Cattle Genetic Resources of India

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The Champion Dairy Breed

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FOREWORD

Largely livestock are understood to have created from few, often a single domestication event for every species, from which comprehensive radiation, genetic alteration and modification has emerged. Natural and artificial selection has created huge genetic diversity among breeds. This diversity is perceptible in the shape of adaptation to rigorous and unpredictable environments, resistance to many of the leading indigenous diseases, and vastly improved and specialized production ability. Nearly all wild ancestors of livestock are either vanished or existing in inadequate number with limited genetic diversity. Thus, contrary to many agricultural plant species, most or all genetic diversity in livestock exists within and between the available domesticated farm animals. Extensive, but still meager effort is in progress to characterise livestock at the phenotypic and molecular genetic levels, and to document their production environments, utilization and status.

The enormous and diverse cattle genetic resources of India are signified in the form of 30 documented breeds of zebu cattle besides numerous populations yet uncharacterized and undefined. An abundance of the Indian cattle breeds enter the draft category as cattle development in India principally rested on the production of bullock energy required for conventional agricultural operations and load pulling. A distinctive tendency for enhanced animal production using a few, superbly selected breeds have instigated speedy erosion in the number of local breeds triggered by crossbreeding or breed replacements.

Sahiwal breed of zebu cattle symbolizes the best germplasm in India and Pakistan as far as dairy merits are concerned. Notwithstanding being the best dairy cattle breed of the country, Sahiwal is degenerating not only in its population but also in its production both in the farmers' flock as well as at organized farms. Currently, only a few herds of pure Sahiwal cattle are available around Fazilka and Abohar towns in Ferozepur district of Punjab besides some animals maintained at governmental organized farms. The authors merit deepest appreciation for their intense efforts in assembling such extensive and outstanding information in a comprehensive bulletin and signifying an undelayed need to reformulate the breeding and developmental strategies to stop further deterioration and dilution of this valuable germplasm.

(S.P.S. Ahlawat)

PREFACE

Sahiwal breed of zebu cattle symbolizes the best germplasm in India and Pakistan as far as dairy merits are concerned. Sahiwal cattle are also known as Montgomery cattle, as they are largely bred in the district of Montgomery of Pakistan. Though the original breeding tract of this breed lies in Montgomery (now Sahiwal) district of Pakistan, yet some herds are also found in India along the Indo-Pak border in Ferozepur and Amritsar districts of Punjab, and Sri Ganganagar district of Rajasthan. Sahiwal cattle are believed to be related to cattle of Afghanistan and may contain some Gir blood also. It is, thus, closely related to Red Sindhi, Afghan and Gir breeds.

Currently, only a few herds of pure Sahiwal cattle are available around Fazilka and Abohar towns in Ferozepur district of Punjab (India). The dairy qualities of this breed were appreciated and exploited by people known as "junglies" who reared them in large herds. However, unfortunately, this convention vanished with the transformation of irrigation and farming systems in recent years. Lately, this precious germplasm has been declared as an endangered breed (FAO 1991). According to the FAO reports (FAO 1991) the world population of true Sahiwal cattle has dwindled to less than 5000 heads with a large number found in Pakistan, India and Kenya. Due to its unique attributes, Sahiwal is one of the few indigenous breeds which has been imported by many tropical countries from India or Pakistan and has been used either for first crossing or later on for incorporating valuable Zebu genes.

It may shock a common reader that notwithstanding being the best dairy cattle breed of the country, Sahiwal is degenerating not only in its population but also in its production both in the farmers' flock as well at organized farms. This warrants an undelayed need to reformulate the breeding and developmental strategies to stop further deterioration and dilution of this valuable germplasm and bring about genetic improvement in the productivity of the breed which is undoubtedly the best indigenous cattle milk breed. In this compilation an attempt has been made to describe the breed characteristics of the breed by collecting and compiling the available published information and suggest strategies for the conservation and improvement of this most important dairy breed of the country.

We wish to put on record our gratefulness to Dr. Mangla Rai, Director General ICAR, Dr. V.K. Taneja, Deputy Director General (AS), ICAR and Dr. S.P.S. Ahlawat, Director, NBAGR, Karnal for their persistent encouragement and support and granting the essential conveniences and precious suggestions in the preparation of the document. Distinctive credits are due to Dr M.S. Tantia and his coworkers who conducted field study on the breed in the breeding tract and created precious first hand information. We also offer appreciation to chairpersons and members of all the species working groups of NBAGR for constructive suggestions and remarks in the completion and development of the bulletin. The assistance offered by the photography section, computer section, library and other divisions and sections of NBAGR is appropriately accredited. Persistent support rendered by Mrs Amita Kumari, PA, Sh. K.C. Sharma and Sh. Moti Ram technical assistants in typing and arranging the manuscript and providing photographs is thankfully acknowledged.

(AUTHORS)

CONTENTS

SAHIWAL

Common Name	:	Sahiwal
Other Common Names	:	Lambi Bar, Lola, Montgomery, Multani and Teli.
Scientific Name	:	*Bos indicus*
Group	:	Zebu
Origin or Range	:	Pakistan and India
Relative Size	:	Average
Compatibility	:	Relatively Non Aggressive
Category	:	Mammals » Cattle

Characterization of Sahiwal Cattle

Various aspects of a population are useful in its characterization, including phenotypic traits (monogenic and polygenic), reproduction, geographic distribution, origin and habitat etc. The genetic characterization of populations, breeds and species allows the assessment of genetic variability, a crucial element in determining breeding strategies and genetic conservation programs. The information available on these aspects for Sahiwal, the most important Dairy breed of Asia, is presented in the following text.

Origin of Cattle

Cattle are considered to have been one of the first animals domesticated by man for agricultural purposes. They were tamed to provide milk, meat and hides and for draft purposes. Where and when exactly this domestication started is not clearly documented historically, but it is thought cattle were probably first domesticated in Europe and Asia about 8500 years ago.

Domesticated cattle belong to the family Bovidae, which includes ruminants with paired, hollow, unbranched horns that do not shed and an even number of toes. Species belonging to the family Bovidae that are so closely related to true cattle that they can interbreed include the bison, and yak. (of course, the term 'Cattle' extends only to the Cow and its progeny).

Cattle belong to the genus Bos and there are two species *taurus* (which includes all breeds of British and European cattle which do not possess a hump) and *indicus* (which includes the humped cattle of the tropical countries like India and Pakistan). Purebred cattle breeds have been selectively bred over a long period of time to possess a distinctive identity in color, size, conformation, and function and have the prepotency to pass these traits to their progeny.

There is general concern (the world over) that the genetic variation within the few domestic animal species is disappearing through breed substitution and crossbreeding. Any reduction in the diversity of genetic resources narrows the scope to respond to changes in the environment, disease challenges, or demand patterns. In the tropics, however, the most serious concern is the imminent loss of locally adapted breeds.

Origin and Breeding Tract of Sahiwal Cattle

Olver (1938) observed that the Sahiwal breed is closely related to the cattle of Afghanistan, that they are pale red or dun mixed with white and are among the best milking breeds of India (Pakistan). He further mentions that large numbers of people from Rajputana and Kathiawar with their cattle at one time came into the area of the Sahiwals and it is evident that some Gir blood, introduced in all probability at that time, still exists in this breed. Sahiwal cattle are also known as Montgomery cattle, as they are largely bred in the district of Montgomery. The Sahiwal is one of the best dairy breeds of zebu cattle. Though its original breeding tract lies in Montgomery (now Sahiwal) district of Pakistan, yet some herds are also found in India along the Indo-Pak border in Ferozepur and Amritsar districts of Punjab, and Sri Ganganagar district of Rajasthan. Sahiwal cattle may be related to cattle of Afghanistan and may contain some Gir blood also. It is, thus, closely related to Red Sindhi, Afghan and Gir breeds.

Thus, the Sahiwal originated in the dry Punjab region which lies along the Indian-Pakistani border. The breed derives its name from the Sahiwal area in

***Figure 1** : Map showing the breeding tract of Sahiwal breed*

Montgomery district of Punjab (Pakistan) where they originated. As one of the best dairy animals existing in India and Pakistan, Sahiwal cattle were once ordinary draft animals. Their dairy qualities were appreciated, and people known as "junglies" reared them in large herds. However, unfortunately, this convention vanished with the transformation of irrigation and farming systems in recent years.

Currently, a few herds (around 70) of pure Sahiwal cattle are available around Fazilka and Abohar towns in Ferozepur district of Punjab (India). About 200 years ago, the Maharaja of Bikaner invited Sahiwal breeders from Montgomery area. These breeders migrated and settled in various parts of Bikaner state because of pressure on pasturelands in the breeding tract. During the partition many breeders went back to Pakistan but some remained in India. Rearing of these cattle was the sole occupation and livelihood of these breeders. With the advent of Rajasthan canal, more land came under crops and free pasturelands were reduced to the outskirts of various towns in Sri Ganganagar and Ferozepur districts. The closeness to urban population provided better market for milk and milk products and they settled there temporarily (Tantia et al 1998).

India is the most significant resource of cattle diversity in the world. Cattle breeds of Indian derivation are being exploited in quite a few countries including Australia, South Africa, Latin America and USA for developing major livestock economies. Sahiwal breed of zebu cattle symbolizes the best germplasm in India and Pakistan as far as dairy merits are concerned. Lately, this precious germplasm has been declared as an endangered breed (FAO 1991). According to the FAO reports (FAO 1991) the world population of true Sahiwal cattle has dwindled to less than 5000 heads with a large number found in Pakistan, India and Kenya.

Significance of Sahiwal breed cannot be described in a better way than what has been quoted by Kanglade Sahiwal Cattle Stud, a member of the Austarlian Society for Sahiwal cattle, it goes like:

Do you want to improve your Herd ?

Why not switch to Sahiwals for

Ease Of Calving

Excellent Mothers

Resistance to eye Cancer

Resistant to Ticks

Drought Resistant

Bloat Tolerance

Flourish in Tropical Areas

Equable Temperament

Lean Meat with even Fat

Due to these attributes, Sahiwal is one of the few indigenous breeds which has been imported by many tropical countries from India or Pakistan and has been used either for first crossing or later on for incorporating some Zebu genes, after the failure of the crossbreeding to make improvements by increasing the exotic inheritance for developing suitable dairy breeds (Nagarcenkar, 1982). The multi-faceted usage of this breed is clear from the fact that in Kenya, a National Sahiwal Stud has been established at Naivasha by importing Sahiwal cows from India and Pakistan. The animals of these breeds have also been utilized for the production of synthetic strains like Jamaica Hope (JH), Australian Milking Zebu (AMZ) and Australian Friesian Sahiwal (AFS) in other countries

Location and Topography of Breeding Tract

The breeding tract of Sahiwal in India lies between 29°10′ and 30°55′ north latitude and 73°6′ and 74°4′ east longitude. The area is an undulating plain. The main crops grown in the area are wheat, barley, cotton, chickpea, lentil and rapeseed. Grazing areas are limited, as pasturelands have been converted into agricultural fields. These are now available only along the river bands and roadsides.

Figure 2 : *A Sahiwal herd moving about for grazing along roadside*

Soil

Sandy loam and loam soils are predominant in this area. A very large proportion of agricultural land is now under irrigation either through canals or through tube wells.

Climate

Weather in this area is extremely hot during summer (April to August) and extremely cold during winter (December to February) with temperature varying between 0° and 48°C. The climatic environment is sub-tropical and arid. Annual rainfall is around 25 to 30 cm. Heavy dust storms occur frequently during summer.

Socio-Economic Status of Sahiwal Owners

The farmers in the districts of Ferozpur, Amritsar and Gurdaspur of Punjab state and Ganganagar district of Rajsthan primarily keep Sahiwal cattle. A survey of more than 13, 000 farmers in the 3 districts of Punjab revealed that as high as 34-48 % of the Sahiwal keepers are landless farmers, 9.2 –20.3 % are marginal farmers with 0-1 hectare of land; 17.5- 26.0 % are small farmers with 1-2 hectare of land; 11.6 –24.6 % farmers are medium with 2-8 hectare of land and only 0.7 –4.2 % farmers are large with land holding of more than 20 hectares (Tantia et al 1999). The landless farmers, to a very large extent, are dependant on animal rearing and keep the Sahiwal cattle. Almost 54% of the farmers keep cattle in addition to buffaloes which have occupied the more favourable position since the shift in agricultural operations from bullocks to machines.

Figure 3 : *Sahiwal animals secured in enclosure prepared from locally available thorny bushes*

The average family size of Sahiwal rearers is on the higher side (5.35, 5.39 and 6.32 respectively in Ferozpur, Amritsar and Gurdaspur districts) mainly due to their low education level. The corresponding number of literate members per family was 1.99, 1.01 and 2.24 respectively. More male members were occupied with rearing of animals than females. The socio economic status of Sahiwal rearers is summarized in Table 1.

Table 1. Family and Land status of farmers in Sahiwal tract

District	Family size	Literate members			Land holding (Acres)
		Total number	Male	Female	
Ferozpur	5.35	1.99	0.96	1.11	4.99
Amritsar	5.39	1.01	0.62	0.30	3.59
Gurdaspur	6.32	2.34	0.56	0.12	2.34

Source: Tantia et al 1998

Survey of 70 Sahiwal breeders in the breeding tract of Ferozpur District revealed that the breeders are landless Muslim families with family size of 7.1 and the literacy rate a mere 5%. On an average 3.3 male and 2.8 female members per family were associated with cattle rearing activities. The sole source of their living is rearing cattle, mainly Sahiwal (Tantia et al 1999).

