% wheat bran, 3.5% bonemeal and 0.5% salt were fed to all animals at a rate of 2 to 4 kg per cow per day depending on the level of milk yield.

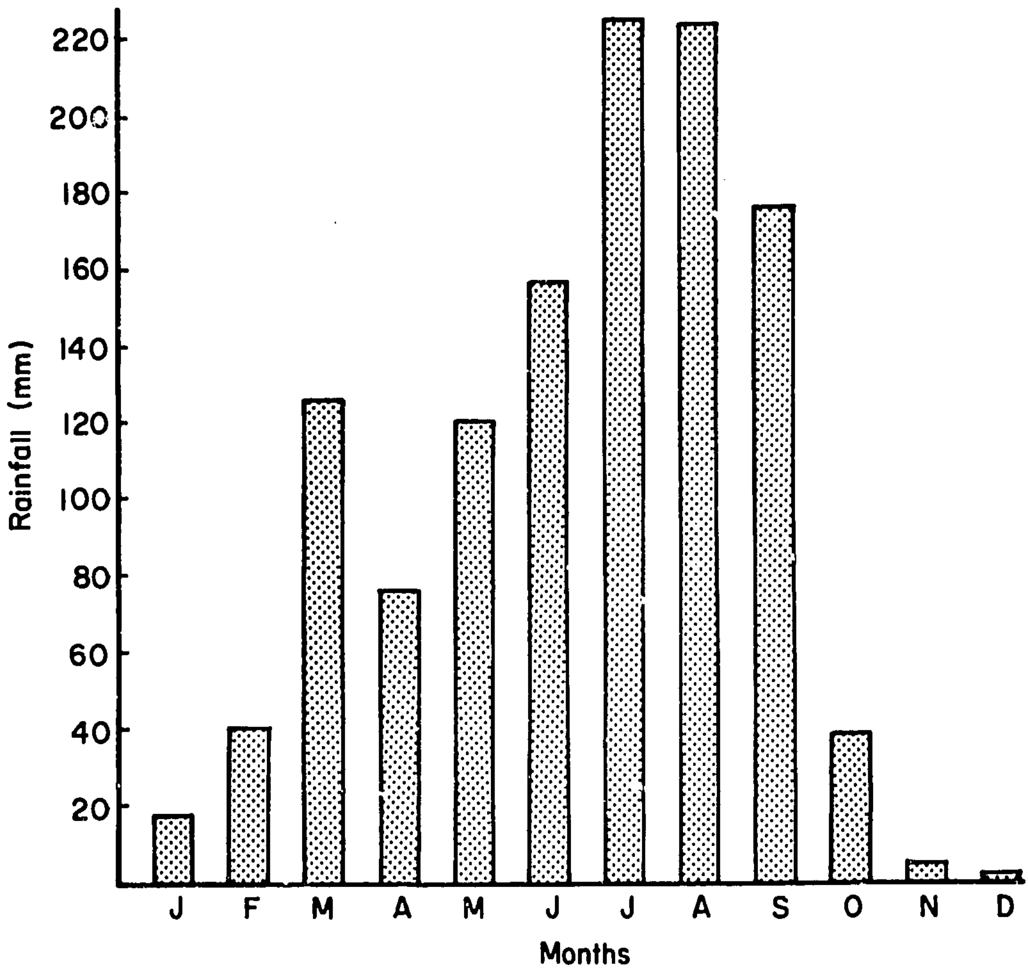
Cows were hand milked twice daily during the first 4 years until machine milking equipment was installed in 1972. Arsi cows, however, continued to be milked by hand and without their calves at foot, while crossbreds were gradually started on machine milking.

Newborn calves were taken away from their dams shortly after birth. They were bucket fed to weaning, which occurred at between 49 and 79 days. Colostrum and whole milk substitutes were fed to calves twice daily at the rate of 1.0 kg to 2.5 kg of milk equivalent per day. Animals were routinely vaccinated against anthrax, rinderpest, blackleg and pleuropneumonia. Regular dosing against internal parasites and measures against mastitis were undertaken. All crossbred calves were vaccinated against brucellosis, using S19 vaccine. Culling among the local Arsi breed was mostly based on very short lactations that exhibited milk letdown interference and poor temperament.

DATA RECORDING

All animals purchased were assigned individual eartag numbers. At each calving, the date, sire number, breed, sex, colour, weight and individual number of the calf were recorded. All abortions were noted. Body weights were taken at birth, puberty and after each parturition. Milk recording was initially carried out daily, but in 1973 was changed to either twice monthly or once every 3 weeks. Butterfat testing was also carried out on each milk yield recording day. Vaccinations and treatments against identified ailments were recorded. No individual supplementary feeding records were kept, except for the animals in feeding trials.

Figure 2. *Mean monthly rainfall at Asela station, 1968–1977.*



DATA PREPARATION AND ANALYSES

DATA PREPARATION

A number of factors were identified in the preliminary screening of the data at Asela that had a bearing on the analysis techniques to be used.

First was the largely disproportionate representation of the indigenous breed groups in the trial. The majority were Arsi, with smaller numbers of Fogera, Barca and Boran. The latter three breeds belong to the group characterized by the large East African Zebu. Additional crossbred Friesian x Boran heifers had also been purchased from Kenya to increase the number of Boran crosses. Thus it was decided that the Fogera, Barca and Boran animals could best be treated as a single Zebu group larger in body size than the Arsi.

Second, there had been from 1969 to 1973 irregular changes in breeding policy, milking and recording practices at Asela. Hand milking was practised from 1968 to 1972, then discontinued for the crossbreds but continued for the Arsi breed. Breeding policy had changed from crossbreeding with Jersey to crossbreeding with Friesian. The production of F_2 animals was dropped and straight upgrading was adopted. It was therefore decided to combine various genetic groups into the most appropriate grades of *Bos taurus* germplasm. This procedure would make it possible to determine environmental and breed group differences.

Breed groups. Data were available on ten breed groups:

1. The Arsi, which are the local dominant type found in the Arsi Region of Ethiopia; they are small in size (200 - 250 kg), and were the major foundation stock used in the crossbreeding scheme.
2. The Zebu, which consisted of three types - Barca, Fogera and Boran - native to other provinces of Ethiopia; they are larger framed, with heavier body sizes (300 - 350 kg) than the Arsi.
3. ½ Jersey ½ Arsi crossbreds, which were the products of first crosses between the Jersey *(Bos taurus)* and the Arsi *(Bos indicus)* breeds. Crossing between these two breeds was discontinued after the early phases of the crossbreeding scheme.
4. ½ Friesian ½ Arsi crossbreds, which were the products of first crosses between Friesian *(Bos taurus)* and Arsi *(Bos indicus)* breeds. Crossing between the two breeds continued as the first step in the upgrading that is still being practised today in Ethiopia.
5. ½ Friesian ½ Zebu crossbreds, which were the products of first crosses consisting of Friesian x Barca, Friesian x Fogera or Friesian x Boran. The Barca, Fogera and Boran are larger sized and originated in regions other than Arsi.
6. ½ Exotic ½ Arsi grades, which developed as a result of intercrossing between ½ Jersey ½ Arsi females and ½ Friesian ½ Arsi bulls. This group thus carried 25% of Jersey breed germplasm.
7. ¾ Friesian ¼ Arsi grades, which developed as a backcross of ½ Friesian ½ Arsi females to purebred Friesian bulls.
8. ¾ Friesian ¼ Zebu grades, which developed as a backcross of ½ Friesian ½ Barca, ½ Friesian ½ Boran, and ½ Friesian ½ Fogera females to purebred Friesian bulls.
9. ¾ Exotic ¼ Zebu grades, which resulted from upgrading ½ Exotic ½ Arsi cows to purebred Friesian bulls. This breed group thus retained ⅛ of the Jersey breed germplasm and ⅝ of the Friesian.
10. ⅞ Friesian ⅛ local grades, which consisted of a small number of high grade cattle of ⅞ Friesian ⅛ Arsi and ⅞ Friesian ⅛ Zebu that were grouped together.

Seasonal classification. Based on the rainfall records from 1968 to 1977, the months of the year were grouped into five subseasons covering the first and second parts of the dry season, the first and second parts of the long wet season, and the short wet season:

Months	Sub-seasons	Average rainfall (mm) per month	Average No. of rainy days per month
Oct-Dec	First part of dry	15	3
Jan-Feb	Second part of dry	30	5
March-May	Short wet	108	12
June-July	First part of wet	191	24
Aug-Sept	Sccond part of wet	200	24

Cow performance traits. Individual records were built up for each cow and each parturition. These gave breed group, number and date of birth (when known) of the cow, and the current parturition date, previous parturition date, lactation milk yield, mean butterfat percentage, drying off date, sex of calf, calf birth weight, cow weight at parturition and next parturition date. From these data, the age at first calving, calving interval, breeding efficiency, lactation length, milk yield per day of lactation, length of dry period, total fat yield, fat-corrected milk yield, annual milk yield per cow, annual fat-corrected milk yield per cow and annual fat-corrected milk yield per unit metabolic weight of cow were additionally computed, as indicated in each appropriate section under the heading Results.