Managemental Practices in the Breeding Tract

Housing

The animals are not provided with any specific type of housing. Rather the animals are maintained unchained in open area. Only the young calves are contained in bush enclosures. The human dwellings and cattle enclosures are common such that differentiation between the two is not possible. Practically the owners share their shelters with their cattle heads. Though the animals are maintained under very poor hygienic conditions yet the animals are resistant to majority of the tropical diseases. This goes to substantiate the popular belief that Indian cattle in general and Sahiwal in particular are naturally resistant to tropical diseases. The average herd size ranges from 30 to 70 animals with about 15-25 milking cows (Tantia et al 1998 and 1999).

Figure 4 : Open type housing provided to sahiwal cattle in the breeding tract

Grazing and Feeding

The animals are taken out for grazing for the whole day. The milking cows are brought early for milking while the rest of the herd returns by sunset. The animals are also supplemented with green and dry fodder. Milking cows are also compensated by feeding concentrate in the form of cottonseed, barley and cakes. The concentrate is provided in soaked form at the time of milking. The animals are fed in groups. Source of drinking water for the animals as well as their owners is hand pump. Special attention and care is provided to young calves. They are provided whole milk up to the age of about one month when supplementing feed in the form of green is initiated. Calves are allowed to suckle 1 teat up to the age of about 6 months. At birth the sex ratio is almost equal which starts deviating towards female dominance from the age of 1 year or so (Tantia et al 1998, 1999).

Selection of breeding males and females

The male calves are selected for breeding at a very young age based on their dam's milk yield, body conformation and breed characteristics. The selected males are provided special care and attention while rest of the males are disposed off by the age of 1 to 1.5 years. The heifers are reared with utmost care and fed properly. The breeders are more careful after the heifers attain puberty. Natural service is the only method of breeding adopted by these breeders (Tantia et al 1999).

Figure 5 : A mature Sahiwal heifer (left) and a young bull (right)

Population status in India

Only few herds of pure Sahiwal cattle are now available in the breeding tract comprising of certain pockets of the bordering districts lying in the states of Punjab, Haryana and Rajasthan. A survey of Ferozepur, Amritsar and Gurdaspur districts of Punjab, described as the breeding tract of Sahiwal cattle, revealed that only 8.8 and 8.5% of the cattle in the districts of Amritsar and Gurdaspur respectively were Sahiwal type, while this proportion was 39.1% in Ferozepur district. The proportion of true Sahiwals was even much smaller. These are mainly concentrated around Fiazilka and Abohar towns of Firozepur Districts of Punjab state. The Sahiwal cattle breeders around these towns are landless Muslim families whose sole source of livelihood is rearing cattle. These people prefer to be called as 'Joiay' or 'Gujar'. The breeders are mainly landless illiterate farmers (literacy rate of mere 4.8%) with large families (average family size of 6.9).

With the introduction of crossbreeding on a very large scale in the state of Punjab the population of Sahiwal in the breeding tract has shrunk considerably and now only few heads of pure Sahiwal are available with few enthusiastic Sahiwal breeders (Tantia et al 1998). However the hereditary keepers of Sahiwal cattle are extraordinarily committed to keeping this breed in a purebred state, resisting efforts to convert them to cross-breeding (Tantia et al., 1998). While implementing crossbreeding with exotic bulls/semen on extensive scale in the country, Sahiwal was used as the female stock, to a large extent, thus eroding the genetic base of this prized germplasm fatally and irretrievably. The situation is further aggravated by the facts that the agriculture is absolutely mechanized and the farming community of Punjab always favored buffalo milk over cattle milk mainly due to its high fat content, causing a sharp decline of about 20% from 1997 to 2002 in cattle population of the state. The exact population of pure Sahiwal cannot be precisely determined, as breed wise allotment of livestock population data is not available in the country. However, pedigreed and performance recoded Sahiwal are available in some organized farms spread in several states of the country (Table 2).

Table 2. Sahiwal Cattle Farms in India

S. No	Name of Farm	Location	City	State
1	Government Livestock Farm	Hisar	Hisar	Haryana
2	National Dairy Research Institute	Karnal	Karnal	Haryana
3	Cattle Breeding Farm	Beli Charna	Jammu Cantt	Jammu & Kashmir
4	Cattle and Buffalo Breeding Farm	Anjora	Durg	Chhatisgarh
5	Cattle Breeding Farm	Bilaspur	Bilaspur	Chhatisgarh
6	Cattle Breeding Farm	Nabha	Patiala	Punjab
7	State Livestock cum Agricultural Farm	Chak Gajaria	Lucknow	Uttar Pradesh
8	All India Co-coordinated Project on cattle	Haringhata	Nadia	West Bengal
9	Bull Mother Farm	SAGP, Bidaj	Kheda	Gujarat
10	Sabarmati Gaushala Ashram	Bidaj	Bidaj	Gujarat
11	Cattle Breeding Farm	Bod	Amravati	Maharashtra
12	Satguru Sewa Sangh	Bheni Sahib (Khanna)	Ludhiana	Punjab
13	Livestock Farm of Punjab Agricultural University	Ludhiana	Ludhiana	Punjab
14	Livestock Farm of GB Pant University of Agriculture	Pantnagar	Nainital	Uttaranchal
15	Military Dairy Farm	Meerut	Meerut	Uttar Pradesh
16	Amritsar Pinjrapole Gaushala,	Amritsar	Amritsar	Punjab
17	Namdhari Gaushala	Sri Jeevan Nagar	Sirsa	Haryana
18	Sabarmati Ashram Gaushala	Bidaj Farm	P.O. Lali	Gujarat

About 1500 breedable females are maintained on these farms (Joshi et al 2001). The average herd size in these farms is simply around 100 animals, which is too insignificant to execute any breed improvement plan. Though there is proper recording of pedigree and performance of animals on these farms but there is hardly any synchronization between the farms to carry out sire evaluation programmes based on multi location testing. Only few of these farms enjoy infrastructure facilities for proper rearing of breeding males, collection and cryopreservation of semen and artificial insemination. Non-accessibility of high merit bulls to the farmers in the breeding tract forces them to get their cows serviced by the bull effortlessly accessible to them notwithstanding its genetic merit. This is the main cause of critical decline in the performance of animals under farmers' herds. Rendering the situation even worse, there is no record keeping of the pedigree or performance data of the animals under field conditions, thus further jeopardizing scientific improvement strategies.

Status of Sahiwal cattle at organized farms The precious Sahiwal germplasm of the country has been used extensively for developing synthetic strains of crossbred cattle like Karan Swiss, Karan Fries and Frieswal. Though these crossbred strains are superior in their milk producing capacity, yet their superiority falls short when the overall economy is considered mainly due to their susceptibility to tropical diseases and reproductive failures. This drastically reduced the number of Sahiwal cattle on these organized farms and hampered the genetic improvement and multiplication programme of the breed.

It may shock a common reader that notwithstanding being the best dairy cattle breed of the country, Sahiwal is degenerating not only in its population but also in its production both in the farmers' flock as well at organized farms. But those having understanding of the geographical location of the breed and the circumstances at organized farms will categorically not be amazed. To sum up, three issues can be singled out which are predominantly accountable for the abrupt drop in Sahiwal population not only in the breeding tract but also at the organized farms

1. Agricultural processes in the breeding territory of the breed are totally mechanized, substituting bullock force with tractor power. The farmers who were rearing Sahiwal cattle principally for bullocks, no more need it as a result of this shift in production system.
2. Buffalo milk has a preference over cow milk in the country normally and in the breeding tract of Sahiwal predominantly. This, on top of the availability of two of the best buffalo breeds of the country in the breeding tract (Nili Ravi and Murrah) or its vicinity, has virtually replaced Sahiwal cattle by

buffaloes. This is substantiated by a sharp fall in cattle population in the states of Punjab and Haryana and a concomitant escalation in buffalo population.

3. Sahiwal germplasm existing at the organized farms was extensively consumed for crossbreeding with exotic bull/semen to generate crossbreds with the singular intention of enhancing milk productivity of the country without taking into consideration other factors like adaptability of the crossbreds under minimal input production systems and inhospitable tropical climatic conditions.

The state of affairs today is critical, as the country could not generate a stable and durable crossbred genetic group well adapted to the local climatic conditions and low input production system and at the same time also has lost its best cattle germplasm (Sahiwal), to a large extent.

Physical Characteristics of the Breed Animal Description

Sahiwal cattle are generally a lovely burnished red color, and bulls' extremities are a darker shade than the rest of the body. Shades may vary from a mahogany red-brown to a more grayish red color. Occasionally, there are white patches on the Sahiwal, and its muzzle and eyelashes are a lighter color than the rest of the cow. In body type, Sahiwal are long and heavy, fleshed out in loose skin. The Sahiwal is a heavy breed with symmetrical body and loose skin. Animals are long, deep, fleshy and comparatively lethargic. Fore head is medium sized in females but broad and massive in males. Horns are short and stumpy. Hump in males is massive and frequently falls on one side. Navel flap is loose and hanging. Ears are medium sized with black hair on the fringes. Dewlap is large and heavy. Sheath in males is also pendulous. Tail is long and fine with a black switch reaching almost to the ground. Udder is generally large, bowl shaped, pliable, firmly suspended from the body. Pendulous udder is also found in high producing females. Teats are large and cylindrical in shape.

After years of use as draft animals, Sahiwal cattle have docile temperaments. They are slow to hostility or anger- in fact, they are slow in most things. As draft animals they cannot be expected to do quick work, although they can pull heavy weights. Sahiwal Cattle operate extremely well under drought conditions, need little feed, and are heat and tick resistant. This makes them ideal for tropical, arid or sub-tropical dairy farmers. Easy to handle and adaptable to most climates and management systems, Sahiwal cattle are easy to care for. At maturity, Sahiwal cattle usually weigh around 350 kilograms, although weights vary from region to region. Bullocks, which are not to be kept for breeding, are castrated when they are about 3 years old. At this age, well-fed animals usually weigh around 350 Kg. Sahiwal bullocks are observed to be slow yet steady workers. A pair of bullocks can pull a load of about 2 tons in a cart with pneumatic tires on a hard road and cover a distance of 15 miles in a day of 6 to 8 hours' travel.

Specific Care Information

Relative Care Ease

In addition to being tick resistant, Sahiwal cattle show a general resistance to all internal and external parasites. They are best suited to slow work when used as draft animals, and are extremely well suited to warm or hot climates.

Breeding and Propagation

Relative Breeding Ease

Sahiwal cattle have very good milk production and can suckle a calf while donating milk to your dairy. Calves are small at birth, but grow extremely quickly. This makes Sahiwal bulls good cross breeders who will not impart calving problems to the cows they are breeding. Sahiwal cows rarely have calving difficulties, and usually reach sexual maturity at three to four years of age. The calving interval for Sahiwal cows is around 430 to 580 days. Sahiwals demonstrate the ability to sire small, fast-growing calves and are noted for their hardiness under unfavorable climatic conditions.

Udder and Teat Shapes

Based on examination of udder and teat shapes of 102 Sahiwal cows, Khire et al. (1976) reported the trough shaped, globular and pendulous shaped udders as 63.72%, 20.58% and 15.69%, respectively (Table 3). Incidence of conical, cylindrical and bottle shaped teat was 51.96, 41.17 and 6.86 percent, respectively whereas incidence of supernumerary teats was 37.25 per cent. Average length of right teat and left teat in fore and rear quarter was 7.53, 7.64, 6.08 and 6.18 cm, respectively. Average distance of longest teat from ground was 45.14 cm.

Figure 6 : A representative Sahiwal female selected from the breeding tract

Table 3. Udder and Teat shape of Sahiwal Cows

102	Trough shaped udders 63.72%	Globular shaped 20.58%	Pendulous shaped 15.69%		Khire et al., 1976
	Incidence of conical shaped teats 51.96%	Incidence of cylindrical shaped teats 41.17%	Incidence of bottle shaped teats 6.86%	Incidence of supernumerary teats 37.25%	
	Av. Length of right teat in fore quarter 7.53 cm	Av. Length of quarter left teat in fore 7.64 cm	Av. Length of right teat in rear quarter 6.08 cm	Av. Length of left teat in rear quarter 6.18 cm	
	Av. Distance of longest teat from ground 45.14 cm				

Figure 7 : Well-developed udder and teats of a representative Sahiwal cow

Functional Characteristics of the Breed

The averages of various economic traits give an overview of general performance of the breed. Heritability of a character is the fraction of total variability that is attributable to genes and their effects. Estimates of heritability of traits are useful for construction of selection indices, prediction of genetic response to selection and for deciding how much one can rely upon individual's own phenotype for selection. Hence, accurate estimates of heritability for different economic traits are indispensable in breeding programmes.

Birth weight and growth rates

The average birth weight of male and female Sahiwal calves is 22.35 and 20.67 kg, respectively. The highest birth weights of male and female calves were reported during 4th parity at NDRI Farm, while Sivarajasingam et al. (1986) reported highest birth weight during 3rd parity in Sahiwal cattle in Malaysia. Mwandotto (1986) reported average birth weight of 22.9 ± 0.09 kg of Kenyan Sahiwal cattle, whereas Singh and Bhat (1987) reported lowest birth weight (20.4 kg) in Indian Sahiwal calves. Different factors like sex, dam, year, month/season and herd parity were reported to have significant effects on birth weight.

The growth rate serves as a check on feeding systems and management efficiency for rearing calves and it influences the maturity age and lifetime productivity of cows. Mudgal and Ray (1965) reported that daily growth rate (309 and 293 g in male and female calves) was slow from birth to 2½ months and later it exhibited an increasing trend (476 and 407 g from 2.5 to 6 months). The growth rate was lower from seven months to one year of age. Mwandotto (1986) reported absolute daily growth rates in Kenyan Sahiwal animals as 339.5±2.9, 409.7±3.3, 329.0±9.6 and 37.9±7.0 g from birth to 55 kg, 55 kg-125 kg, 125 kg-27 months of age and from birth to 27 months of age, respectively. The average weight at first conception and at calving in Indian Sahiwal cows was 288.74±31.07 and 380.16±31.00 kg, while in Kenyan Sahiwal cattle weight at first calving was 410.9±1.8 kg (Mwandotto, 1986).

Mwandotto (1986) reported heritability estimates as 0.17±0.06 for birth weight, 0.25±0.06 for absolute growth rate to 27 months of age, 0.03±0.04 for relative growth rate to 27 months and 0.33±0.07 for 27 months body weight of Kenyan Sahiwal cattle. Low and non-significant genetic and phenotypic correlations of growth traits with milk yield were reported.

Body Weights at Different Ages

Different workers have reported body weights of Sahiwal cattle at different stages of life and these are summarized in Table 4. Birth weight ranged from 19.1 kg (Tahir et al. 1985) to 22.9±0.09 kg (Mwandotto, 1986) with overall weighted mean of 21.26 kg with heritability of 0.21 (Taneja et al. 1978) and 0.40±0.07 (Wakhungu et al. 1991). Weaning weight ranged from 42.6 kg (Tahir et al., 1985) to 63.0 kg (Rai et al., 1974) with weighted mean of 49.23 kg and heritability of 0.63 (Taneja et al., 1978). Weight at 27 months of age was reported as 284.2±1.6 kg (Mwandotto, 1986) with heritability of 0.73 (Taneja et al., 1978). Weight at calving ranged from 287.4 kg (Taneja et al., 1979) to 410.9±1.8 kg (Mwandotto, 1986) with weighted mean of 405.29 kg and heritability of 0.18 (Taneja et al., 1978). Adult body weight was reported as 423.5±1.9 kg by Mwandotto (1986).

Table 4. Body weights of Sahiwal cattle reported by various workers

N	Birth Wt.	BW 12wk	At 27 month	Wt. at calving	Adult body wt	Reference
6022	22.9±0.09	—	284.2±1.6	410.9±1.8	423.5±1.9	Mwandotto BJ 1986
73	19.40	—	—	—	—	Bala et al., 1985
430	19.1	42.6	—	—	—	Tahir et al., 1985
259	—	—	—	313±5	—	Tahir et al., 1983
h^2	0.21	0.63	0.73	0.18	—	Taneja et al., 1978
84	19.8	58.9	—	287.4	—	Taneja et al., 1979
148	20.7	63.0	—	—	—	Rai et al., 1974
h^2	0.4±0.07	—	—	—	—	Wakhungu et al, 1991
>6000	20.04 (h^2=7±0.03)	—	—	—	—	Khan et al., 1992
1529	20.4±0.1	—	—	—	—	Nandagawali et al.1997
Weighted Mean	21.26	49.23	—	405.29	—	

Reproductive Traits (Male)

The male reproductive traits of Sahiwal bulls as reported by various workers are summarized in Table 5.

Table 5. Reproductive parameters of male Sahiwal cattle

N				
53	Age at first ejaculation 1365±631 days	Monthly no. of ejaculations/ bull: 6.5±3.6	Ejaculate volume : 4.8 ml	Usmani et al., 1985
	Sperm motility: 71.6±5.3%	Sperm conc. (x10^6ml) : 880.2±538.2	Post thawing motility: 40.9±5.4%	
6	Post thaw % swollen spermatozoa: 23.49	Normal acrosomes: 26.4±10.4	Spermatozoa head involved in head to agglutination: 12.4±6.7	Azam et al., 1998
	Spermatozoa with intact: 20.1±8.3%	Partially damaged: 11.6±4.4%	Completely damaged plasma membranes: 68.5±10.4%	
5	Seminal plasma cholesterol conc.: 312.16mg/100ml	Sperm cholesterol conc.: 128.56mg/100ml		Iqbal et al., 1984
	Total lipids: 656.54mg/100ml	Total lipids: 1212mg/100ml		
4	Fructose content: 593.24 to 712.4mg/100ml			Choudhary & Sadhu, 1981
	Vol/ ejaculate: 3.64±0.09	Mass motility: 1.36±0.04	Individual motility of spermatozoa: 60.55±0.33%	Ahsan ul Haq et al., 2003
	Dead spermatozoa: 27.73±0.87%	Abnormal spermatozoa: 15.41±0.86		

Semen

Some characteristics of semen studied by different workers are summarized in Table 5. Azam et al. (1998) reported the post thaw percent swollen spermatozoa, normal acrosomes, spermatozoa involved in head to head agglutination, spermatozoa with intact, partially damaged and completely damaged plasma membranes as 23.49, 26.4±10.4, 12.4±6.7, 20.1±8.3, 11.6±4.4 and 68.5±10.4 percent, respectively. Iqbal et al. (1984) studied the seminal plasma cholesterol concentration, total lipids, sperm cholesterol concentration and total lipids as 312.16, 656.54, 128.56

and 1212 mg/ 100ml, respectively in Sahiwal bulls. Volume per ejaculate, mass motility, individual motility of spermatozoa, dead spermatozoa and abnormal spermatozoa as 3.64±0.09, 1.36±0.04, 60.55±0.33%, 27.73±0.87% and 15.41±0.86%, respectively were reported by Ahsan ul Haq et al. (2003). Usmani et al. (1985) presented the results on age at first ejaculation, monthly number of ejaculations per bull, ejaculate volume, sperm motility, sperm concentration (x10^6ml) and post thawing motility as 1365±631days, 6.5±3.6, 4.8 ml, 71.6±5.3%, 880.2±538.2 and 40.9±5.4 percent, respectively. Choudhary and Sadhu (1981) reported fructose content as 593.24 to 712.4 mg per 100ml.

Sarder (2003) reported the semen characteristics of Sahiwal bulls in Bangladesh. The attributes included mean volume of ejaculation (6.0 ± 0.22 ml); sperm concentration (1471 ± 37 X 10^6); sperm motility (64 ± 0.035 %); total number of motile sperms/ ejaculate (6520 ± 396 X 10^6); total number of semen doses per ejaculate (314 ± 18) and total number of semen collections per month (3.0 ± 0.23).

Reproductive Traits (Female)

Age at First Calving (AFC)

Age at first calving is an important dairying trait because economics of milk production depends upon how early the production starts. Large AFC in Sahiwal breed of cattle has been the biggest setback to profitable dairying enterprise in India. Results of average AFC and its heritability estimates reported by different workers are presented in Table 6. Average AFC ranged from 879±9.00 days (Bhatnagar and Sharma, 1976) to 1579 days (Mirza et al., 1985) with overall weighted mean of 1267.28 days.

The overall average age at first calving was 1080 days ranging from 879 days in Indian Sahiwal maintained at Karnal (Bhatnagar and Sharma, 1976) to 1487 days at Hisar (Reddy, 1983). The heritability estimates of the trait reported by different workers ranged from zero (Reddy and Nagarcenkar, 1989) to 0.75±0.21 (Singh, 1977). A field survey in Ferozpur District indicated that the average age at first calving is around 4 years (Tantia et al 1998, 1999) under village conditions in the breeding tract.

The heritability estimates reported by various workers for AFC in Sahiwal cattle ranged from 0.18±0.04 (Gandhi and Gurnani, 1988) to 0.70±0.18 (Singal, 1993). But in general, AFC has been found to be a medium heritable trait. This indicates that selection on individual's performance can be relied upon for improvement in the trait.

Table 6. Age at First Calving (AFC) in Sahiwal Cattle

No of Observations	Age at First Calving	h^2 (AFC)	Refernces
398	1142.2		Gopal and Bhatnagar (1972)
490	1204±7.13		Kaul et al. (1973)
928	1465±12.85		Ahmad and Ahmad (1974)
258	1131±147	0.240.18	Tomar et al. (1974)
177	1177		Bhatnagar et al. (1975)
125	879±9		Bhatnagar and Sharma (1976)
689	1178±81		Singh (1977)
80	1095.9±16.7		Basu et al. (1979)
422	1226		Chhikara et al. (1979)
579	1175±62		Chawla and Mishra (1982)
126	1184.52		Sharma and Dhingra (1982)
580	1176		Bhatnagar et al. (1983)
661	1147.9		Reddy (1983)
385	1487		Reddy (1983)
383	1144.8		Reddy (1983)
637	1167.8		Reddy (1983)
223	1365.5		Reddy (1983)
259	1360±14		Tahir et al., 1983
	1579		Mirza et al., 1985
596	1228.7±15.24		Rao (1985)
571	1222.78±8.9		Singh (1986)
263	1180.62±12.75		Singh (1986)
756	1163.69±8.45		Singh (1986)
213	1398.18±14.29		Singh (1986)

360	1486.21±11.98		Singh (1986)
442	1168.62±146.53	0.69±0.29	Shah & Zafar, 1986
424	1212.82±10.84	0.18±0.04	Gandhi & Gurnani (1988)
2051	2108.0	0.29	Rege et al. (1992)
>6000	1321		Khan et al. (1992)
506	1369.25±8.00	0.70±0.18	Singal (1993)
	1210.8		Chaudhary and Ahmad (1994)
8009		0.367	Gandhi & Gurnani, 1995
323	1567.64±20.06		Kuralkar et al. (1996)
4700	1321		Khan et al. (1999)
277	1077.33±8.01		Mohanty (2001)
805	1188.79±15.95		Singh et al. (2001)
323	1101.07±8.54		Kannan (2002)
275	1069.98±9.31		Kumar (2003)
400	1330.92±10.82		Kushwaha et al. 2003
272	1098.23±7.74		Raja (2004)
Weighted Mean	1267.28		

Service Period

It is the period between calving and subsequent conception. Generally an optimum period of 60 days is allowed as postpartum rest. However, this period should not exceed 100 days for a cow to be reproductively efficient. This is also to ensure calving interval of 13-14 months. The average service period (SP) in Sahiwal cattle has been summarized in Table 7. The table reveals that average SP range from 68.07±2.3 days (Basu et al., 1979) to 271±8.71 days (Pundir and Raheja, 1995) with overall weighted mean of 168.74 days.

Estimates of heritability for SP have been found to be varying between -0.28±0.11 (Kannan, 2002) to 0.36±0.10 (Shah and Shah, 1981).

Table 7. Service Period (Days) reported in Sahiwal Cows

No. Observations	Service period (days)	h^2 (SP)	Reference
64	68.07±2.3		Basu et al. (1979)
664	177.5		Reddy (1983)
252	194.5		Reddy (1983)
397	246.5		Reddy (1983)
390	126.5		Reddy (1983)
651	207.5		Reddy (1983)
2468	124.51±78.89	0.36±0.10	Shah & Shah, 1981
	106		Mirza et al., 1985
>6000	171.8	0.18±0.05	Khan et al. (1992)
271	174.3		Sahota & Gill (1994)
352	271±8.71	0.03±0.05	Pundir & Raheja (1995)
323	216.45±9.06		Kuralkar et al. (1996)
50	165.12±9.3		Singh (1998)
192	151.96±12.62	0.254±0.256	Mohanty (2001)
204	157.89±16.31	-0.28±0.11	Kannan (2002)
237	145.41±10.93	-0.17±0.13	Kumar (2003)
400	195.02±6.36		Kushwaha et al. 2003
272	143.32±8.21	0.267±0.147	Raja (2004)
Weighted Mean	168.74		

Calving Interval

Calving interval has direct bearing both on reproduction and production efficiencies. Total lifetime production by an individual cow depends upon how early the production starts and how little it is interrupted. Thus, short calving interval along with early age at first calving is required for better efficiency of milk production. The average first calving interval reported by different workers was 440 days in Sahiwal cows and it ranged from 413 days (Reddy, 1983) to 498±124 days (Kushwaha and Misra, 1969). Perusal of Table 8 shows that calving interval in Sahiwal cows may be as long as 746.06±7.24 days (Rao, 1985) and as short as 283 days (Reddy and Nagarcenkar, 1989) and its overall weighted mean was 475.31 days. The literature revealed a considerable variability in this trait and hence a pointer of improvement for calving interval in Sahiwal breed. The average calving interval of Sahiwal cows in the breeding tract was reported between 18-22 months (Tantia et al 1998). The range of heritability estimates varied from -0.09±0.01 (Narayankhedkar, 1973) to 0.249±0.144 (Raja, 2004). Most of the estimates of heritability reported in the literature for sahiwal cattle were not significantly different from zero.

Table 8. Calving Interval (Days) reported for Sahiwal Cows

No of Observations	Average CI (days)	h^2 (CI)	Reference
118	484.4		Singh & Chaudhary (1961)
		0.05	Desai (1964)
75	485		Sunderasan et al. (1965)
99	465		Sunderasan et al. (1965)
84	482		Sunderasan et al. (1965)
81	462.56±12.15		Johar & Taylor (1973)
245	498.11±124.20		Kushwaha & Misra (1969)
		-0.09±0.01	Narayankhedkar (1973)
844	490.21		Ahmad & Ahmad (1974)
219	450.51±8.25		Taneja (1974)
		0.06	Taneja et al., 1978
558	465.7		Reddy (1983)
335	495.1		Reddy (1983)
307	413.2		Reddy (1983)
538	493.1		Reddy (1983)
205	475.1		Reddy (1983)
2357	472.0		Reddy (1983)
	412		Mirza et al., 1985
502	746.06±7.24		Rao (1985)
480	477.40±5.97		Singh (1986)
226	427.80±8.41		Singh (1986)
185	508.47±5.37		Singh (1986)
318	525.84±7.81		Singh (1986)
1883	481.26±3.61		Singh (1986)
283	0 to 0.17±0.22		Reddy & Nagarcenkar (1989)
20000	465		Dahlin A. 1998
400	505.49±6.32		Kushwaha et al. (2003)
471	425.10±8.68		Soumen Naskar (2003)
272	730.29±8.24	0.249±0.144	Raja (2004)
Weighted Mean	475.31		

Lactational Characteristics

Lactational Total Milk Yield

Lactation milk yield reflects the real economic worth of the cow and is considered as a selection criterion for the improvement of genetic potential of dairy animals. The trait shows considerable variability between lactation within individuals. Therefore, first lactation milk yield (FLMY) is considered in the studies to avoid the effects due to selection of animals in subsequent lactation. Averages of FLMY and its heritability estimates have been summarized in Table 9. It is evident that FLMY ranged from 1145.0 kg (Rege et al., 1992) to 2520.0±80.0 kg (Puri and Sharma, 1965). The overall weighted mean of FLMY was 1481.42 kg. The overall weighted average first lactation milk yield of Sahiwal cows was reported as1902 kg with a range of 1519 kg (Singh et al., 1980) to 2499 kg (Sundersan et al., 1965).