DATA ANALYSES

All characters were analysed by least squares procedures (Harvey, 1977) using fixed models. Unequal and disproportionate subclass numbers gave unbalanced factorial designs for which conventional analyses of variance techniques were not applicable. Typical models used included the fixed effects of breed group, year of birth or parturition, parity number, and the interaction between breed group and season. The specific factors included in the model used will be evident when the results are presented for each character analysed. The residual mean square was used as the error term to test the significance of all differences evaluated. Linear contrasts of least squares means were computed to determine the significance of differences between groups. More comparisons were made using the least squares means than there are independent degrees of freedom. Therefore, all of the comparisons are not independent, and the error rate over the entire set of comparisons may be different from that indicated by the level of probability. Tests of significance associated with the linear contrasts, although not independent, can be taken as guides as to whether the observed values could have occurred by chance.

RESULTS

REPRODUCTIVE PERFORMANCE

Introduction. Reproductive performance is a trait of outstanding importance in dairy cattle enterprises. The size of the calf crop is all-important for herd replacement, and the production of milk depends heavily on reproductive activity. Possible genetic improvement in virtually all traits of economic importance is closely tied to reproductive rate.

Differences in breeding efficiency are largely due to environment, although between breeds heredity also plays a part in the variation of reproductive performance. The best cows are clearly those that have their first calf at an early age and have minimum calving intervals thereafter.

Age at first calving. The mean age at first calving for 524 heifers born on the station was 32.9 ± 0.3 months, with a coefficient of variation of 22%.

The analysis of variance shown in Table 1 indicates that breed group, year of birth and breed group x season of birth interactions significantly affected age at first calving.

Table 1. *Analysis of variance of age at first calving.*

Source	d.f.	MS × 10^{-3}
Breed group	7	61.52*
Year of birth	8	1054.74**
Season of birth	4	33.87
Breed × season	27	37.83*
Remainder	477	22.99

* = P < 0.05
** = P < 0.01

The least squares mean estimates of age at first calving are shown in Table 2[1]. The ¾ Exotic ¼ Arsi grades calved significantly earlier (31.3 months) than all other breed groups, whose individual ages at first calving ranged from 33.6 to 35.7 months. It appears that Arsi cattle, when managed well, can express their genetic potential

Table 2. *Estimated least squares means for age at first calving (months).*

Variable	Number	Mean
Overall	524	33.8
Breed group		
Arsi	62	34.4 a
½ Jersey ½ Arsi	39	33.7 a
½ Friesian ½ Arsi	154	33.9 a
½ Friesian ½ Zebu	60	34.8 a
¾ Friesian ¼ Arsi	66	33.7 a
¾ Friesian ¼ Zebu	37	33.6 a
¾ Exotic ¼ Arsi	70	31.3 b
⅞ Friesian ⅛ Local	36	35.7 a
Year of birth		
1968	51	36.1 d
1969	43	30.2 b
1970	70	27.5 a
1971	83	29.0 ab
1972	62	28.8 ab
1973	67	32.9 c
1974	42	37.4 ed
1975	50	39.6 e
1976	56	43.3 f
Season of birth		
Jan–Feb	86	32.8
March–May	150	34.7
June–July	72	34.0
Aug–Sep	90	34.2
Oct–Dec	126	33.7

Within variable groups, row means followed by the same letter do not differ significantly (P < 0.05). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

[1] Sample means can differ substantially from computed least squares means, as the latter are computed by adjusting for unequal subclass numbers.

for early maturity. Mahadevan (1966) observed that irrespective of whether cattle were of Indian, African, European or crossbred origin, their mean age at first calving under a given tropical environment was essentially the same and ranged from 3 to 4 years. The present study seems to indicate that in the subtropical highlands environment, given reasonably good management, age at first calving can be reduced to between 30 and 36 months.

The significant year effects (Table 2) indicate that age at first calving ranged from 27.5 months in 1970 to 43.3 months in 1976. Above-average ages at first calving occurred more during later years, a trend which could be attributed to factors such as reduced availability of supplementary feed and problems associated with obtaining semen.

Calving interval. The calving interval is the period between two consecutive parturitions, and ideally should be in the region of 12 to 13 months. The calving interval is thus closely matched to a yearly production cycle and influences the amount of milk a cow is likely to produce in a given period. The mean calving interval for 1099 records was 459 ± 4 days with a coefficient of variation of 28%.

The analysis of variance shown in Table 3 indicates that breed group, year of calving, lactation number and breed group x season interactions significantly affected calving interval.

Table 3. *Analysis of variance of calving interval.*

Source	d.f.	MS × 10^{-2}
Breed group	9	492**
Year of calving	12	914**
Season of calving	4	163
Lactation number	3	4451**
Breed group × season	34	179*
Remainder	1036	123

* = $P < 0.05$
** = $P < 0.01$

Estimated least squares means of calving interval are shown in Table 4. The longest calving interval (525 days) occurred among the ⅞ Friesian ⅛ Local breed group, these being the highest grade. The ½ Jersey ½ Arsi (403 days) and the ½ Exotic ½ Arsi (393 days) had significantly shorter calving intervals than the pure Arsi (439 days), both these groups sharing common Jersey germplasm. All crosses with the Zebu were Friesian, and their calving intervals did not significantly differ from those of the pure Zebu. The superiority of Jersey crosses over Friesian crosses with respect to reproductive performance and fitness has often been noted in the literature (Khishin and El-Issawi, 1954; Marples and Trail, 1966; Kumar, 1969). A comprehensive review of the subject (Kiwuwa, 1974) concluded that large sized *Bos taurus* breeds (Friesian, Brown Swiss, Red Dane) and their crosses with *Bos indicus* manifest longer calving intervals than smaller sized breeds (Jersey, Criollo, Guernsey) or their crosses with the indigenous cattle.

The effect of year of calving (Table 4) suggested significant increases in calving intervals between 1970 and 1978. To determine any linear trend in calving interval over the complete period from 1968 to 1980, the regression of the least squares constants on year of calving (represented as 1 to 13) was calculated. The regression coefficient was 13 days, significant at the 1% level, indicating that calving interval has increased by 13 days per year over the 13-year period.

Parturition number effects indicated decline in calving interval from first to fourth parturition, the mean intervals being 510, 454, 423 and 396 days respectively. Shorter calving intervals at later parturition stages are a function of selective culling against repeat breeder cows and were as expected for a well managed herd.

Breeding efficiency. Calculated as a percentage, breeding efficiency (BE) is a measure based on the regularity of calving and the age at which cows first calve. If an animal calves late for the first time its maintenance cost as a fraction of total cost tends to increase and its life-time production decreases. BE provides for objective comparisons between breeds with respect to their suitability/adaptability for growth and reproduction in a given environment. Its derivation requires a choice of the desirable age at first calving and the desirable length of subsequent calving intervals.

The average age at first calving at Asela was 33 months, ranging from 31 to 36 months among breed groups (Table 2). Previous literature on the subject (Kiwuwa, 1974) indicated that age at first calving of *Bos taurus* or their crosses with *Bos indicus* throughout the tropics was around 32 months, and the results in Table 2 concur with these observations.

Assuming 13 months (396 days) as the upper limit of an ideal calving interval, and 32 months (960 days) to be the optimal age at first calving, the following formula was used to derive the BE index:

$$BE = [(N-1)396 + 960]/(\text{age in days at each successive calving})$$

Where: BE is the breeding efficiency coefficient; (N − 1) is the number of calving intervals in N gestations; 396 is the upper limit of the desirable calving interval (days); and 960 is the upper limit of the desirable age at first calving (days). The estimated coefficients were expressed as percentages by multiplying by 100.

The mean BE index for 1269 available calving records was 95 ± 0.6 % with a coefficient of variation of 23%. BE in the Asela herd was thus below 100%, indicating that either the breed groups or the standards of herd management were not adequate for optimal growth and regular reproduction.

The analysis of variance in Table 5 demonstrates significant breed, year, season and parity influences on BE.

Table 4. *Estimated least squares means for calving interval (days).*

Variable	Number	Mean
Overall	1099	446
Breed group		
Arsi	202	439 cd
Zebu	94	451 cde
½ Jersey ½ Arsi	92	403 ab
½ Friesian ½ Arsi	306	427 abc
½ Friesian ½ Zebu	194	458 de
½ Exotic ½ Arsi	10	393 a
¾ Friesian ¼ Arsi	64	464 de
¾ Friesian ¼ Zebu	44	475 e
¾ Exotic ¼ Arsi	66	425 abc
⅞ Friesian ⅛ Local	27	525 f
Year of calving		
1968	14	399 fgh
1969	69	374 hk
1970	82	356 k
1971	100	392 gh
1972	85	409 fg
1973	125	424 ef
1974	139	446 e
1975	111	477 cd
1976	85	495 bcd
1977	76	505 b
1978	84	542 a
1979	84	502 bc
1980	45	474 d
Season of calving		
Jan – Feb	206	447
March – May	267	451
June – July	162	464
Aug – Sep	170	424
Oct – Dec	294	443
Parturition number		
1	447	510 a
2	284	454 b
3	172	423 c
4+	196	396 d

Within variable groups, row means followed by the same letter do not differ significantly (P < 0.05). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

Table 5. *Analysis of variance of breeding efficiency.*

Source	d.f.	MS × 10^{-1}
Breed group	9	380**
Year of calving	10	1848**
Season of calving	4	71*
Lactation number	3	152**
Breed group × season	32	36*
Remainder	1210	24

* = P < 0.05
** = P < 0.01

Estimated least squares means of BE are given in Table 6. Mean BE estimates were lowest (64 – 68) among the indigenous (Zebu, Arsi) breed groups and highest (98 – 107) among the higher ¾ and ⅞ grades. Although there were no significant differences in BE between half-breds and the ¾ to ⅞ higher grades, the half-breds tended to have rather lower BEs than the higher grades.