Estimates of heritability of FLMY have been found to be varying between 0.104±0.101 (Singal, 1993) to 0.576±0.200 (Raja, 2004). Heritability estimates ranging from zero to 0.92±0.40 have been reported. Positive and significant genetic and phenotypic correlations of milk yield with first lactation length and first calving interval have been reported. The estimates reported in literature suggested that the proportion of additive genetic variance in the trait is of medium type, and therefore, selection on individual basis is likely to result improvement in the next generation.

Table 9. Lactation Total Milk Yield (Kg.) of Sahiwal Cows

No. Observations	LMY (Kg.)	h^2 LMY	Reference
118	1492.3±64.5		Singh & Chaudhary (1961)
30	2520.0±80.0		Puri & Sharma (1965)
408	1620.8±21.5	0.51±0.21	Khanna (1968)
456	1596.0±21.0	0.36±0.18	Nagpal (1969)
857	1570.5±29.9		Mishra & Kushwaha (1970)
398	2236.0±33.5		Gopal & Bhatnagar (1972)
410	1548.2±86.51		Narayankhedkar (1973)
		0.41	Taneja et al., 1978
443	1617.0		Kumar & Narain (1979)
816	2116.0		Bhatia (1980)
3995			Kimenye D. 1981

108	1595.7±30.6		Sharma & Singh (1981)
343	1436.25		Taneja & Sikka, 1981
579	2022.1±38.87		Chawla & Mishra, 1982
126	1617.62		Sharma et al. (1982)
135	1163±31		Shah et al., 1982
974	1900		Chaudhary et al., 1985
442	1623.79±16.23	0.28±0.17	Shah & Zafar (1986)
173	1880.26±44.56	0.30±0.02	Sharma et al. (1987)
424	2352.39±38.64	0.195±0.04	Gandhi & Gurnani (1988)
2015	1145.0	0.35	Rege et al. (1992)
222	1695.88±20.55	0.30±0.15	Yadav et al., 1992
506	1488.42±17.70	0.104±0.101	Singal (1993)
341	1220±42		Nandagawali et al., 1997
8009		0.177	Gandhi & Gurnani (1988)
20000	1395		Dahlin A. 1998
		0.184±0.146	Choudhary et al. 2003
272	1941.59±58.76	0.576±0.200	Raja (2004)
Weighted Mean	1481.42		

Lactation (305 days) Milk Yield

The range of the mean values for the lactation 305 days milk yield was from 1183±31 kg (Shah et al., 1982) to 2499 kg (Sundaresan, 1965). The weighted mean for lactation 305 days milk yield was 1522.98 kg. The average performance of Sahiwal cows reported by different workers has been given in Table 10.

The estimates of heritability reported by various workers have been presented in the Table 10. The range was from 0.2136±0.221 (Kumar, 2003) to 0.630±0.26 (Kannan, 2002).

Table 10. 305 Days lactation Milk Yield (Kg.) of Sahiwal Cows

No. of Observation	305 DLMY	$h^2$305 DLMY	Reference
74	2499		Sundaresan et al. (1965)
396	2236±33.46	0.358	Gopal and Bhatnagar (1972)
251	2138±44.2		Chopra et al. (1973)
247	1597.23±31.19		Taneja et al. (1978)
753	1703		Taneja & Chawla (1978)
44	1602.5±180.83		Basu et al. (1979)

2185	1622.02		Singh (1981)
3995	1455±10		Kimenye D. 1981
343	2028.53±51.17		Taneja & Sikka (1981)
461	1853.6±33.32		Chawla & Mishra (1982)
135	1183±31		Shah et al (1982)
580	2088±33		Bhatnagar et al. (1983)
571	1971.39±24.24		Singh (1986)
263	1574.17±34.73		Singh (1986)
756	1550.06±23.01		Singh (1986)
213	1899.12±38.91		Singh (1986)
360	1553.44±32.64		Singh (1986)
424	2106.95±28.94	0.27	Gandhi & Gurnani (1988)
222	1679.40±18.95	0.32±0.16	Yadav et al., 1992
8009		0.337	Gandhi & Gurnani (1995)
20000	1363		Dahlin A. 1998
192	1365.93±81.46	0.447±0.227	Mohanty (2001)
805	1511.06±29.42		Singh et al. (2001)
249	1714.09±48.29	0.63±0.26	Kannan (2002)
273	1494.29±69.72	0.2136±0.2210	Kumar (2003)
272	1756.41±47.61	0.566±0.198	Raja (2004)
Weighted Mean	1522.98		

Based on a survey of Sahiwal cows in the breeding tract, it was found that the average daily milk yield varied from 6 to 10 Kg. Milk yield recorded at monthly intervals (test day yield) from 1st to 7th month of lactation are given in Table 11.

Table 11. Test Day Average milk Yield (Kg) of Sahiwal Cows in the Breeding Tract

Number of observations	Stage of Lactation (month)	Avearge milk yield (Kg)
177	1st	9.39
127	2nd	8.89
95	3rd	8.42
94	4th	8.24
90	5th	7.83
72	6th	7.38
48	7th	7.31

Source: Tartla et al 1999

It may be shocking to note from Tables 9, 10 and 11 that there has hardly been any improvement in the total lactation as well as 305 days milk yield during the four decades from 1960s. This simply goes to indicate that notwithstanding being the best dairy cattle breed of the country, Sahiwal has degenerated in its production both in the farmers' flock as well at organized farms.

Milk Composition

Composition of milk determines the economics of milk production. Under Indian farming conditions milk with higher fat content fetches more price irrespective of other constituents. Due to lower milk fat content of exotic and crossbred cattle, these have not found a preferred position despite higher milk yields. The milk composition of Sahiwal cattle (Sharma et al 1983, Jain et al 1998) in different lactations and different stages of lactation is given in Table 12.

Table 12. Fat and SNF concentration in different parity and stages of lactation of Sahiwal cows

	No of Observation	Fat content (g/Kg)	No of Observation	SNF content (g/Kg)
Lactation No				
1	666	46.8 ± 0.19	606	90.4 ± 0.14
2	455	47.3 ± 0.25	429	90.7 ± 0.17
3	358	48.0 ± 0.26	340	91.2 ± 0.18
4	320	47.3 ± 0.32	302	91.1 ± 0.22
5	265	47.4 ± 0.29	243	91.0 ± 0.21
6	169	47.9 ± 0.39	161	91.1 ±0.27
Stage of Lactation in Months				
1	51	44.6 ± 0.71	50	89.1 ± 0.48
2	235	43.5 ± 0.32	224	88.6 ± 0.23
3	260	45.1 ± 0.30	249	89.4 ± 0.21
4	272	46.2 ± 0.29	249	90.0 ± 0.21
5	260	47.1 ± 0.30	232	90.7 ± 0.22
6	252	48.1 ± 0.31	239	91.2 ± 0.22
7	251	48.2 ± 0.31	233	91.9 ± 0.22
8	231	49.6 ± 0.32	209	92.2 ± 0.23
9	223	50.5 ± 0.33	208	92.8 ± 0.24
10	198	50.9 ± 0.35	188	93.3 ± 0.25

It is evident that the fat content in milk of Sahiwal cows is as high as 4.75 percent which is quite high compared to the milk of exotic and crossbred cattle.

Cholesterol Content of Butterfat

Elevation of plasma cholesterol levels is indicative of a number of risk factors like atheromatus arterial diseases, coronary heart diseases and hypercholesterolemia resulting in hypertension. The cause of elevation of serum cholesterol is correlated with a higher intake of animal fat through pork and or beef. However in India the main source of cholesterol is butter fat. Keeping in view the dietary importance of butter fat, Prasad and Pandita (1987) studied the level of cholesterol in butterfat of Indian, crossbred cattle and buffaloes. The butterfat cholesterol content was found to be lowest in Indian cattle i.e. 310 mg/g in Sahiwal, 303 mg/g in Hariana cattle, higher in crossbred cattle (328 mg/g) and highest in Murrah buffaloes (410 mg/g).

Lactation Length

It is the period of economic return to the animal breeder. It is an important economic trait as it reflects the periodicity of milk production and this influences the milk yield to a greater extent. Cows with long lactation length are generally high milk producer provided they exhibit sufficient dry period for replenishment before subsequent calving. The various reports (Table 13) reveal that lactation length (LL) in Sahiwal cattle ranges from 170.44±4.58 days (Gehlot and Malik, 1967) to 349.7 days (Reddy, 1983) with overall weighted mean of 268.7 days. A large variation in the lactation length thus indicates a scope of improvement. Heritability estimates of LL reported by various workers have been presented in Table 13. Estimates of heritability for this trait ranged from 0.0323 (Gandhi and Gurnani, 1988) to 0.889±0.242 (Raja, 2004).

The weighted average of lactation length was 315 days. It ranged from 214±9 days (Kavitkar et al., 1969) to 345±4 days (Gandhi and Gurnani, 1988). Low to high estimates of heritability were reported by different workers ranging from close to zero (Reddy and Nagarcenkar, 1989) to 0.67±0.26 (Chopra et al., 1973) in Sahiwal cattle. The genetic and phenotypic correlations of this trait with first calving interval were positive and significant (Rao, 1985).

Lactation Peak Yield

Attainment of peak yield by a cow reflects the manifestation of milk secretion at its maximum in lactation. Average of peak yield reported by various workers have been presented in Table 13. Review of first lactation peak yield indicated that the variability in the trait ranged from 7.50 kg. (Taneja and Sikka, 1981) to 10.1±0.2 kg. (Chauhan et al., 1976).

Table 13. Lactation length, Heritability of LL and peak day Yield (PDY) of Sahiwal Cows

No.	LL (Days)	h^2 LL	PDY (Kg)	Reference
118	264.7			Singh and Chaudhary (1961)
79	299±4.8			Singh and Dutt (1963)
51	170.44±4.58			Gehlot and Malik (1967)
245	297.25±78.53			Kushwaha & Misra (1969)
80	320.94±8.59			Johar & Taylor (1973)
857	284.17±70.4			Mishra & Kushwaha (1970)
251	328±5.4	0.67±0.26		Chopra et al. (1973)
928	306.58±2.67	0.39±0.12		Ahmad & Ahmad (1974)
248	288.28±3.64			Taneja (1974)
265			10.1±0.2	Chauhan et al., 1976
		0.16		Taneja et al., 1978
3995	274±0.8			Kimenye D, 1981
108	281.1±3.9			Sharma & Singh, 1981
343	323.18		7.50	Taneja & Sikka, 1981
753	284.9			Taneja & Chawla (1978)
579	322.0±4.50		8.96±0.004	Chawla & Mishra, 1982
615	349.7			Reddy (1983)
596	329.87±5.59	0.28±0.12		Rao (1985)
571	336.73±3.8			Singh (1986)
263	268.59±5.45			Singh (1986)
757	316.23±3.61			Singh (1986)
424	345.38±4.49	0.07		Gandhi & Gurnani (1988)
271	298			Sahota & Gill (1994)
8009		0.0323		Gandhi & Gurnani (1988)
222	280.40±2.38	0.23±0.13	9.22±0.18	Yadav et al., 1992
20000	252			Dahlin A. 1998
2532	260.52±2.64			Javed et al. (2000)
	8.82±0.18			Singh et al., 2001
192	245.03±12.18	0.44±0.23		Mohanty (2001)
249	297.93±6.83	0.23±0.19		Kannan (2002)
		0.132±0.131		Choudhary et al. 2003
282	249.08±9.44	0.48±0.22		Kumar (2003)
272	295.00±5.86	0.889±0.242		Raja (2004)
Weighted Mean	268.7	8.86		

Dry Period

The dry period is an important phase of lactation that exerts pronounced influence both on production and reproduction performance of dairy animals. The dry period reported by various researchers during the last four decades are given in Table 14. A perusal of Table indicates that the shortest DP of 120.33±7.62 days was observed by Kannan (2002) while, the longest one of 242 days was reported by Mirza et al. (1985) with overall weighted mean of 184.02 days. Heritability estimates of DP ranged from -0.12±0.14 (Kumar, 2002) to 0.30±0.24 (Kannan, 2002) (Table 14)

Table 14. Dry Period (Days) in Sahiwal Cows

No.	Mean Dry Period	h^2 DP	Reference
926	182.86±4.44		Ahmad & Ahmad (1974)
689	134.7±4.9		Singh (1977)
753	143.8		Taneja & Chawla (1978)
		0.17	Taneja et al., 1978
80	142.76		Basu et al. (1979)
126	134.6±4.9		Chawla & Mishra (1983)
461	139.7		Bhatnagar et al. (1983)
	242		Mirza et al. 1985
>6000	192.4	0.121±0.04	Khan et al. (1992)
271	163.5		Sahota & Gill (1994)
159	137.54±15.65		Mishra & Prasad (1994)
2532	221.68±5.2		Javed et al. (2000)
192	178.73±12.56	0.123±0.234	Mohanty (2001)
204	120.33±7.62	0.30±0.24	Kannan (2002)
236	167.86±11.87	-0.12±0.14	Kumar (2003)
400	191.56±5.69		Kushwaha et al. 2003
272	126.25±7.77	0.226±0.139	Raja (2004)
Weighted Mean	184.02		

Life Time Traits

The lifetime production performance is a reflection of both productive and reproductive efficiency of farm animals and helps in evaluating relative merits and demerits of different breeds in given set of conditions. Further, longer herd life increases the total calf production and lifetime milk production permitting higher intensity of selection. Gill and Allaire (1976) reported that herd life accounted for 81 per cent of the variation in cow profit. Little information is yet available on lifetime performance of Sahiwal cattle. The averages and heritability estimates for lifetime traits available in the literature are presented in Table 15.

Life Time Milk Yield

Calculation of milk production for whole life is not possible in practice, since many of the cows are not kept in the herd until their natural death. Different criteria had been used for estimating lifetime milk production in dairy cows. Gandhi and Gurnani (1990) calculated lifetime milk yield as total yield upto five and eight lactations in Sahiwal cattle. Pundir and Raheja (1994) defined lifetime milk yield as the total amount of milk produced by a cow from initiation of first lactation till last day in milk in Sahiwal cattle. The literature showed that lifetime milk yield ranged from 2555.67±35.02 kg. (Gandhi and Gurnani, 1990) to 7712.01±370.0 kg (Mathru and Gill, 1981) with overall weighted mean of 6438.09 kg. The large variation indicates enough scope for improvement in this trait through selection and breeding.

Lifetime milk production ranged between 5244 kg (Reddy, 1983) and 6405 kg (Bhatia, 1980) upto three lactations and between 8928 kg (Reddy, 1983) to 17652 kg (Gopal and Bhatnagar, 1972). Lifetime milk production upto ten years of age was between 10794 (Gandhi, 1986) and 24406 kg (Gopal and Bhatnagar, 1972). The heritability of lifetime production upto ten years from adjusted and unadjusted data was not significantly different from zero as reported by Rao (1985). The heritability estimates reported in Table 16 reveal that the heritability for lifetime milk yield ranged from 0.07±0.28 (Gopal and Bhatnagar, 1972) to 0.92±0.83 (Khanna and Bhat, 1971).

Table 15. Lifetime Production Traits of Sahiwal Cows

N	LTMY (Kg)	PL	No. of Days in Milk	Reference
2136	2555.67±35.02	5 yr		Gandhi & Gurnani, 1990
2136	7384.85±117.93	8 yr		-do-
	5677.94			Khanna and Bhat, 1971
456	5696.0±88.00			Nagpal & Acharya, 1971
816	6407.70			Bhatia, 1980
	7710.01±370.0	1951.0±70.0		Mathru & Gill, 1981
1616 1988	5244.0	1971.0		Reddy & Nagarcenkar,
352	4707.00	1771.0±101.41	960.00±35.41	Pundir & Raheja, 1994
413	6120.60±174.53	1636.73±43.61	1047.59±30.64	Ramesh Chander, 2000
Weighted Mean 6438.09		1883.79	1007.28	

Productive Life

Different workers have defined productive life differently. Dalal et al. (1999) defined it as total number of days from date of first calving to the date of disposal or the last dry date if the cow remained in the herd upto the completion of 5 lactations in Hariana cattle. The difference between date of first calving and last date of dry was counted as a measure of PL in Sahiwal cattle by Pundir and Raheja (1994). The literature showed that PL ranged from 1638.73±43.61 days (Ramesh Chander, 2000) to 1971.0 days (Reddy and Nagarcenkar, 1988) with weighted mean of 1883.79 days. Estimates of heritability summarized in Table 16 ranged from 0.08 (Pundir, 1991) to 0.47±0.20 (Ramesh Chander, 2000) in Sahiwal cattle.

Number of Days in Milk (ND)

It is the sum of numbers of days in milk in different lactations in the same herd. Pundir and Raheja (1994) reported ND as 960.00±35.41 days whereas Ramesh Chander (2000) reported 1047.59±30.64 days in Sahiwal breed. The heritability estimates reported in Table 16 indicate that this trait is low (0.17; Pundir, 1991) to medium (0.40±0.19; Ramesh Chander, 2000).

Herd Life

Different workers defined herd life in different ways. Mathru and Gill (1981) defined herd life as the period between date of first calving and date of disposal of the animal from the herd. Kaushik et al. (1994) defined it as the period from date of birth to disposal or death of the animal. Pundir and Raheja (1994) defined it as the period between first and last calving. Herd life traits reported by various workers are given in Table 16. Mathru and Gill (1981) reported lowest herd life (1551.00±70.00 days) whereas Reddy and Nagarcenkar (1988) reported longest herd life (3722.00 days) but overall weighted mean for herd life was 2935.22 days. Estimates of heritability summarized in Table 16 show that the heritability for herd life ranged from 0.03 (Pundir, 1991) to 0.73±0.24 (Ramesh Chander, 2000) in Sahiwal cattle.

Table 16. Herd Life Traits of Sahiwal Cattle and their heritability.

N	HL	h^2 HL	h^2 ND	h^2 PL	h^2 LTMY	
456					0.61±0.27	Acharya & Nagpal, 1971
					0.92±0.83	Khanna & Bhat, 1971
					0.07±0.28	Gopal & Bhatnagar, 1972
816					0.15±0.09	Bhatia, 1980
189	1551.00±70.00					Mathru & Gill, 1981
	3639.00					Ganpule & Desai, 1983
274	3722.00					Reddy & Nagarcenkar, 1988
38	2145.89±41.73					Singh et al., 1988
424					0.23±0.04	Gandhi & Gurnani, 1989
1877	3220.00					Reddy & Nagarcenkar, 1989
238		0.03	0.17	0.08	0.15	Pundir, 1991
138	2989.00±95.28	0.29±0.18	0.28±0.18	0.39±0.01	0.33±0.19	Pundir & Raheja, 1994
413	1807.05±35.55	0.73±0.24	0.40±0.19	0.47±0.20	0.81±0.25	Ramesh Chander, 2000

The Sahiwal in Other Countries

Due to their heat tolerance and high milk production, Sahiwal has also been used for breed improvement in countries other than India and Pakistan. It is used both as a pure breed, for upgrading of unimproved cattle and for crossbreeding with European breeds. Sahiwal has made important contributions to most of the new breeds of Zebu x temperate cattle. They have been exported to other Asian countries as well as Austarlia, Africa and the Caribbean.

Pakistan

There are 22 million cattle in Pakistan. They belong to eight distinct breeds. The Sahiwal and Red Sindhi are dairy type while Tharparkar is considered dual purpose (dairy and draught type). The other five (Bhagnari, Dhanni, Ajal, Lohani and Rojhan) are draught type. The Sahiwal and Red Sindhi are well known dairy breeds for the tropics but their number has been decreasing over the years. A current estimate of Sahiwal population is about 1.4 million which is about 6.8% of the total cattle population of Pakistan (GOP 1996). About 58% of the cattle population is non-descript.

The majority of the cattle population belongs to landless or small-scale farmers under an extensive production system. Cattle herds have been estimated to be around 4.7 millions. Most of the cattle (56%) are in herds of less than 5. About 76% of the cattle are in herd sizes of 10 or less. Traditionally, cattle have been raised to produce draught power. However, mechanisation has slowed their growth rate. According to a recent livestock census (GOP 1996), the numbers of bullocks have decreased from 5.1 million in 1986 to 3.4 million in 1996.

Productivity information

Productivity data on various performance traits of cattle are available from the institutional herds. Sahiwal is the more extensively studied of the cattle breeds. Sporadic reports are available on the draught breeds, too. Average birth weight of dairy breeds is 20–30 kg, female calves are 2 kg lighter than the male calves. Weight at maturity varies a lot. Adult females weigh 300–350 kg while males are usually heavier than females by 100 kg or more. Weights for bulls of 1000 kg or more is not uncommon. Age at first calving is above 40 months. Males start producing viable sperm at the age of 2 years. Females produce 1200 litres of milk per lactation for a lactation length of 250 days. Milk fat percentage averages above 4.5%. Calving intervals and dry period are 450 and 150 days, respectively (Hasnain and Shah 1985).

Dahlin (1998) reported that for 4700 Sahiwal cows, birth weight was 22 kg; weight at the age of one and two years, was 130 and 222 kg, respectively. Age at first calving, weight at post-partum and calving interval were 44 months, 319 kg and 465 days, respectively. First lactation mean values were 1365 kg, 1395 kg and 252 days for milk yield up to 305 days after calving, total lactation yield and lactation length, respectively. Studies based on data from institutional herds have indicated that there has not been any genetic improvement in traits like milk yield (Dahlin 1998). A progeny testing program for Sahiwal cattle has been started in Punjab but it is limited to institutional herds.

Marketing of animals and their products is traditional. Live animals are marketed in the local markets called 'mandies' arranged by local governments. On special occasions like Eid, cattle from rural areas are brought to urban centres to fetch better prices. Type and appearance are the more commonly used attributes; actual live weight or other parameters are rarely considered.

National breeding policy prohibits the crossing of locally available purebreds, yet indiscriminate crossing continues and poses a major threat to the local breeds for which no conservation program is in practice. Karyotyping of the Sahiwal breed has been undertaken (Anis et al. 1990). There are no efforts at public or private level to conserve livestock genetic resources in general. Efforts are especially needed for dairy cattle breeds such as Sahiwal, Red Sindhi and Cholistani and draught breeds such as Lohani and Rojhan.

Australia

Australia had no cattle or buffalo prior to European settlement in the 1800s. Since then, cattle numbers have steadily increased to peak at 33.4 million in 1976 reducing to the around 26.6 million in 1996 (Allen 2001). However, Australian livestock numbers in general have considerable fluctuations due to wide climatic variations across years. Dairy cattle are generally restricted to the southern, coastal districts of Victoria, New South Wales, South Australia and Western Australia. However, beef cattle are reared in most areas of Australia with a concentration in Queensland and New South Wales.

The introduction of Brahman cattle into Australia is an excellent example of the way technology can change an industry. The history of Brahman type cattle in Australia goes back more than 200 years to the early days of colonisation. However, these cattle had no impact on the industry as is known today Dr J.A. Gilruth, a veterinarian who, after a period as administrator of the Northern Territory became chief of the new division of Animal Health in the Council for Scientific and Industrial Research (CSIR) of Austarlia, concluded after a tour of Texas USA in 1920 that 'vigorously controlled cattle breeding experiments in North Queensland would be wise'.

When preparing a research program for CSIR in North Queensland, he included a proposal 'for an enquiry into Zebu crossbreeding experiments carried out by the United States Bureau of Animal Industry and others in the southern US states. The enquiry was carried out by Dr R.B. Kelly who concluded that Brahman crossbreeds: (1) matured earlier; (2) grew and finished on inferior pasture; (3) had a two to three percent carcass yield advantage; (4) had a high drought survival rate; and (5) carried relatively few ticks.

A project to import Brahman cattle eventuated in 1933 with the co-operation of three Queensland pastoral companies and one individual grazier. The syndicate imported 18 head in the 1933 shipment which was put together by Dr Kelly. On arrival, the cattle were divided among the syndicate members and used in breeding trials controlled by the CSIR.

In 1946, two north Queensland graziers, Mr Ken Atkinson of Wairuna and Mr Maurice de Tournouer of Wetherby, Mt Malloy, who had bought cattle and joined the syndicate, decided to form the Australian Zebu Breeders Association. Shortly afterwards, the name was changed to the Australian Brahman Breeders' Association.

The CSIR became the CSIRO (Commonwealth Scientific and Industrial Research Organisation) and continued research into the mechanisms of adaptation which made the Brahman a superior animal for northern Australia. Brahman cattle were estimated to be 8.8% of the population in 1990 and influencing another 31.9% through crossbreeding and Brahman derived breeds such as Brangus, Braford and Charbray etc. With the Brahman cross and derived breeds increasing to 35.5%, the Brahman influence now impacts on more than half of the Australian herd.

As one of the best dairy animals existing in India and Pakistan, the Sahiwal was introduced to Australia from New Guinea in the early 1950s. It is a dual-purpose breed, playing a major role in the development of the Australian Milking Zebu (AMZ) and the Australian Friesian Sahiwal (AFS) tropical milking breeds. It is the heaviest milking breed of *Bos Indicus*, but is now used mailnly in beef production, including crossbreeding programs with British breed cattle. Sahiwals are now predominately used in Australia for beef production, as crossing high grade Sahiwal sires with Bos taurus animals produced a carcass of lean quality with desirable fat cover.

The Australian experience with Sahiwal suggests that although Zebu cattle have been reported to be poor milkers, the Sahiwal breed might change that. The udder conformations of Sahiwal cows are remarkable, and usually 1,400 to 2,500 kilograms of milk are expected with each lactation. The best milkers of all Zebu breeds, Sahiwal can produce up to 5,000 kilograms of milk in a single lactation. Fat percentages range from three to five percent, depending upon the area in which the Sahiwal was raised.

At maturity, Sahiwal cattle usually weigh around 350 kilograms, although weights vary from region to region. They are generally a lovely burnished red color, and bulls extremities are a darker shade than the rest of the body. Shades may vary from a mahogany red-brown to a more grayish red color. Occasionally, there are white patches on the Sahiwal, and its muzzle and eyelashes are a lighter color than the rest of the cow. In body type, Sahiwal are long and heavy, fleshed out in loose skin. The udder conformations of Sahiwal cows are remarkable, and usually 1,400 to 2,500 kilograms of milk are expected with each lactation.

The breed is recognised as being most suitable for use in tropical dairy areas, and has been shown to produce high quantities of milk under tropical pasture conditions and a high resistance to heat, humidity, ticks and other parasites.

Sahiwal cattle have very good milk production and can suckle a calf while donating milk to your dairy. Average milk yield is 3,000 liters for mature cows (4,458 litres under 293 day official 1998 test), Milk quality is good - protein level is 3.4 % and butterfat is approximately 4%. Calves are small at birth, but grow extremely quickly. This makes Sahiwal bulls good cross breeders who will not impart calving problems to the cows they are breeding. Sahiwal cows rarely have calving difficulties, and usually reach sexual maturity at three to four years of age. The calving interval for Sahiwal cows is around 430 to 580 days.