The significant year effects in Table 6 indicate that between 1971 and 1974 BE at Asela was above 100%, but dropped substantially from 1976 to 1981. To determine the linear trend in BE over the complete period from 1971 to 1981, the regression of the least squares constants on year of calving (represented as 1 to 11) was calculated. The regression was −6.6%, significant at the 1% level, indicating that BE has decreased by 6.6% per year over the 11-year period.

The significant (P <0.05) seasonal effects indicate that the BE index was higher (94 to 95%) among records starting from January to May than those starting from June to December (Table 6). Parity effects on BE indicated significantly higher (93 – 94%) indices in third and fourth parturitions than in first and second ones (88 – 89%). BE gradually improved from the first to the fourth parturition and above. Improvement in the fertility of older cows following systematic culling at the younger ages could be the key. These results follow closely the decrease in calving intervals from the first to the fourth parturition and above.

Table 6. *Estimated least squares means for breeding efficiency coefficient.*

Variable	Number	Mean
Overall	1269	91
Breed group		
Arsi	80	68 c
Zebu	3	64 c
½ Jersey ½ Arsi	131	91 b
½ Friesian ½ Arsi	459	95 b
½ Friesian ½ Zebu	179	97 ab
½ Exotic ½ Arsi	14	92 b
¾ Friesian ¼ Arsi	129	101 ab
¾ Friesian ¼ Zebu	80	98 ab
¾ Exotic ¼ Arsi	132	107 a
⅞ Friesian ⅛ Local	62	98 ab
Year of calving		
1971	75	128 a
1972	92	116 b
1973	123	111 c
1974	150	106 d
1975	165	99 e
1976	141	90 f
1977	108	82 g
1978	121	75 h
1979	99	70 i
1980	109	64 j
1981	86	63 j
Season of calving		
Jan–Feb	231	94 a
March–May	303	95 a
June–July	164	89 b
Aug–Sep	216	89 b
Oct–Dec	355	89 b
Parturition number		
1	531	88 b
2	295	89 b
3	185	93 a
4+	258	94 a

Within variable groups, row means followed by the same letter do not differ significantly (P < 0.05).

BODY WEIGHT

Cow postpartum weight. A total of 1310 cow postpartum weight records, taken within 30 days of calving, were available. The mean weight was 276 ± 1.4 kg, with a coefficient of variation of 18%.

The analysis of variance shown in Table 7 indicates that breed group, year of calving, season of calving, lactation number and breed x season interactions significantly affected body weight.

Estimates of least squares means of postpartum body weight are given in Table 8. Large and significant breed differences were shown to exist. The other indigenous Zebus were significantly heavier (309 kg) than the Arsi (236 kg). In general higher grades were heavier (306 – 336 kg) than F_1 crossbreds, the exception being the ½ Friesian ½ Zebu cross, which weighed 328 kg, about the same as the ¾ and ⅞ Friesian crosses. The lightest crosses, 269 kg and 278 kg, were the ½ Jersey ½ Arsi and ½ Exotic ½ Arsi breed groups, indicating the influence of both the Arsi and the Jersey.

Table 7. *Analysis of variance of cow postpartum weight.*

Source	d.f.	MS × 10^{-2}
Breed group	9	647**
Year of calving	11	187**
Season of calving	4	27*
Lactation number	3	1494**
Breed × season	34	16*
Remainder	1248	11

* = P < 0.05
** = P < 0.01

Year effects on mature body weight (Table 8) indicated significant differences between the early (1969 – 1970) and the later years (1971 – 1980). From 1971 onwards, however, no definite trends could be detected. The season of calving, from March to May, had significantly lower (293 kg) body weights than the others (304 – 305 kg). This season is preceded by dry weather conditions from November to February, and the lower weight during this March – May season is probably due to lower pasture availability during the later stages of pregnancy. Body weights increased by significant amounts from the first (268 kg) to the fourth (331 kg) parturition and above.

Calf birth weight. A total of 1111 birth weights of female calves, recorded within 24 hours of calving, were available. The mean weight was 24.7 ± 0.13 kg, with a coefficient of variation of 18%.

The analysis of variance shown in Table 9 indicates that breed group, year of birth, lactation number of dam, and breed x season interactions significantly affected birth weight.

Estimated least squares means of birth weight are presented in Table 10. Breed differences in birth weight followed similar trends to those in postpartum weight. Heaviest mean birth weights were among the ½ Friesian ½ Zebu, ¾ Friesian ¼ Zebu and ⅞ Friesian ⅛ Local crosses (27.1 – 28.4 kg), while the lightest were among the Arsi (21.5 kg) and the ½ Jersey ½ Arsi crosses (21.9 kg).

Table 8. *Estimated least squares means for cow post-partum weight.*

Variable	Number	Mean
Overall	1310	302
Breed group		
Arsi	337	236 d
Zebu	107	309 b
½ Jersey ½ Arsi	97	269 c
½ Friesian ½ Arsi	342	307 b
½ Friesian ½ Zebu	157	328 a
½ Exotic ½ Arsi	10	278 c
¾ Friesian ¼ Arsi	85	324 a
¾ Friesian ¼ Zebu	41	325 a
¾ Exotic ¼ Arsi	93	306 b
⅞ Friesian ⅛ Local	41	336 a
Year of calving		
1969	96	342 a
1970	94	335 a
1971	182	300 bc
1972	129	296 bc
1973	125	305 b
1974	146	299 bc
1975	138	283 d
1976	118	290 cd
1977	100	297 bc
1978	95	283 d
1979	61	298 bc
1980	26	295 bc
Season of calving		
Jan–Feb	221	304 b
March–May	352	293 a
June–July	184	305 b
Aug–Sep	209	304 b
Oct–Dec	344	304 b
Parturition number		
1	646	268 a
2	317	291 b
3	190	317 c
4+	157	331 d

Within variable groups, row means followed by the same letter do not differ significantly (P < 0.05).

Table 9. *Analysis of variance of calf birth weight.*

Source	d.f.	MS
Breed group	9	268**
Year of birth	10	88**
Season of birth	4	32
Lactation number of dam	3	275**
Breed × season	34	22*
Remainder	1050	15

* = P < 0.05
** = P < 0.01

No clear trends were indicated by year of birth effects on birth weight. Parity effects on birth weights were significant after the second parturition. While there was no significant difference in birth weight between the first and second parturitions, both were significantly lower than those from later parturitions.

Table 10. *Estimated least squares means for birth weight of female calves (kg).*

Variable	Number	Mean
Overall	1111	24.7
Breed group		
Arsi	49	21.5 a
Zebu	81	23.0 ab
½ Jersey ½ Arsi	94	21.9 a
½ Friesian ½ Arsi	372	24.4 bc
½ Friesian ½ Zebu	175	27.1 d
½ Exotic ½ Arsi	14	24.2 bc
¾ Friesian ¼ Arsi	109	25.5 c
¾ Friesian ¼ Zebu	69	27.2 d
¾ Exotic ¼ Arsi	103	24.1 bc
⅞ Friesian ⅛ Local	45	28.4 d
Year of calving		
1971	15	24.1 ab
1972	100	25.5 cde
1973	136	26.4 e
1974	154	24.7 bcd
1975	145	26.1 de
1976	139	25.6 cde
1977	96	24.5 abc
1978	108	24.3 abc
1979	77	23.1 a
1980	86	23.4 ab
1981	55	24.1 abc
Season of calving		
Jan–Feb	187	24.8
March–May	263	23.9
June–July	152	25.4
Aug–Sep	190	24.9
Oct–Dec	319	24.5
Parturition number		
1	399	23.6 a
2	254	23.8 a
3	187	25.3 b
4+	271	26.2 c

Within variable groups, row means followed by the same letter do not differ significantly (P < 0.05). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

LACTATION MILK YIELD

Introduction. The common procedure in data validation for dairy records is to exclude all those curtailed by sale, slaughter or sickness of the animal. However, temperament effects associated with milk letdown interference among indigenous cattle cause problems concerning the best way to handle such records. Some workers have excluded short lactations due to milk letdown interference; others have argued that since the phenomenon is breed-characteristic, such records should be included in the analysis. Clear definition of milk letdown refusal and short lactation *per se* needs further study. Kiwuwa et al (1983) have examined the data and the conditions under which certain animals have displayed apparent milk letdown interference at Asela. They concluded that lactations in which peak yields were reached (generally between 21 and 60 days) and cows later voluntarily dried up should be regarded as normal records, if no extraneous factors led to the cessation of milk yield. Thus, in the current comparison between breed groups, all records that exceeded 75 days in lactation length were used in the analyses provided that such records were not later affected by slaughter, sale or sickness.