The Sahiwal in Kenya: The National Sahiwal Stud

Cattle for pure-breeding in the arid areas are being selected for milk and beef production at the National Sahiwal Stud at Naivasha.

History

Attempts to develop an improved indigenous dairy zebu in a number of livestock improvement centres came to an unsuccessful end in 1939 when four Sahiwal bulls were imported by the Government from Pusa, India, for an upgrading programme. By 1963, 60 bulls and 12 females had been brought from four herds in India and Pakistan. Early successes in upgrading the indigenous zebu (Mahadevan et al., 1962) were followed by disappointments. Despite careful pedigree selection, some bulls with an undesirable dairy temperament were brought in from all four places of origin. This resulted in a high percentage of their progeny failing to let down milk in the absence of their calves. The formation of the National Sahiwal Stud at Naivasha in 1962 concentrated the breeding work on one farm, and was the start of a scientific breeding programme for a dual-purpose zebu to be kept under extensive pasture conditions, but under good management. A progeny test programme for milk production commenced in 1965 following recommendations by Mason (1965). The current breeding programme has operated since 1968.

Management

The stud consists of 500 cows plus followers, a total of about 1 300 head. All heifer calves born and about 80 bull calves are reared per year. At birth the calves are immediately removed from their dams, weighed, and their identification number is tattooed in their ear. They are weighed weekly until they reach 55 kg live weight, and thereafter fortnightly until 125 kg live weight. They are dehorned with a hot iron at six weeks of age.

Calves are weaned from whole milk on to concentrates at nine weeks of age, having consumed about 210 kg milk in the rearing period. Concentrates are offered in the fifth week of life and they are consuming about 0.5 kg per day at the time of weaning. This gradually increases to 1.4 kg per day, and they are fed at this level until they reach 125 kg live weight. Calves are reared on natural pasture. Only during times of drought do they receive Lucerne hay as a supplement. Bulls are selected at two years of age, either for progeny testing or for natural service in the range development areas. All heifers are inseminated at 27 months. Seasonal calving is not practiced. Pregnant cows are drafted into the milking herd for one month and heifers for two months before calving. Small quantities of concentrates (0.5 kg) are on offer.

All cows and heifers are weighed immediately after calving. They are bred again 70 days after parturition and are dried off at 305 days of lactation. The herd is milked in the field twice a day through four mobile bails, each manned by six hand milkers and a recorder. Individual yields are recorded at every milking and butterfat analyses are carried out once a month. The indigenous pasture is expected to provide for maintenance and the production of 5 liters of milk per day throughout the year. After prolonged rain, concentrates are fed only to cows exceeding 9 kg milk per day, at the rate of 1 kg for 2.5 kg milk produced.

The milking herd has the best pasture available. Good paddocking permits rotational grazing, with the cows rarely staying longer than seven days in one paddock. Dry herds follow the milking herd to eat the less palatable grasses.

Productivity and genetic parameters

The collection of production data over a number of years has permitted the estimation of genetic parameters. Table 17 gives the averages, standard deviations and heritability of some production traits. The existing variance and the corresponding heritability estimates give promise of a rapid genetic improvement in respect of milk yields, and to a lesser extent in respect of growth rates. This is also demonstrated by the increase in yields since the systematic selection programme commenced in 1968 (see Table 18).

Table 17. Least square means, standard deviations and heritability estimates for some production traits of Sahiwal cattle at Naivasha, Kenya.

Trait	Number	Least square means	Standard deviations	Heritability estimates
Birth weight (kg)				
Male	1563	23.9	2.7	0.36
Female	1515	21.4	2.5	0.14
Average daily gain to 125 kg live weight (g)				
Male	452	553	90	0.19
Female	[1]424	526	70	0.07
Bulling heifer weight at 27 months (kg)	944	307	37	0.30
First calving age (months)	851	37.3	4.5	
First lactation				
Length (days)	851	234	105	0.38
Yield (kg)	851	931	611	0.33
Butterfat (%)	[2]647	5.15	0.61	0.44
Butterfat (kg)	[2]647	60.6	24.5	[3]0.14

SOURCE: Meyn and Wilkins (unpublished)

1. From 1963 to 1965 birth weights have been recorded only for bull calves scheduled to be reared for breeding.
2. Butterfat samples taken only from cows yielding over 3 kg milk per day.
3. The corresponding heritability estimate for milk yield on the reduced material was 0.19.

Table 18. Lactation lengths and milk yields at the National Sahiwal Stud, Naivasha, 1965–72.

Year	First lactations		Second lactations			Third and later lactations			
	Number of cows	Length (Days)	Milk yield (Kg)	Number of cows	Length (Days)	Milk yield (Kg)	Number of cows	Length (Days)	Milk yield (Kg)
1965	149	184	710	149	228	1102	198	239	1246
1966	136	259	1001	128	261	1131	282	276	1382
1967	121	245	1042	129	247	1071	335	263	1280
1968	233	250	959	106	260	1175	353	266	1317
1969	182	255	1011	86	286	1534	176	290	1763
1970	171	261	1057	74	296	1770	154	297	1934
1971	224	245	1143	70	298	1769	180	292	1910
1972	144	277	1306	125	271	1689	187	286	1840

SOURCE: Wilkins et al. (unpublished)

Heifers and first calvers are inseminated with semen from test bulls, while all cows calving for the second time or more—the so-called elite herd—are inseminated with semen of proven bulls to produce the next bull generation. The 180 elite cows produce 150 calves, i.e., 75 bull calves per year. Of these, about 70 survive the bucket-rearing period and range-performance; test for growth rate to an age of two years. The best 15 are then identified by a selection index, comprising the estimated breeding values for milk yields of the sire and dam, and the estimated breeding value for weight for age of the young bull itself. An inspection of the selected bulls and their dams for physical faults, muscling, udder conformation and teat shape eliminates three more bulls. The remaining 12 are tested for semen quality, leaving about 10 for test mating. The aim is to produce 14 milking daughters per test bull.

The average daily gain to weaning, the bulling; heifer weight at 27 months, the 30-day milk yield and the 305-day milk yield of the first lactation are analysed by contemporary comparison. First decisions on test bulls are made when the 30-day yields become available. Bulls with outstanding daughter performances are sent to the AI station for semen production, while all the remaining bulls are kept on. Final decisions are made on the results of the 305-day milk yields. Two bulls are selected annually for the AI station and for use in the elite herd. The remainders are sold for natural service or for slaughter. Genetic progress in terms of milk yield may be expected at 3 to 4 percent per year (Meyn, Were and Bartilol, unpublished).

In recent years the demand for Sahiwals from the range areas of Kenya and from abroad has risen sharply. Deep-frozen semen or breeding stock has been exported to many countries, mainly in tropical Africa. There are plans to extend the Sahiwal breeding programme to other government farms. This could lead to even faster genetic progress.

Bangladesh

Bangladesh had 21.18 million cattle in 1984 which rose to 21.57 million cattle in 1996 (Anon 1996). The cattle population in Bangladesh consists mainly of the indigenous deshi type. There are also a number of crossbred cattle of different genotypes (crosses of Holstein, Jersey, Sahiwal and Sindhi with indigenous) which represents now about 2–3% of the total cattle population of the country. The country also has two varieties of dairy cattle, viz. Red Chittagong (RC) and Pabna cattle (PC). Bangladesh has now seven institutional herds under Directorate of Livestock Services (DLS); one institutional herd under BLRI and one institutional herd under BAU. These institutional herds maintain about 5000 cattle of different genotypes, viz. Red Chittagong cattle, Pabna cattle, Sahiwal, Holstein, Sahiwal cross, and Holstein cross. Performance of Sahiwal cattle in Bangladesh is moderate i.e birth weight 18 Kg; age at first heat 36 months; age at first calving 50 months; lactation length 308 days; lactation yield 1500 Kg; average daily milk yield 5 Kg and calving interval 424 days (Faruque and Bhuyiyan 2001)

Bangladesh has a long history of importing exotic germ plasm. The imports of exotic germplasm have been made during 1930–1937: Hariana; 1937: Hariana, Sindhi and Sahiwal; 1960: Sindhi, Sahiwal and Tharparker; 1967: 50% Holstein and Jersey; 1973: Holstein and Jersey (Australia); 1987: Sahiwal; 1989: Holstein from Spain; 1992: Sahiwal; 1992: AFS from Australia; 1983: frozen semen from Germany, New Zealand and Kenya; 1987: frozen semen from Australia and New Zealand, 1990—2000: frozen semen of Freisian from France, USA etc. (Bhuiyan 1997).

Genetic Characterization of Sahiwal Cattle

Blood Groups and Biochemical Polymorphism

During the 1950s innovative techniques were described which enabled the detection of diverse qualitative genetic variations at the biochemical level within a breed/species. These variations initially reported in humans and later extended to farm animals were mainly comprised of the following categories:

- Blood groups and immunological variants of plasma proteins studied by serological methods.
- Inherited variants of proteins studied by the technique of gel electrophoresis in combination with histochemical staining methods.

In this context a polymorphic genetic system was defined as one in which there are two or more allelic variants and in which an allele does not have a frequency of more than 99% in the population.

Haemoglobin

Haemoglobin is the oxygen carrying substance present in the erythrocytes of vertebrates. It is a conjugated protein consisting of the protein, globulin combined with a pigment containing iron-haem. Structural differentiation of haemoglobin has been studied by gel electrophoresis and the polymorphism observed shown in Table 19. Three genotypes (Hb AA; Hb AB and Hb BB) governed by two codominant alleles (Hb A and Hb B) have been reported in Sahiwal cattle (Sudhakar et al 1993).

Table 19. Polymorphic forms of Haemoglobin in Sahiwal Cattle

Genetic Group	No	Observed Genotypes			Gene Frequency		Reference
		Hb AA	Hb AB	Hb BB	Hb A	Hb B	
Sahiwal	19	12	7	0	0.82	0.18	Sudhakar et al 1993
					0.807	0.193	Singh and Bhat 1980d
					0.79	0.21	Singh and Nair 1981

Sahiwal as well as Jersey X Sahiwal populations were found to be in Hardy-Weinberg equilibrium. Sahiwal cattle with Hb AB type were found to have a higher fat content (%) than the other two genotypes (Sudhkar et al 1993).

Transferrin

Transferrin is a globulin and has the vital function of transporting iron from plasma to receptor cells of the bone marrow and tissue storage compartment. Transferrin polymorphism as compared to other protein polymorphisms has been exploited to a larger extent in attempting to associate gene controlled variations with economic and reproductive traits in farm animals. Based on a study of 324 Sahiwal animals from three different farms, Singh and Bhat (1980e) observed 6 different alleles governing the transfer in locus in Sahiwal cattle. The observed genotypic and gene frequencies are shown in Table 20. In general the distribution of transferrin in phenotypes actually observed and those expected on the basis of Hardy-Weinberg equilibrium agreed well in all the three Sahiwal herds as well as other zebu breeds (Singh and Bhat 1980e). All the indigenous cattle populations including the three Sahiwal herds showed a high gene frequency of Tf^E. Tf^D was the second most frequent allele. Similar high frequencies for Tf^E allele were observed for Sahiwal, Tharparkar and Red Sindhi breeds (Hesselholt et al 1964, Ashton and Lampkin 1965).

Table 20. Transferrin polymorphism in Sahiwal Cattle

Genetic Group	N	Transferrin allele Frequencies						Reference
		TfA	TfB	TfD1	TfD2	TfF	TfE	
Delhi	58	0.319	0.026	0.009	0.000	0.095	0.552	Singh and Bhat 1980e
Meerut	90	0.206	0.033	0.061	0.133	0.228	0.339	
Lucknow	176	0.117	0.000	0.006	0.043	0.349	0.486	
Pooled	324	0.178	0.014	0.022	0.060	0.270	0.457	
Pantnagar	13	0.039	0.000	0.269	0.000	0.692		Singh and Choudhary 1989a
Karnal	290	0.083	0.238	0.000	0.007	0.000	0.672	Shanker and Bhatia 1984
		0.075	0.005	0.216		—	0.704	Singh and Nair 1981

Sahiwal cattle, thus with the existence of at least 6 transferrin variants, manifested remarkably pronounced polymorphism at the transferrin in locus. The three populations exhibited apparent differences in the gene frequencies of various variants of Tf. However, in general, the distribution of transferrin phenotypes actually observed and those expected on the basis of Hardy Weinberg equilibrium agreed well in the three Sahiwal herds as well as the pooled population (Singh and Bhat 1980e). Singh and Choudhary (1989a) described 10 transferrin phenotypes. These phenotypes were the combination of allelomorphic variants Tf^A, TfB, Tf^D, Tf^F and Tf^E in the order of decreasing mobility in Sahiwal cattle. The fastest moving homozygote was Tf AA and slowest moving homozygote was Tf EE. The most frequent transferrin phenotypes observed were Tf EE (46.15%) and Tf DE (38.46) in Sahiwal cattle. The effect of transferrin phenotypes was found to be significant on age at first oestrus where lowest AFO was found in Tf EE animals and highest in Tf BE animals (Singh and Choudhary (1989b). Similar gene frequencies of transferrin variants were also reported by Singh et al (1972), and Shanker and Bhatia (1984) in Sahiwal cattle.

Serum post Transferrin

Serum post transferrin polymorphism was studied in Sahiwal cattle and their Jersey, Holstein and Red Dane crosses (Singh and Choudhary 1988b). Vertical polyacrylamide gradient gel electrophoresis revealed the existence of 2 variants of post transferrin alleles (Ptf^{-2F} and Ptf^{-2S}) in 3 phenotypic combinations (Ptf-2 FF and Ptf-2 FS and Ptf-2 SS). Least square analysis revealed significant effect of serum post transferrin phenotypes on 18 and 24 months body weights and peak day yield for first lactation. Animals with Ptf-2 FF types were superior to Ptf-2 SS types in growth and milk production (Singh and Choudhary 1988b).

Ceruloplasmin

Ceruloplasmin polymorphism in Sahiwal cattle has been studied by Singh and Bhat (1980b). A pattern of 3 allelic variants (Cp-A; Cp-B and Cp-C) in 6 different combinations was observed in three different populations of Sahiwal cattle maintained at Delhi, Lucknow and Meerut (Table 21). All the 6 possible combinations of the 3 Cp variants were observed in Sahiwal cattle. Cp-A allele was the most predominant Cp allele in all the three Sahiwal populations as well as other indigenous zebu breeds (Singh and Bhat 1980b). Genotypes observed in pedigreed samples in the progeny always corresponded to those expected in accordance with the parental types and the alleles segregated in Mendelian proportions (Singh and Bhat 1980b).

Table 21. Ceruloplasmin polymorphism in Sahiwal cattle

Group	No	Observed Genotypes						Gene Frequency			Reference
		AA	AB	CC	AB	AC	BC	Cp^A	Cp^B	Cp^C	
Delhi	58	39	00	4	1	14	00	0.802	0.009	0.190	Singh and
Lucknow	176	106	00	7	4	59	00	0.781	0.011	0.207	Bhat 1980b
Meerut	91	69	1	2	8	11	00	0.863	0.035	0.083	
Pooled	325	214	1	13	13	84	00	0.808	0.023	0.169	

Serum Albumin

Albumin is the major blood protein involved in the transport of various biologically active compounds, it seems possible that some functional consequence might be attached to some of the variants. The existence of gene controlled, multiple-molecular variation of the bovine specific albumin has been described in Sahiwal cattle (Singh and Bhat 1980c). Four electrophoretic variants (Alb-A, Alb-B, Alb-C and Alb-D) in 8 phenotypic combinations were detected and codominant mode of inheritance through 3 alleles described (Table 22). Sahiwal displayed a high frequency of Alb-BB phenotype like all other zebu breeds (Singh and Bhat 1980c). There was a very high variation in its frequency even in the three different populations of Sahiwal Cattle. The heterozygote genotypic frequencies were generally low in Sahiwal as well as other zebu breeds. A good agreement between observed and expected albumin phenotypic values was observed in the three populations. Of the three Alb alleles, Alb-B was predominant. The presence of an additional allele Alb-D was recorded in Sahiwal as well as Red Sindhi and Tharparkar cattle but in very rare frequencies (Singh and Bhat 1980c). Test of heterogeneity revealed a highly significant variation between zebu breeds and between Sahiwal herds. The functional significance of the genetic variants of bovine serum albumin is still not definitely known. Singh and Choudahry (1988a) observed 5 albumin phenotypes (Alb AA, Alb BB, Alb AB, Alb AC and Alb BC) controlled by three alleles (Alb^A, Alb^B and Alb^C) in 13 Sahiwal cattle maintained at GB Pant University Pantnagar.

Table 22. Albumin polymorphism in Sahiwal cattle

Groups	N	Observed Albumin Phenotypes									
		AA	BB	CC	DD	AB	AC	AD	BC	BD	CD
Delhi	58	5	13	1	0	26	0	0	13	0	0
Lucknow	176	2	92	0	0	28	5	4	34	11	0
Meerut	91	1	66	2	0	13	0	0	9	0	0
Pooled	325	8	171	3	0	67	5	4	56	11	0
		Albumin Gene Frequencies									
		Alb^A		Alb^B		Alb^C			Alb^D		
Delhi	58	0.310		0.560		0.129			0.000		
Lucknow	176	0.117		0.700		0.111			0.043		
Meerut	91	0.082		0.846		0.071			0.000		
Pooled	325	0.142		0.732		0.103			0.023		

The allele Alb^B was most frequent in Sahiwal cattle with a frequency of 0.54 while Alf^A allele was more frequent in crossbreds with frequency ranging from 0.53 to 0.64. The serum albumin phenotypes were significantly associated with age at first calving and they exhibited non-significant influence on other reproductive growth production traits (Singh and Choudhary 1988a). Singh and Nair (1981) reported the frequencies of Alb^A, Alb^B and Alb^C as 0.000, 0.862 and 0.138 respectively in Sahiwal cattle.

Serum Amylase

Three phenotypic combinations viz Am-BB, Am-BC and Am-CC of 2 commonly reported allozymes Am-B and Am-C of Am-I locus were detected in Sahiwal cattle (Singh and Bhat 1979, Kirmani et al 1990). The distribution of amylase phenotypes among the offsprings confirmed the codominant alleles Am^B and Am^C for the 2 variants. The genotypic and gene frequencies observed in three herds of Sahiwal cattle are depicted in Table 23. Am-BB type constituted the major phenotype among the purebred indigenous zebu populations, accounting 84.6% in Sahiwal (Meerut). Am^B gene predominated in Sahiwal as well as all other indigenous cattle breeds (Singh and Bhat 1979). Significant heterogeneity was observed between the three herds within the Sahiwal breed. Kirmani et al (1990) denoted the two alleles as Am^F and Am^S and the three phenotypes as Am FF, Am FS and Am SS. The Am^F variant was more frequent with its frequency ranging from 0.50 to 0.674. Cows with Am SS genotype yielded 341, 53 and 178 kg more milk than Am FS and Am FF cows respectively during first lactation.

Table 23. Amylase polymorphism in Sahiwal cattle

Group	N	Amylase phenotypes			Gene Frequency		Reference
		BB	BC	CC	Am^B	Am^C	Singh and Bhat 1979
Delhi	58	55	3	0	0.974	0.026	
Lucknow	176	173	3	0	0.992	0.008	
Meerut	91	77	14	0	0.923	0.077	
Pooled	325	305	20	0	0.969	0.031	
Pantnagar	13	6	4	3	0.615	0.0.385	Kirmani et al 1990

Serum Alkaline Phosphatase (SAP)

The electrophoretogram of Serum Alkaline Phosphatase of Sahiwal cattle and its exotic crossbreds showed the presence of only two phenotypes named SAP A and SAP O (Kirmani et al 1989). The expression of these phenotypes was controlled by two alleles viz FA and FO. Of the two, the FA allele exhibited higher frequency (0.745 to 1.0) in all the genetic groups and the population was found to be in equilibrium. The influence of SAP phenotypes on growth, reproduction and production traits were found to non-significant.

Interleukins

Indigenous breeds of cattle are believed to exhibit a greater resistance to tropical diseases as compared to exotic and crossbred groups. Interleukin-2 along with other cytokines has been associated with resistance to infection. Jyotsna and Verma (2005) isolated interleukin-2 from Sahiwal cattle and characterized it from the culture supplements of the activated lymphocytes. The protein had a molecular weight of approximately 30,000 D when passed through Sephadex G-100 column and it got separated into two distinct bands of approximate molecular weights of 14,000D and 28,000D. When heated to 50°C for 15 min, about 35% reduction in the activity of the IL-2 was observed. Optimum pH of the molecule was around 7 – 7.8.

It was observed that IL-2 levels present in the culture supernatants of Sahiwal cattle were higher than those present in Holestein and Karan Fries cattle (Verma and Behl 2003). It was also observed that IL-2 levels increased in the plasma of the animals suffering from mastitis as compared the healthy animals. Interleukin-6 is produced by the monocytes and macrophages during an inflammatory response in the body and also under in vitro conditions by cells when activated with protein A. The IL-6 levels in Sahiwal as well as Rathi and Hariana (all zebu breeds) were greater than those in Holstein breed (Verma and Behl 2003).

Potassium, Sodium and Total Electrolyte Concentration of Erythrocytes

Potassium and sodium perform many functions in living beings. They play major roles in conducting impulses in nervous system, functioning of muscles including the cardiac muscles and maintaining electric potential across the plasma membrane of the cells. Their concentration in blood plasma is intimately related to water metabolism and thirst mechanism. Polymorphic forms in population get established because either they have advantages in natural selection or they are closely linked with some advantageous traits. Erythrocyte potassium types are found to be related to climatic adaptation and some productive and reproductive traits.

On the basis of concentration of sodium, potassium and total erythrocyte electrolytes in Sahiwal cattle, Sengupta (1974) classified the animals into three categories as low-level potassium (LLK), medium level potassium (MLK) and high level potassium (HLK). The average concentrations of the constituents reported by the author are provided in Table 24.

Table 24. Erythrocyte Electrolyte Concentration in Sahiwal cattle

No of observations	Concentration of electrolytes (m.eq/Lt)			Classification
	Potassium (K)	Sodium (N)	Total electrolytes	
86	12.60	88.00	100.60	LLK
88	19.40	80.90	100.30	MLK
14	39.50	62.20	101.78	HLK

The concentrations of K and Na are inversely related. With an increase in K concentration there is a concomitant decrease in Na concentration such that the total erythrocyte concentration remained more or less consistent.

George (1982) found the average concentration of erythrocyte potassium as 20.48± 1.19 m eq/Lt in Sahiwal cattle and observed no HK type animal. He observed only one mode at 17.5 m eq/Lt. He also studied the concentration of erythrocyte potassium in different seasons and found the average concentration of erythrocyte potassium during hot dry, hot humid and winter seasons as 18.24±0.72, 16.38±0.66 and 19.52±0.92 respectively indicating a significant effect of season on K conc. The heritabilty of K conc. ranged between 0.082-0.366 (George 1982). The effect of age group was also found to be significant on K conc in Sahiwal cattle. Calves at birth had the highest K conc which reached the adult level by about 3 months of age. Animals with different ranges of K conc did not seem to differ in their feed and water consumption. K conc affected the rectal temperature and pulse rate in Sahiwal cattle.

Milk Protein Polymorphisms

Studies on milk proteins play a very vital role in understanding the nature of milk and its physio-chemical properties. Genetic variation is a significant contributor to variation in the quality and quantity of milk produced by individual cows. All the five major milk proteins have been typed in Sahiwal milk samples using three different electrophoretic techniques.

In a comparative study to investigate the differences of α-, β-, and γ- casein fractions among milk of Sahiwal, Red Sindhi and Tharparkar breeds of cattle, Murrah buffalo and a local breed of goat, Sabharwal and Bhalerao (1974) found significant differences among different species as well as breeds. α- casein was always highest in cow milk casein and lowest in that of goat milk. Among the breeds of cow, α- casein was highest in Sahiwal (52.64%), followed by Tharparkar (51.26%) and lowest in Red Sindhi (49.66%). On the other hand β- casein was lowest in Sahiwal (43.85%) followed by Red Sindhi (43.90%) and highest in Tharparkar (45.00%). γ- casein was found to be highest in Red Sindhi (6.44%), followed by Tharparkar (3.74%) and lowest in Sahiwal (3.51%).

Álpha-S1 Casein

Three different phenotypes (α- S1Cn-BB, BC and CC) controlled by two codominat alleles (α-S1Cn- B and C) have been reported in Sahiwal cattle. In a study involving a total of 130 Sahiwal cattle (Jairam 1975 and Jairam and Nair 1983a) 25 were BC type and 105 CC type. α-S1Cn-BB type was absent in Sahiwal as well as Red Sindhi cattle. Sahiwal is thus a predominantly α -S1Cn-C population with gene frequency of this allele as high as 0.91 and that of allele B only 0.09. The α -S1Cn gene was not found to be associated with other milk protein genes (Jairam and Nair 1983b).

Beta-Casein

The electrophoretic separation of β- casein milk protein in Sahiwal cattle revealed the presence of three phenotypes (β- Cn- AA, AB and BB) controlled by a pair of codominant alleles β- Cn-A and B. In an investigation of 130 Sahiwal cattle (Jairam 1975 and Jairam and Nair 1983) 120 were AA type, 9 AB type and 1 BB type. Sahiwal is thus a predominantly β - Cn -A population with gene frequency of this allele as high as 0.95 and that of allele B only 0.05. Singh and Bhat (1980d) designated the four β - Casein alleles as Cn^{A1}, Cn^{A2}, Cn^{A3} and Cn^{B} and reported their frequencies in pooled Sahiwal populations as 0.030, 0.843, 0.003 and 0.124 respectively.

Kappa Casein

Three different phenotypes were observed at the kappa casein milk protein gene. The phenotypes were designated as κCn-AA, κCn-AB and κCn-BB and were controlled by a pair of co-dominant alleles, κCn-A and B (Jairam 1975 and Jairam and Nair 1983a). Out of 130 Sahiwal cattle genotypes, 88 were found to be AA type and 42 AB type yielding gene frequencies of κCn-A and B alleles as 0.84 and 0.16 respectively. κCn-BB animals were conspicuous by their absence in Sahiwal population.

Genetic superiority of zebu cattle for casein production has been reported by Misra et al. (2004). The mean casein protein (CP) % in Sahiwal cattle was 2.78 which were higher than that of Tharparkar (2.70), Karan Swiss (2.69%) and Karan Fries

(2.55%). Similarly the total protein and casein / total protein ration (CPR) of sahiwal cattle were 3.47% and 0.801. The highest CP and CPR were found in Sahiwal breed indicating the higher potentiality of indigenous cattle for casein production compared to the two crossbred groups. There is need to exploit this superiority for the economic and viable utilization of our indigenous cattle genetic resources.

Alpha Lactoalbumin

Investigation of α -Lactoalbumin milk protein polymorphism (α-Lb) in Sahiwal cattle revealed the presence of three phenotypic variants (α-Lb-AA, AB and BB) governed by two co-dominant allles (α-Lb-A and B). Genotyping of 130 animals showed that 2 animals were α-Lb-AA type, 43 α-Lb-AB type and 85 α -Lb BB type yielding gene frequencies of α-Lb A and B alleles as 0.18 and 0.82 respectively (Jairam 1975 and Jairam and Nair 1983a).