Analyses of milk production characteristics. Milk production parameters were total lactation yield, lactation length, yield per day of lactation, and dry period. The values covered 1371 milk yield/lactation length records and 1032 dry period records which satisfied the "above 75 days lactation period" criterion. The discrepancy between the number of lactations and the number of dry periods was due to one more record for lactations being available than for dry periods, while animals culled after their first lactation did not have a dry period recorded.

The analyses of variance for total lactation milk yield, lactation length, milk yield per day of lactation, and dry period are given in Table 11.

Estimated least squares means of total lactation milk yield, lactation length, milk yield per day of lactation, and dry period are indicated in Table 12.

Total lactation milk yield. The mean total lactation milk yield was 1775 ± 26 kg with a coefficient of variation of 55%. The analysis of variance in Table 11 indicates that breed group, year of calving and parturition number significantly affected lactation milk yield.

Estimated least squares means of lactation milk yield are shown in Table 12. Lactation milk yields of the indigenous breed groups (Arsi and Zebu) were not significantly different. Neither were those of the ½ Jersey ½ Arsi, ½ Friesian ½ Arsi and ½ Exotic ½ Arsi groups. Within the higher grades, the ¾ Friesian ¼ Arsi, ¾ Friesian ¼ Zebu, ¾ Exotic ¼ Arsi and ⅞ Friesian ⅛ Local were not significantly different and produced at virtually the same level as the ½ Friesian ½ Zebu breed group. The F_1 crosses produced significantly more milk (123%) than the indigenous Arsi and Zebu, and the higher grades outyielded the equivalent F_1 crosses (+ 19%) with the exception of the ½ Friesian ½ Zebu. Crossbreeding the indigenous cattle with the *Bos taurus* breeds had more than doubled milk yields of the F_1 generation, and further upgrading to ¾ Exotic had almost tripled the yields.

The significant year effects (Table 12) indicated that lactations in the period 1976 – 1979 outyielded those of other years. Yields in second and subsequent lactations were at least 9% higher than the first, with the mean increase being 11%.

Lactation length. The mean lactation length was 364 ± 4 days, with a coefficient of variation of 39%. The analysis of variance in Table 11 indicates that breed group, year of calving and parturition number significantly affected lactation length.

Table 11. *Analyses of variance of total lactation milk yield, lactation length, milk yield per day of lactation and dry period.*

Source	Lact. yield		Lact. length	Yield/day	Dry period	
	d.f.	MS × 10^{-3}	MS × 10^{-2}	MS × 10^{2}	d.f.	MS × 10^{-2}
Breed group	9	23078**	1163**	1320**	9	602**
Year of calving	12	4981**	703**	209**	12	98*
Season of calving	4	424	51	19	4	142*
Parturition number	3	3554**	4422**	1663**	3	80
Breed × season	35	677	188	29*	34	64
Remainder	1307	427	143	19	969	49

* = P < 0.05
** = P < 0.01

Table 12. *Estimated least squares means for total lactation milk yield, lactation length, milk yield per day of lactation and dry period.*

Variable	No.	Lact. yield X̄ (kg)	Lact. length X̄ (days)	Lact. yield/day X̄ (kg)	No.	Dry period X̄ (days)
Overall	1371	1872	350	5.3	1032	100
Breed group						
Arsi	233	809 a	272 e	2.7 d	152	165 a
Zebu	104	929 a	303 cde	2.8 d	92	154 a
½ Jersey ½ Arsi	115	1741 bc	334 bcd	5.2 c	91	76 bc
½ Friesian ½ Arsi	392	1977 cd	356 abc	5.7 abc	305	81 bc
½ Friesian ½ Zebu	220	2352 e	378 ab	6.3 a	185	83 bc
½ Exotic ½ Arsi	12	1672 b	282 de	5.6 bc	10	108 b
¾ Friesian ¼ Arsi	98	2374 e	408 a	6.0 ab	64	70 c
¾ Friesian ¼ Zebu	53	2356 e	378 ab	6.2 ab	41	90 bc
¾ Exotic ¼ Arsi	102	2193 de	384 ab	6.0 ab	66	79 bc
⅞ Friesian ⅛ Local	42	2318 e	411 a	5.9 ab	26	90 bc
Year of calving						
1968	6	1636 a	312 def	5.2 abcd	6	164 a
1969	53	1704 ab	330 cdef	5.1 abc	52	85 bc
1970	79	1488 a	290 ef	4.8 ab	66	74 bc
1971	127	1615 a	303 ef	5.0 abc	86	68 c
1972	124	1731 ab	315 def	5.5 cde	84	101 bc
1973	145	1945 bc	338 bcdef	5.7 de	123	90 bc
1974	174	1750 ab	373 abc	4.8 ab	137	93 bc
1975	173	1766 ab	378 abc	4.7 a	109	98 bc
1976	126	1983 bc	354 bcde	5.5 cde	84	106 b
1977	108	2307 de	383 abc	5.9 e	74	109 b
1978	103	2473 e	424 a	5.9 e	84	103 bc
1979	95	2158 cd	394 ab	5.4 bcde	84	106 b
1980	58	1778 ab	362 bcd	4.8 ab	43	98 bc
Season of calving						
Jan–Feb	260	1826	350	5.2	198	87 a
March–May	353	1807	341	5.1	252	115 c
June–July	174	1963	350	5.5	144	108 bc
Aug–Sep	197	1912	357	5.3	152	88 a
Oct–Dec	387	1853	354	5.2	286	98 ab
Parturition number						
1	556	1724 a	406 a	4.2 a	401	108
2	330	1892 b	359 b	5.1 b	269	96
3	232	1988 b	332 c	5.8 c	170	98
4+	253	1883 b	305 d	6.0 c	192	95

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

Estimated least squares means of lactation length are shown in Table 12. The overall mean of 350 days was longer than the 305 days generally accepted as the ideal period. The shortest lactation lengths were among the Arsi (272 days), Zebu (303 days), ½ Exotic ½ Arsi (282 days) and ½ Jersey ½ Arsi (334 days) breed groups, which did not differ significantly from each other. Friesian grades had lactation lengths of 378 days in both ½ Friesian ½ Zebu and ¾ Friesian ¼ Zebu, and 411 days in the ⅞ Friesian ⅛ Local grade. Thus all breed groups with Friesian genes tended to have longer lactation lengths.

There were no clear trends in year effects on lactation length. Table 12 indicates, however, that lactations in the period 1974 – 1980 were longer than those between 1968 and 1973.

The significant parity effects on lactation length show a definite reduction from the first lactation (406 days) to the fourth (305 days) lactation and above. This trend could be the result of a gradual improvement in the fertility of individual cows together with the culling of repeat breeder animals.

Milk yield per day of lactation. The mean milk yield per day of lactation was 5.0 ± 0.06 kg, with a coefficient of variation of 44%. The analysis of variance in Table 11 indicates that breed group, year of calving, parturition number and breed x season of calving significantly affected milk yield per day of lactation.

Estimated least squares means of milk yield per day of lactation are shown in Table 12. The breed differences followed the same pattern as for total lactation milk yield, except that whereas the F_1 crosses produced significantly more milk (107%) than the indigenous Arsi and Zebu, the higher grades did not significantly outyield the equivalent F_1 crosses.

From parturition numbers one to three, yield increased significantly at each stage.

Dry period. The mean dry period was 97 ± 2 days, with a coefficient of variation of 78%. The analysis of variance in Table 11 indicates that breed group, year of calving and season of calving significantly affected dry period.

Estimated least squares means of dry period are shown in Table 12. Dry periods were significantly shorter in all crosses (70 – 108 days) than in the indigenous Arsi and Zebu (154 – 165 days) breed groups. Year effects indicated shorter dry periods from 1969 to 1975 than from 1975 to 1979. An exception seems to have been 1968, with a mean dry period of 164 days, possibly due to management problems during the initial stages of the crossbreeding scheme.

Significant season effects on dry period indicate that cows calving from March to May (short rains) experienced a longer dry period (115 days) than those calving during other seasons (87 to 108 days). Cows calving from March to May face increasingly dry and hot weather during the last third of their lactation (November to February), and as a result climatic and nutritional stress may bring about an early curtailment of their lactation. Although not significant, a longer dry period (108 days) was found after the first lactation than after later lactations (95 – 98 days).

Under the conditions that prevailed at Asela station, initial crossbreeding between the Arsi or Zebu *(Bos indicus)* and the Friesian or Jersey *(Bos taurus)* cattle had at least doubled, and a further generation of upgrading tripled, milk yields over those of the indigenous cattle. Although the best F_1 cross was the Friesian x Zebu, the F_1 Friesian x Arsi did not significantly outyield the F_1 Jersey x Arsi. Upgrading to ¾ and ⅞ Friesian inheritance had produced significant increases in milk yield, but lactation periods were longer. The Friesian x Zebu cross did not show any difference in milk yield between the F_1 and the ¾ Friesian.

BUTTERFAT

Introduction. Knowledge of the fat content of milk and total fat yield of dairy cattle is vital where the dairy industry is involved in the production of milk byproducts such as butter, ghee, cream and cheese. The standard fat-corrected milk (FCM) method permits comparisons on a common energy basis per unit of milk produced. In the current study, actual milk yields were adjusted to a 4% butterfat standard.

Analyses of butterfat characteristics. The parameters analysed were butterfat percentage, total fat, total fat-corrected milk yield and fat-corrected milk yield per day of lactation. A total of 768 records were available. The analyses of variance for the four measures are shown in Table 13.

Table 13. *Analyses of variance of butterfat percentage, total fat, total fat-corrected milk yield and fat-corrected milk yield per day of lactation.*

Source	d.f.	Butterfat % MS × 10^2	Total fat MS × 10^{-1}	Total fat-corrected yield MS × 10^{-3}	Fat-corrected yied per day MS × 10^2
Breed group	9	664**	1927**	11667**	7272**
Year of calving	7	205**	217**	1344**	1683**
Season of calving	4	13	187*	1127*	331
Parturition number	3	31	64	426	3621**
Breed × season	34	13	75	462	204
Remainder	710	20	73	410	195

* = P < 0.05
** = P < 0.01

Estimated least squares means of butterfat percentage, total fat, total fat-corrected milk yield and fat-corrected milk yield per day of lactation are indicated in Table 14.

Butterfat percentage. The mean butterfat percentage was 4.8 ± 0.03, with a coefficient of variation of 15%. The analysis of variance in Table 13 indicates that breed group and year of calving significantly affected butterfat percentage. Breed differences in butterfat percentage (Table 14) indicate that the local Arsi, Zebu and F_1 Jersey x Arsi breed groups recorded significantly higher (5.1 to 5.5%) percentages than the F_1 crossbreds and higher grades of the Friesian (4.1 to 4.5%). Thus crossing the indigenous cattle with the Jersey breed maintains butterfat percentage at levels similar to those of the indigenous breeds, but doubles total milk yields. In remote rural areas, where the marketing of fresh milk is often a problem, the use of Jersey crosses for production of butter or ghee could well be desirable. Year trends in butterfat percentage (Table 14) suggested a gradual decline from 1969 to 1977.

Total fat and fat-corrected milk yield. The mean total fat yield was 72 ± 1.4 kg, with a coefficient of variation of 53%, and the mean fat-corrected milk yield was 1724 ± 33 kg, with a coefficient of variation of 54%. The analysis of variance in Table 13 indicates that breed group, year of calving and to a lesser degree season of calving sig-

Table 14. *Estimated least squares means for butterfat percentage, total fat, total fat-corrected milk yield and fat-corrected milk yield per day of lactation.*

Variable	No.	Butterfat (%)	Total fat (kg)	Total fat-corrected yield (kg)	Fat-corrected yield per day (kg)
Overall	768	4.6	73	1760	5.3
Breed group					
Arsi	147	5.5 e	35 a	805 d	2.8 d
Zebu	57	5.3 de	41 a	922 d	3.2 d
½ Jersey ½ Arsi	68	5.1 d	82 bc	1894 bc	6.1 ab
½ Friesian ½ Arsi	250	4.5 c	81 bc	1942 bc	5.9 abc
½ Friesian ½ Zebu	121	4.4 bc	98 d	2367 a	6.5 a
½ Exotic ½ Arsi	9	4.4 bc	76 bc	1840 c	5.8 abc
¾ Friesian ¼ Arsi	44	4.3 abc	80 bc	1958 bc	5.2 c
¾ Friesian ¼ Zebu	21	4.2 ab	90 cd	2246 ab	5.9 abc
¾ Exotic ¼ Arsi	42	4.4 bc	79 bc	1909 bc	5.6 bc
⅞ Friesian ⅛ Local	9	4.1 a	69 b	1718 c	6.1 ab
Year of calving					
1969	48	5.2 a	71 b	1661 cd	5.3 bc
1970	76	4.9 b	60 a	1431 e	4.9 ab
1971	88	4.6 c	62 a	1499 de	5.1 abc
1973	77	4.5 cd	77 bc	1849 abc	5.5 cd
1974	152	4.6 c	75 bc	1795 bc	4.8 a
1975	155	4.6 c	78 bc	1886 ab	4.9 ab
1976	120	4.4 de	83 c	2022 a	5.8 d
1977	52	4.3 e	78 bc	1937 ab	6.3 e
Season of calving					
Jan–Feb	132	4.7	71 b	1699 bc	5.1
March–May	192	4.7	65 a	1559 c	5.0
June–July	123	4.6	82 c	1968 a	5.6
Aug–Sep	123	4.6	73 b	1769 b	5.4
Oct–Dec	198	4.6	75 b	1806 b	5.5
Parturition number					
1	325	4.7	73	1745	4.5 a
2	197	4.7	73	1748	5.2 b
3	136	4.6	76	1843	5.8 c
4+	110	4.5	71	1705	5.8 c

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

nificantly affected both traits. The ½ Friesian ½ Zebu breed group had a significantly higher fat yield (98 kg) and fat-corrected milk yield (236.7 kg) than all others except the ¾ Friesian ¼ Zebu. The local Arsi and Zebu had significantly lower fat yields (35 and 41 kg) and fat-corrected milk yields (805 and 922 kg) than all others. Seasonal influences indicated that cows calving during March to May yielded significantly lower fat yields (65 kg) and fat-corrected milk yields (1559 kg) than those calving during June to December.

Fat-corrected milk yield per day of lactation. The mean fat-corrected milk yield per day of lactation was 4.8 ± 0.08 kg, with a coefficient of variation of 44%. The analysis of variance in Table 13 indicates that breed group, year of calving and parturition number significantly affected fat-corrected milk per day of lactation. All crossbreds had significantly higher yields than the two indigenous breeds (Table 14), but there were no differences between ¾-breds and ½-breds. There were significant increases in yield from first to third parturitions.

DAIRY PRODUCTIVITY

Introduction. Varying milk output over different lactation lengths and calving intervals makes it difficult to compare animal performances directly using the individual traits of lactation milk yield, lactation length, dry period and calving interval. As a first step it is more valuable to express yields over a regular annual cycle, amalgamating the milk production and reproductive performance traits. Milk from different breeds of cattle contains varying proportions of fat. Comparisons between breeds, taking into account the energy value of the milk produced, are thus even more valid.

Finally, maximum returns from a dairy operation depend on the use of animals with high milk output relative to maintenance cost over the annual cycle. The milk-output to feed-input ratio can be directly measured through regularly recording the feed given to individual animals, but not many farmers can keep such records. Thus when breeds are of different body weights, it is more appropriate to express milk yields in terms of a measure of body weight.

In this section, three progressive measures of productivity are constructed and analysed: annual milk yield per cow, combining reproductive performance and milk production; annual fat-corrected milk yield per cow, combining reproductive performance, milk yield and milk quality; and annual fat-corrected milk yield per unit metabolic weight of cow, combining reproductive performance, milk yield, milk quality and an estimate of maintenance cost.

Annual milk yield per cow. Annual milk yield per cow was calculated as total lactation milk yield ÷ calving interval (days) x 365. The mean annual yield for 1024 records was 1474 ± 21 kg, with a coefficient of variation of 46%.

The analysis of variance shown in Table 15 indicates that breed group, year of calving, parturition number and breed group x season interactions significantly affected annual milk yield per cow.

Table 15. *Analysis of variance of annual milk yield per cow.*

Source	d.f.	MS × 10^{-4}
Breed group	9	1093**
Year of calving	12	101**
Season of calving	4	31
Parturition number	3	944**
Breed group × season	34	27*
Remainder	961	18

* = $P < 0.05$
** = $P < 0.01$

Estimated least squares means of annual milk yield per cow are shown in Table 16. The ¾ grades achieved higher annual yields than the ½-breds, which in turn had higher yields than the indigenous breeds. There was no significant difference between the Arsi and Zebu, while the ⅞ Friesian was not superior to the ¾ grades.

Parturition number effects indicated that annual yields increased significantly at each parturition from first to fourth and over.

Annual fat-corrected milk yield per cow. Annual fat-corrected milk yield per cow was calculated as total lactation milk yield adjusted to a 4% butterfat standard ÷ calving interval (days)x365. The mean annual yield for 558 records was 1474 ± 29 kg, with a coefficient of variation of 47%.

The analysis of variance shown in Table 17 indicates that breed group, year of calving, season of calving and parturition number significantly affected annual fat-corrected milk yield per cow.

Estimated least squares means of annual fat-corrected milk yield per cow are shown in Table 18. All crosses had significantly higher yields than the indigenous groups but, in contrast to annual milk yield, the annual fat-corrected milk yield of ¾ grades was not superior to that of ½-breds.

Table 16. *Estimated least squares means for annual milk yield per cow (kg).*

Variable	Number	Mean
Overall	1024	1604
Breed group		
Arsi	149	689 d
Zebu	90	770 d
½ Jersey ½ Arsi	91	1534 c
½ Friesian ½ Arsi	304	1704 bc
½ Friesian ½ Zebu	185	1913 a
½ Exotic ½ Arsi	10	1608 c
¾ Friesian ¼ Arsi	64	2043 a
¾ Friesian ¼ Zebu	41	1930 a
¾ Exotic ¼ Arsi	64	1973 a
⅞ Friesian ⅛ Local	26	1874 ab
Year of calving		
1968	6	1663 abc
1969	52	1566 bcd
1970	64	1490 cd
1971	85	1593 abcd
1972	81	1632 abc
1973	123	1782 ab
1974	137	1506 cd
1975	107	1495 cd
1976	84	1619 abc
1977	74	1808 a
1978	84	1694 abc
1979	84	1604 abcd
1980	43	1392 d
Season of calving		
Jan–Feb	198	1604
March–May	247	1522
June–July	143	1640
Aug–Sep	150	1664
Oct–Dec	286	1589
Parturition number		
1	395	1299 a
2	267	1569 b
3	170	1726 c
4+	192	1822 d

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

Parturition number effects again indicated that annual fat-corrected milk yield increased significantly at each parturition from first to fourth and over.

Annual fat-corrected milk yield per unit metabolic weight of cow. Annual fat-corrected milk yield per unit metabolic weight of cow was calculated as total lactation milk yield adjusted to a 4% butterfat standard ÷ calving interval (days) x 365 ÷ metabolic weight of dam ($kg^{0.75}$). The mean annual yield for 524 records was 20.8 ± 0.4 kg, with a coefficient of variation of 44%.

Table 17. *Analysis of variance of annual fat-corrected milk yield per cow.*

Source	d.f.	MS × 10^{-4}
Breed group	8	656**
Year of calving	8	50**
Season of calving	4	64*
Parturition number	3	150**
Breed group × season	30	24
Remainder	504	19

* = $P < 0.05$
** = $P < 0.01$

Table 18. *Estimated least squares means for annual fat-corrected milk yield per cow (kg).*

Variable	Number	Mean
Overall	558	1581
Breed group		
Arsi	103	704 a
Zebu	49	797 a
½ Jersey ½ Arsi	52	1775 b
½ Friesian ½ Arsi	194	1744 b
½ Friesian ½ Zebu	98	1923 b
½ Exotic ½ Arsi	8	1761 b
¾ Friesian ¼ Arsi	16	1853 b
¾ Friesian ¼ Zebu	18	1776 b
¾ Exotic ¼ Arsi	20	1895 b
Year of calving		
1969	43	1604 a
1970	61	1498 a
1971	56	1650 a
1972	3	1220 b
1973	67	1692 a
1974	115	1519 a
1975	98	1546 a
1976	82	1698 a
1977	33	1804 a
Season of calving		
Jan–Feb	102	1610 a
March–May	128	1383 b
June–July	97	1652 a
Aug–Sep	93	1684 a
Oct–Dec	138	1580 a
Parturition number		
1	212	1388 a
2	165	1537 b
3	99	1681 c
4+	82	1720 c

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$).

The analysis of variance shown in Table 19 indicates that breed type, year of calving and season of calving significantly affected annual

Table 19. *Analysis of variance of annual fat-corrected milk yield per unit metabolic weight of cow.*

Source	d.f.	MS
Breed group	8	727**
Year of calving	8	124**
Season of calving	4	83*
Parturition number	3	50
Breed group × season	30	42*
Remainder	470	33

* = $P < 0.05$
** = $P < 0.01$

Table 20. *Estimated least squares means for annual fat-corrected milk yield per unit metabolic weight of cow (kg).*

Variable	Number	Mean
Overall	524	21.2
Breed group		
Arsi	96	12.1 b
Zebu	45	11.0 b
½ Jersey ½ Arsi	47	26.0 a
½ Friesian ½ Arsi	191	22.7 a
½ Friesian ½ Zebu	84	24.1 a
½ Exotic ½ Arsi	8	24.2 a
¾ Friesian ¼ Arsi	16	23.4 a
¾ Friesian ¼ Zebu	17	22.6 a
¾ Exotic ¼ Arsi	20	24.8 a
Year of calving		
1969	37	18.3 cd
1970	57	18.0 cd
1971	48	20.7 bc
1972	3	16.0 d
1973	65	23.5 ab
1974	110	21.5 abc
1975	92	23.0 abc
1976	81	24.4 ab
1977	31	25.3 a
Season of calving		
Jan – Feb	97	20.5 b
March – May	116	19.4 b
June – July	94	22.2 a
Aug – Sep	89	23.3 a
Oct – Dec	128	20.6 b
Parturition number		
1	199	20.2
2	157	21.3
3	97	21.9
4+	71	21.3

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

fat-corrected milk yield per unit metabolic weight of cow.

Estimated least squares means of annual fat-corrected milk yield per unit metabolic weight of cow are shown in Table 20. Again, all crosses had significantly higher yields than indigenous cattle, but there was no suggestion that ¾ grades were superior to ½-breds. The breed groups with the highest dairy productivity were the ½ Jersey ½ Arsi, followed by the ¾ Exotic ¼ Arsi. Though not significantly different from some other breed groups, the trend seems to testify to the superiority of the Jersey genotype in overall dairy productivity.

Season effects on dairy productivity (Table 20) were significant. The seasons with the highest estimates were June-July and August-September. Both these rainy periods gave significantly higher dairy productivity estimates than the dry season (January – February) and the short rainy season (March – May).

Contrary to the findings with the previous two indices, parturition number had no significant effect when metabolic weight was brought in as a component of the productivity index.

INITIAL INDICATIONS OF PRODUCTION ON SMALLHOLDER FARMS

Introduction. Heifers of the ½ Jersey ½ Arsi, ½ Friesian ½ Arsi, ½ Friesian ½ Zebu and ¾ Friesian ¼ Zebu crossbreds were sold to private farmers, the farmer generally being allowed to purchase only one animal. Farmers were required to demonstrate their willingness to allocate at least a hectare for pasture, and plant an equal area with fodder beet as a supplementary dry-season feed.

They were also required to cooperate in record keeping under the guidance of an extension agent who periodically measured milk yield and associated performance traits. Farmers had access to concentrates, AI services and veterinary care.

Data used in the present analysis were obtained from 124 individual farmers in Sagure, South Aseia, Dera, Lemu, Gobe and Ticho locations in the Chilalo District of Arsi Region (see Figure 1). The information was recorded between 1969 and 1975, after which land reform changes promoted community rather than individual development. Management techniques under producer cooperatives or farmers' associations differ from those of individual farmers; thus it seemed logical for dairy production activities after 1975 to be studied separately at a future date.

After excluding data that were incomplete due to sale, slaughter, sickness or interrupted recording schedules, a total of 232 records of milk yield and 103 records of reproductive performance were available for analysis. The majority of the farms maintained only a single animal as a result of the heifer sales policy outlined above. This meant that individual cow differences were directly confounded with herd differences, and the assumption had to be made that the basic one cow one farmer policy resulted in random allocation of cows over herds and that management differences among farmers occurred at random on farms with one or two cows.

Means and variations of lactation milk yield, lactation length, milk yield per day of lactation, dry period, calving interval and annual milk yield are indicated in Table 21.

The analyses of variance for the six traits are shown in Table 22 and the estimated least squares means are given in Table 23.

Milk yield, lactation length and milk yield per day. Breed group had a significant influence on all three traits, year of calving influenced lactation length and daily milk yield, while parturition number influenced both lactation and daily milk yields.

There were significant differences in total lactation milk yield between all four of the breed groups sold to farmers. The ¾ Friesian ¼ Zebu grades outyielded all others. The ½ Friesian ½ Zebu was superior to the ½ Friesian ½ Arsi, which in turn was superior to the ½ Jersey ½ Arsi. Significant breed differences in lactation length indicated that the ½ Jersey ½ Arsi cross had the shortest lactation, while the ¾ Friesian ¼ Zebu grade had the longest. Lactation lengths of ½ Friesian ½ Arsi and ½ Friesian ½ Zebu were not significantly different from each other. In terms of daily milk yield estimates, the ½ Jersey ½ Arsi and ½ Friesian ½ Arsi were not significantly different. Similarly, the ½ Friesian ½ Zebu cross produced as much as the ¾ Friesian ¼ Zebu grade. The results in Table 23 indicated that, at the F_1 crossbreeding level, the Friesian crossed with the Zebu gave significantly better milk yield performance than when crossed with the Arsi.

Year effects on lactation length and daily milk yield indicated shorter lactation lengths and higher daily milk yields in 1974 than in all other years. Parturition number effects on lactation and daily milk yield were not significant after the first parturition.

Dry period, calving interval and annual milk yield. Breed group, year and season of calving and parturition number had no significant effect on dry period or calving interval, but breed group and parturition number affected annual milk yield. The ½ Friesian ½ Zebu and ¾ Friesian ¼ Zebu crosses had significantly higher annual milk yields than the ½ Friesian ½ Arsi and ½ Jersey ½ Arsi crosses. First parturition annual yields were significantly lower than second and third.

Table 21. *Means and variations of performance traits of crossbred dairy cattle on smallholder farms.*

Variable	No.	Mean	SE	CV(%)
Lactation milk yield (kg)	232	1673	39	35
Lactation length (days)	232	325	6.2	29
Milk yield/day of lactation (kg)	232	5.3	0.12	34
Dry period (days)	103	87	7.7	90
Calving interval (days)	103	436	11.6	27
Annual milk yield (kg)	103	1595	50.1	32

Table 22. *Analyses of variance of total lactation milk yield, lactation length, milk yield per day of lactation, dry period, calving interval and annual milk yield per cow.*

Source	d.f.	Lactation yield MS × 10^{-4}	Lactation length MS × 10^{-2}	Milk yield/ day MS × 10	d.f.	Dry period MS × 10^{-2}	Calving interval MS × 10^{-2}	Annual milk yield MS × 10^{-3}
Breed group	3	391**	324**	258**	3	44	59	1111**
Year of calving	3	33	673**	98**	2	141	86	35
Season of calving	4	35	158	9	4	37	74	116
Parturition number	3	114**	25**	141**	2	139	73	817**
Remainder	218	24	76	23	91	61	141	160

** = $P < 0.01$

Table 23. *Estimated least squares means for total lactation milk yield, lactation length, milk yield per day of lactation, dry period, calving interval and annual milk yield per cow.*

Variable	No.	Total milk yield $\bar{x}$ (kg)	Lactation length $\bar{x}$ (days)	Milk yield/ day $\bar{x}$ (kg)	No.	Dry period $\bar{x}$ (days)	Calving interval $\bar{x}$ (days)	Annual milk yield $\bar{x}$ (kg)
Overall	232	1817	340	5.59	103	99	429	1624
Breed group								
½ Jersey ½ Arsi	27	1353 b	301 c	4.67 b	9	130	411	1265 a
½ Friesian ½ Arsi	112	1613 b	353 ab	4.81 b	29	98	456	1398 a
½ Friesian ½ Zebu	75	1985 a	313 bc	6.40 a	57	79	422	1800 b
¾ Friesian ¼ Arsi	18	2317 a	391 a	6.51 a	8	89	426	2033 b
Year of calving								
1969-71	28	1937	366 a	5.41 ab	27	115	433	1662
1972	42	1892	365 a	5.63 ab	38	113	445	1637
1973	55	1730	349 a	5.15 b	38	69	410	1573
1974	107	1709	279 b	6.21 a	–	–	–	–
Season of calving								
Jan–Feb	44	1920	359	5.70	23	114	439	1697
March–May	60	1851	356	5.47	15	99	423	1502
June–July	46	1895	340	5.73	17	108	459	1696
Aug–Sep	41	1723	308	5.67	24	97	414	1642
Oct–Dec	41	1969	335	5.42	24	78	411	1582
Parturition number								
1	112	1616 a	351	4.75 b	45	80 a	448	1380 a
2	72	1935 b	337	5.87 a	39	121 b	438	1611 ab
3	34	1901 ab	342	5.87 a	19	96 ab	402	1881 b
4+	14	1815 ab	329	5.90 a	–	–	–	–

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

DISCUSSION

The results reported here of the crossbreeding investigations at Asela station provide several guidelines for dairy cattle breeding work in Ethiopia.

The importance of combining the more important components of dairy productivity before coming to decisions on breed comparisons is well illustrated in Table 21. On lactation milk yield alone, the ¾ Friesian ¼ Arsi, ¾ Friesian ¼ Zebu and ½ Friesian ½ Zebu are considered superior to all other crosses.

When the reproductive performance component is added, these three crosses remain in the top four, but the ¾ Exotic ¼ Arsi moves into second place. The ¾ grades thus occupy the first three rankings.

The butterfat component of total milk yields provides guidelines for the choice of breed groups most suited to a dairy products industry. In Ethiopia, problems related to the efficient marketing of fluid milk from remote rural areas may justify the choice of breed groups with higher total annual fat production. When this component is added to lactation milk yield and reproductive performance, the ½ Friesian ½ Zebu, ¾ Exotic ¼ Arsi, and ¾ Friesian ¼ Arsi lead the rankings, with the ½ Jersey ½ Arsi becoming fourth equal with the ¾ Friesian ¼ Zebu.

A successful dairy industry is highly dependent on the quantity and quality of available feeds. Guidelines in this context rely on indices that take into account the feed requirements of animals of different body sizes. Since dairy animals are fed for maintenance and milk production, feed costs become crucial to choices between breeds. Productivity indices based on annual fat-corrected milk yield per unit of metabolic body weight provide clear guidelines to breeding policy relative to feed availability. When this component is added, the smaller animals with varying amounts of Jersey ancestry come to the fore. Based on the index incorporating all four components, the ½ Jersey ½ Arsi and ¾ Exotic ¼ Arsi are ranked first and second, with the ½ Exotic ½ Arsi and ½ Friesian ½ Zebu third and fourth.

Five general implications from this study of dairy productivity are summarized in Tables 24 and 25 and illustrated in Figure 3.

1. The clear superiority of all crossbreds over the indigenous breed groups, culminating in 105% for the productivity index covering all four components (Table 25).
2. The similarity in performance of the 75% *Bos taurus* and the 50% *Bos taurus*. While milk yields were 13% higher in the 75% grades, their overall productivity was identical to that of the 50% grades (Table 25).
3. The lack of superiority of the Friesian cross over the Jersey cross. While the Jersey cross was 12% inferior to the Friesian cross in total milk yield, it was 14% superior in overall productivity (Table 25).
4. The similarity in performance between the indigenous Arsi and Zebu, based on overall productivity for both purebred and crossbred use (Table 25).
5. The major advantages of calving in the wet season. For all evaluation criteria, calving from June to September gave higher productivity than any other period of the year. A 12% increase in overall productivity was achieved for June – September calvings compared with those during the rest of the year (Table 26).

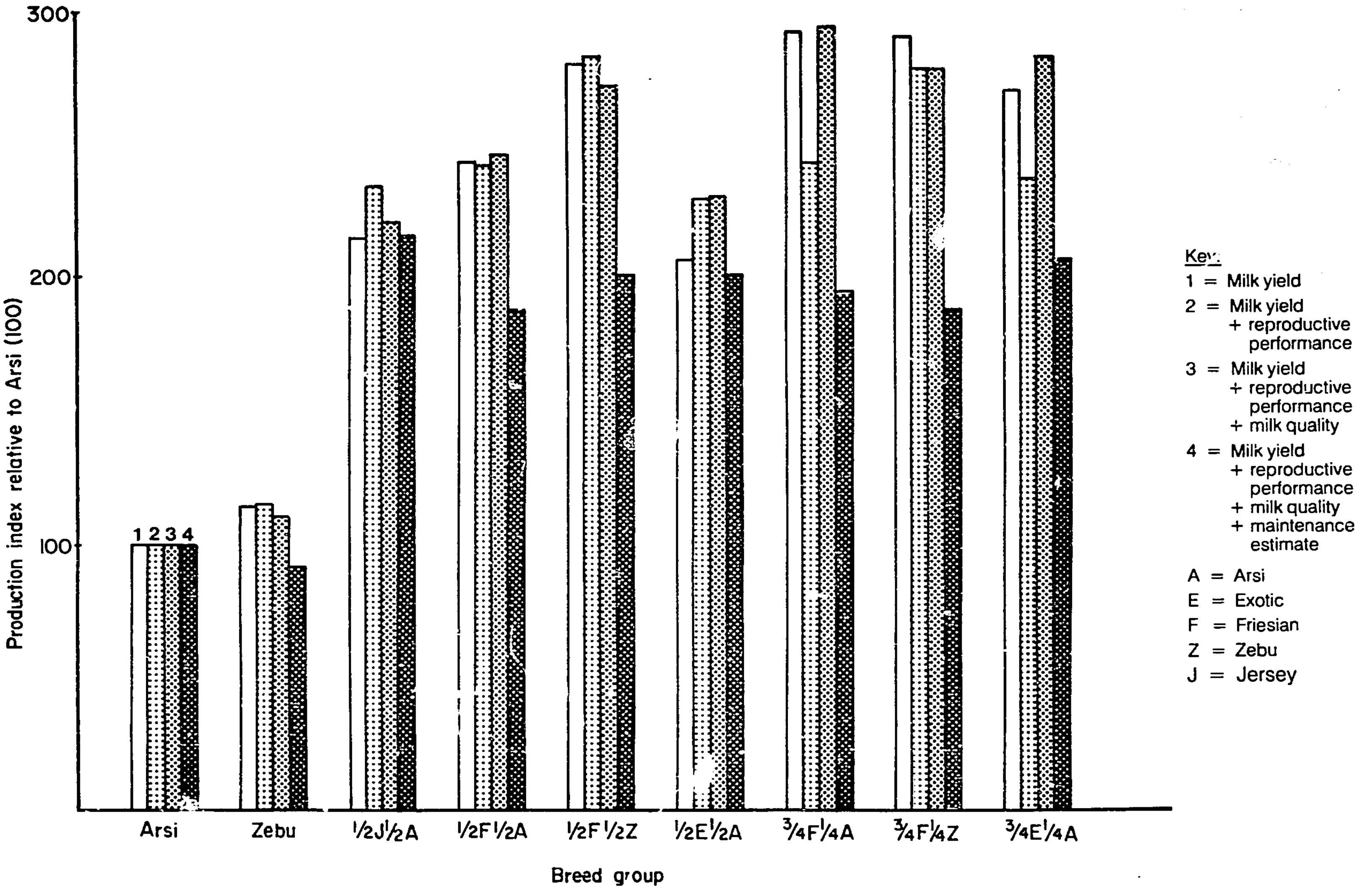
Thus decisions on genotypes most suited to a particular production situation must take careful account of factors such as whether the major target is liquid milk or milk products, annual pasture availability, and the feed supplement resources.

Table 24. *Ranking of breed groups according to different evaluation criteria.*

Breed group	Evaluation criteria: Milk yield (lactation)		Milk yield (lactation) + reproductive performance		Milk yield (lactation) + reproductive performance + milk quality		Milk yield (lactation) + reproductive performance + milk quality + maintenance estimate	
	Rank	Index[a]	Rank	Index[a]	Rank	Index[a]	Rank	Index[a]
½ Jersey ½ Arsi	6	215	7	223	4=	252	1	215
¾ Exotic ¼ Arsi	4	271	2	286	2	269	2	205
½ Exotic ½ Arsi	7	207	6	233	6	250	3	200
½ Friesian ½ Zebu	2=	291	4	278	1	273	4	199
¾ Friesian ¼ Arsi	1	293	1	297	3	263	5	193
½ Friesian ½ Arsi	5	244	5	247	7	248	6	188
¾ Friesian ¼ Zebu	2=	291	3	280	4=	252	7	187
Arsi	9	100	9	100	9	100	8	100
Zebu	8	115	8	112	8	113	9	91

[a] Index is percentage relative to Arsi, which is maintained at 100.

Figure 3. *Breed group evaluation by four criteria of productivity.*



The transferability of research station technologies to the smallholder situation is a key aspect of technology development and related extension work. Thus, it is pertinent to compare the productivity of the crossbred cows when kept under station and smallholder conditions. Table 27 shows the means for the performance traits of four breed groups as measured on smallholder farms and on Asela station.

The production levels were rather similar in each situation, with a lower smallholder farm lactation yield, lactation length, and calving interval, leading to a 4% lower daily yield over the lactation period and an 8% lower annual milk yield.

Breed group rankings according to annual milk yield on smallholder farms and Asela station are presented in Table 28. The rankings of the breed groups on smallholder farms were identical to their rankings on Asela station, although the sizes of the differences between them, reflected by the indices, varied.

Overall, the rather similar production levels and identical ranking of breed groups at Asela and on smallholder farms (Tables 27 and 28) implies that, when farmers manage a few (one or two) cows and are given sufficient extension support, dairy productivity remains satisfactory. Similar observations were made by Stotz (1979) on smallholder dairy farms in Kenya. The general implications arising from the dairy productivity study on Asela station are thus equally applicable to the smallholder farm situation.

Table 25. *Differences between genotypes according to different evaluation criteria.*

Comparison	Difference (%) based on criteria of: Milk yield (lactation)	Milk yield (lactation) + reproductive performance	Milk yield (lactation) + reproductive performance + milk quality	Milk yield (lactation) + reproductive performance + milk quality + maintenance estimate
½-bred versus indigenous	+130	+138	+141	+105
¾ grade versus ½-bred	+13	+12	+2	0
Jersey cross versus Friesian cross	−12	−10	+2	+14
Arsi versus Zebu as purebreds	−13	−11	−12	+9
Arsi versus Zebu for crossbreeding	−7	−3	−3	−1

Table 26. *Differences between calving season according to different evaluation criteria.*

Calving season	Ranking and difference (%) from mean, based on criteria of:							
	Milk yield (lactation)		Milk yield (lactation) + reproductive performance		Milk yield (lactation) + reproductive performance + milk quality		Milk yield (lactation) + reproductive performance + milk quality + maintenance estimate	
	Rank	%	Rank	%	Rank	%	Rank	%
Jan–Feb	4	−2.5	3	0	3	+1.8	4	−3.1
March–May	5	−3.5	5	−5.1	5	−12.5	5	−8.6
June–July	1	+4.5	2	+2.2	2	+4.5	2	+4.8
Aug–Sep	2	+2.1	1	+3.7	1	+6.5	1	+9.8
Oct–Dec	3	−1.0	4	−0.9	4	0	3	−2.9
June–September versus October–May		+5.8		+5.0		+9.1		+12.8

Table 27. *Overall comparison of performance traits on smallholder farms and Asela station.*

Trait	Smallholder farms $\bar{x}$	Asela station $\bar{x}$	Farms versus station %
Lactation milk yield (kg)	1817	2106	−13
Lactation length (days)	340	361	− 6
Milk yield/day of lactation (kg)	5.59	5.85	− 4
Dry period (days)	99	83	+19
Calving interval (days)	429	441	− 3
Annual milk yield (kg)	1624	1770	− 8

Table 28. *Breed group comparisons of annual milk yield on smallholder farms and Asela station.*

Breed group	Smallholder farms		Asela station	
	Rank	Index*	Rank	Index*
¾ Friesian ¼ Zebu	1	125	1	109
½ Friesian ½ Zebu	2	111	2	108
½ Friesian ½ Arsi	3	86	3	96
½ Jersey ½ Arsi	4	78	4	87

* Index is percentage relative to respective column mean only.

SUMMARY

Analyses were carried out on a range of performance traits and productivity estimates for indigenous Arsi and Zebu cattle and eight different grades of these with Jersey and Friesian, maintained for milk production. Data covered the period 1968 to 1981, and the animals were kept at Asela station and on surrounding smallholder farms in the Arsi Region of Ethiopia. Genetic and environmental effects relating to breed group, season and year of calving or birth, parturition number etc, were evaluated as appropriate for each performance trait.

Overall at Asela station, for the different breed groups, age at first calving ranged from 31.3 to 35.7 months, calving interval from 12.9 to 17.2 months, breeding efficiency index from 91 to 107%, postpartum cow weight from 236 to 336 kg, female calf birth weight from 21.9 to 28.4 kg, lactation milk yield from 809 to 2374 kg, lactation length from 272 to 411 days, milk yield per day of lactation from 2.7 to 6.3 kg, dry period from 76 to 165 days, butterfat percentage from 4.1 to 5.5%, total fat per lactation from 35 to 98 kg, fat-corrected milk yield per lactation from 803 to 2367 kg, fat-corrected milk yield per day of lactation from 2.8 to 6.5 kg, annual milk yield from 694 to 2044 kg, annual fat-corrected milk yield from 689 to 1973 kg and annual fat-corrected milk yield per unit metabolic weight of cow from 11.0 to 26.0 kg.

The major points to emerge concerning the final productivity index were the clear superiority of all crossbreds over the indigenous breed groups (105%), the similarity in performance of the 75% *Bos taurus* and the 50% *Bos taurus*, the lack of superiority of the Friesian cross over the Jersey cross, the similarity in performance between the indigenous Arsi and Zebu, and the major advantages of calving in the June – September wet season compared with the rest of the year.

Production levels on smallholder farms were rather similar to those on Asela station, and based on annual milk yield the rankings of the four crossbred groups kept on smallholder farms were the same as their rankings on Asela station.

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ABBREVIATIONS

AI	Artificial insemination	F_2	Second generation
ARDU	Arsi Rural Development Unit	FCM	Fat-corrected milk
BE	Breeding efficiency	kg	Kilogramme
°C	Degree centigrade	m	Metre
CADU	Chilalo Agricultural Development Unit	mm	Millimetre
CV	Coefficient of variation	MS	Mean square
d.f.	Degree of freedom	No.	Number
F_1	First generation	SE	Standard error

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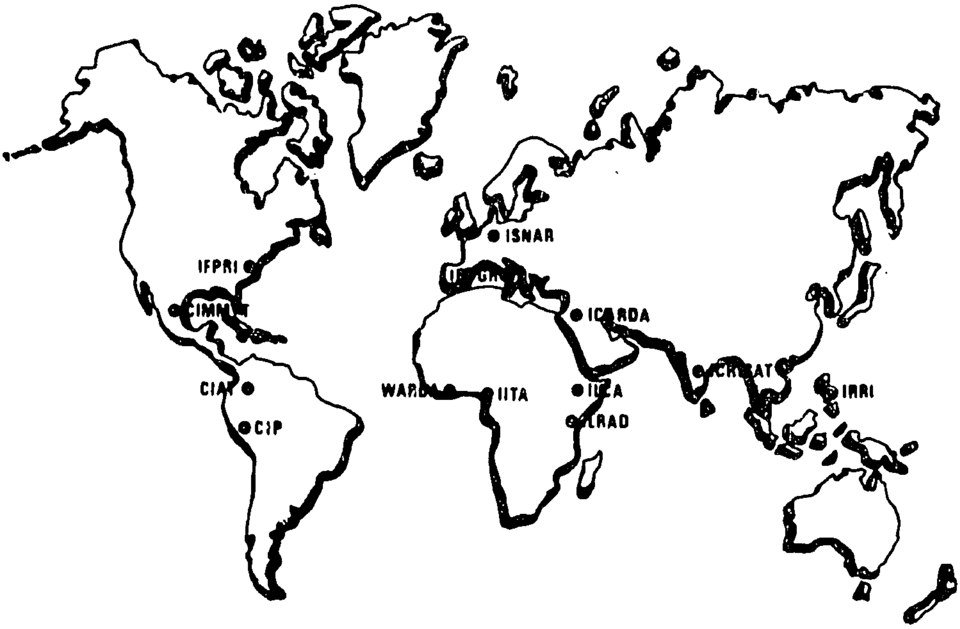

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International Livestock Centre for Africa (ILCA), Ethiopia: African livestock production.

International Rice Research Institute (IRRI), the Philippines: rice.

International Institute of Tropical Agriculture (IITA), Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima bean, soybean).

International Laboratory for Research on Animal Disease (ILRAD), Kenya: trypanosomiasis and theileriosis of cattle.

West Africa Rice Development Association (WARDA), Liberia: rice.

International Service for National Agricultural Research (ISNAR), the Netherlands.

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