Beta Lactoglobulin

Genetic heterogeneity of the bovine β -Lactoglobulins has been studied in Sahiwal cattle by Jairam (1975) and Singh and Bhat (1980a). Jairam (1975) and Jairam and Nair (1983a) observed three phenotypic variants (β -Lg AA, AB and BB) governed by a pair of codominant alleles (β -Lg-A and B) in Sahiwal cattle. However Singh and Bhat (1980a) observed three β -Lg alleles (β -Lg-A, β -Lg-B and β -Lg-C). Genotyping results obtained by the two groups are provided in Table 25. Significant departure from the Hardy-Weinberg equilibrium was observed in the Sahiwal (Lucknow) population. β -Lg B was the predominant allele in Sahiwal as well as other zebu populations of Hariana, Kankrej, Ongole, Red Sindhi, Kangayam, Gir and Tharparkar cattle (Singh and Bhat 1980a). Similar distribution of β -Lg has been reported by Bhattacharya et al (1963) in Sahiwal cattle. β -Lg-C allele was the rarest among the three alleles, but its

Table 25. β-Lactoglobin polymorphism in Sahiwal cattle

Group	No	Observed Genotypes						Gene Frequency			Reference
		AA	BB	DD	AB	AC	BC	Lg^A	Lg^B	Lg^C	
Delhi	17	3	9	0	4	1	0	0.324	0.647	0.029	Singh and Bhat 1980a
Lucknow	79	1	37	8	7	8	18	0.108	0.627	0.266	
Meerut	69	0	14	10	10	7	28	0.123	0.478	0.399	
Pooled	165	4	60	18	21	16	46	0.136	0.567	0.297	
	130	8	79	—	43	—	—	0.230	0.770	—	Jairam 1975

frequency was higher in Sahiwal as compared to other indigenous cattle populations (Singh and Bhat 1980a). Attempts to associate these allelic variants with traits of dairy importance have failed to yield consistent results.

Blood Groups

Singh et al (1981) estimated the gene frequencies of blood group factors of Sahiwal cattle based on a total of 253 animals. The gene frequencies observed are shown in Table 26.

Table 26. Estimated gene frequencies of blood groups factors of Sahiwal cattle

Blood group factor frequency	Gene frequency	Blood group factor	Gene
K1	0.11	K8	0.28
K2	0.04	K9	0.04
K3	0.31	K10	0.24
K4	0.01	K11	0.52
K5	0.40	K12	0.31
K6	0.11	K13	0.50
K7	0.40	K14	0.55

Cytogenetic Characteristics of Sahiwal Cattle

Cattle chromosomes generate special interest among farm animal cytogeneticists. This is evident from the fact that presently, the domestic cattle (*Bos indicus* and *Bos taurus*) is cytogenetically the most extensively studied farm animal.

Karytypic features of Sahiwal cattle have been reported by a number of workers i.e. Yadav 1981, Prakash 1982, Goswami 1982. The Sahiwal breed of zebu cattle (*Bos indicus*) possesses a typical zebu karyotype. The normal diploid count of 60 comprised 29 pairs of autosomes and a pair of sex chromosomes. Sex chromosome dimorphism was typical mammalian, XX females and XY males. All the 29 pairs of autosomes were acrocentric. The X chromosome was a large chromosome and the only biarmed (metacentric) element in the karyotype. The Y chromosome was a small acrocentric element and morphologically not separable from the smaller autosomal pairs. This is the distinguishing chromosome from the karyotype of *Bos Taurus*, which possesses a metacentric Y chromosome. Typical metaphase spreads and karyotypes of male and female Sahiwal cattle are provided in Figures 8 and 9.

The relative length measurements (%) computed from the actual measurements are presented in Table 27 and as ideogram in figure 10. The Y-axis bars represent the proportionate contribution of each chromosome pair towards the total genome.

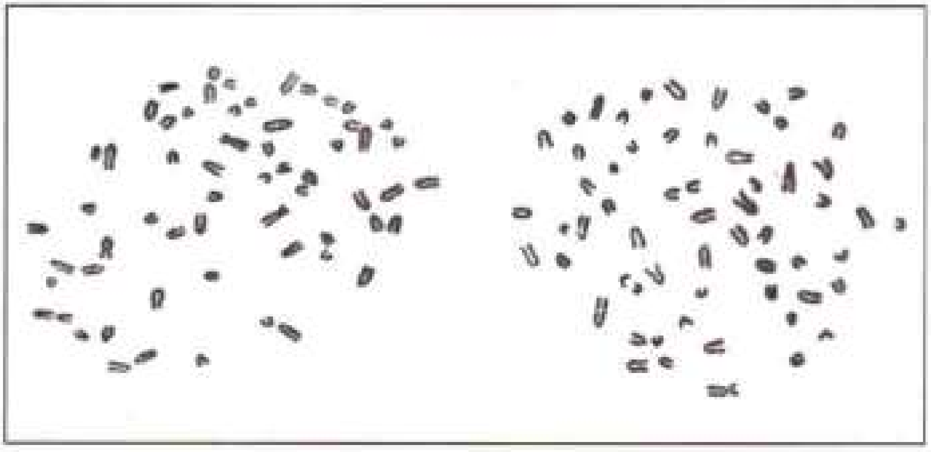

Figure 8 : Metaphase spread of a sahiwal female and male cattle.

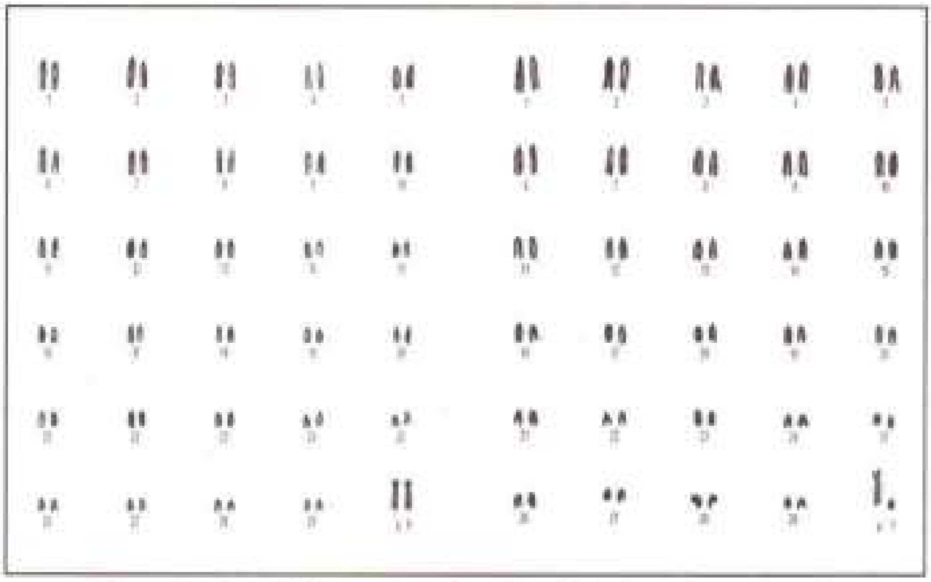

Figure 9 : Normal karyotype of a sahiwal female and male cattle.

Table 27. Relative length measurements of chromosomes of Sahiwal cattle

Chromosome No	Relative lengths of chromosomes (%)				
	M	F	M	M	F
1	5.15	5.21	5.18	5.38	5.41
2	4.68	4.71	5.02	4.92	4.96
3	4.53	4.41	4.98	4.52	4.81
4	4.21	4,25	4.80	4.29	4.59
5	4.09	4.14	4.72	4.22	4.41
6	3.98	4.06	4.62	4.11	4.25
7	3.91	3.96	4.36	3.96	4.16
8	3.84	3.89	4.35	3.90	4.10
9	3.73	3.80	4.26	3.79	3.91
10	3.62	3.69	4.22	3.67	3.74
11	3.49	3.57	4.05	3.56	3.61
12	3.37	3.45	4.03	3.44	3.51
13	3.25	3.32	3.95	3.36	3.33
14	3,15	3.24	3.90	3.25	3.25
15	3.06	3.15	2.93	3.16	3.16
16	3.00	3.08	2.68	2.96	3.01
17	2.93	2.98	2.70	2.87	2.83
18	2.85	2.89	2.63	2.78	2.78
19	2.76	2.89	2.57	2.71	2.71
20	2.67	2.75	2.53	2.66	2.62
21	2.62	2.70	2.52	2.55	2.56
22	2.54	2.66	2.43	2.49	2.46
23	2.45	2.59	2.42	2.43	2.36
24	2.39	2.51	2.40	2.35	2.29
25	2.29	2.41	2.37	2.23	2.15
26	2.23	2.33	2.36	2.18	2.04
27	2.14	2.23	2.28	2.11	1.98
28	2.09	2.15	2.27	2.00	1.89
29	1.99	2.06	2.00	1.86	1.78
X	5.14	5.00	5.07	5.21	5.31
Y	2.06	—	2.18	2.07	—
Source	Yadav 1981		Porwal 1987	Prakash 2005	

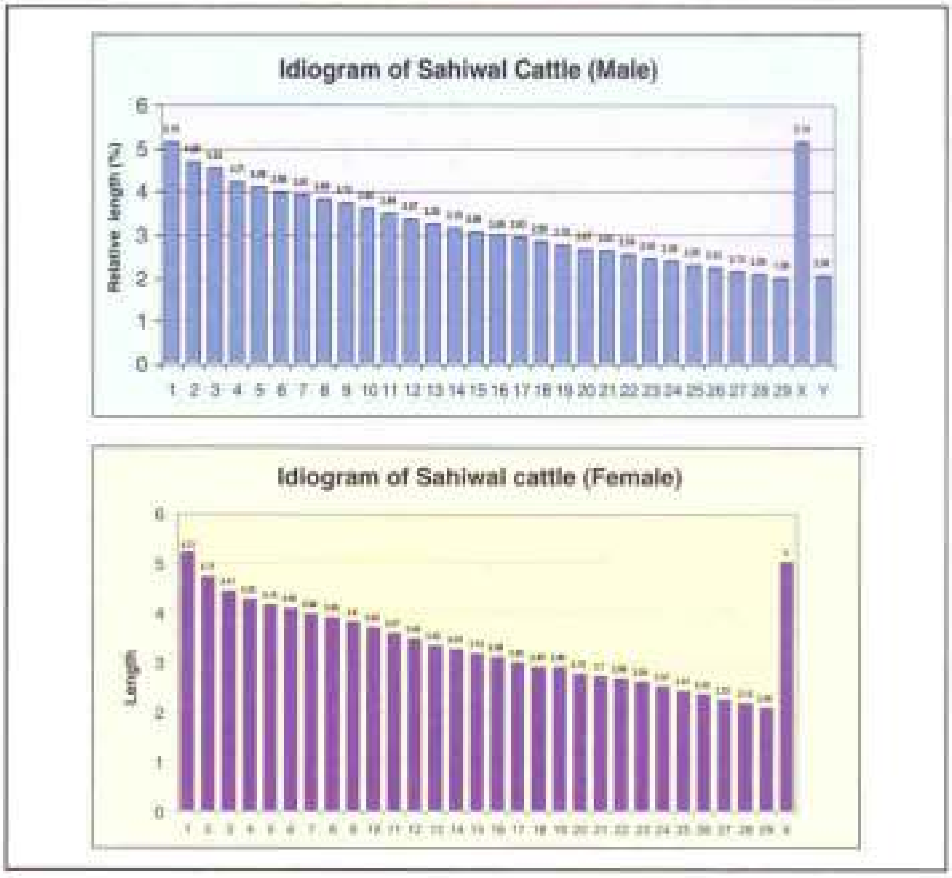

Figure 10 : Ideograms of Male and Female Sahiwal Cattle

Banding studies

C-banding and G-banding of Sahiwal cattle has been studied by Yadav (1981), Porswal (1987), Potter et al (1997) and Praksh (2005). Nucleolus organiser regions have been described by Prakash (1982) and Porswal (1987) and the sister chromatid exchanges by Goswami (1982).

C-banding

The C-banding induced by $HCl/Ba(OH)_2$ method revealed that all the 29 pairs of autosomes carried a large and distinct C-band. The conventionally stained chromosomes occasionally carried very short small arms which were conspicuous by their absence in the C-banded chromosomes (Figures 11 and 12). Although some variation in the amount of centromeric heterochromatin (C-band) could be observed in some of the homologous pairs, but no distinct pattern emerged. No other heterochromatic regions were observed along the chromatids of any of the chromosomes.

The X chromosome did not reveal a distinct centromeric heterochromatin. This chromosome showed a normal staining reaction. Similarly the Y chromosome in males did not show any centromeric heterochromatin (C-band). However it was stained darker than all other chromosomes in the karyotype.

G-banding

Digestion of chromosome preparations with trypsin enzyme produced alternate light and dark areas along the length of each chromosome pair (Figure 13). These light and dark areas are termed as G-bands. Each pair of homologous chromosomes possessed an identical and specific pattern of G-bands, which was specific and unique for each pair and distinguishable from the pattern for other chromosomes. This feature makes it possible to identify each and every pair of chromosome precisely and correctly.

Nucleolus Organiser Regions (NORs)

Nucleolus organiser regions depict the locations of ribosomal RNA genes on the chromosomes. The rRNA genes that were active in the preceding cell division can be revealed by silver staining of chromosome preparations. After silver staining the NORs are stained dark on the yellowish background of chromosomes. The rRNA gene is found in clusters of multiple copies and at multiple locations. The NORs in Sahiwal cattle were localised on 5 pairs of autosomes. The NORs were located at the terimini of these autosomes. These chromosomes have been identified as numbers 2,3,4,11 and 28 (Porswal 1987, Prakash 2005). In an earlier study Prakash (1982) identified these chromosomes as numbers 2,3,4,5 and 28. A silver stained metaphase of Sahiwal depicting NORs staining is shown in Figure 14.

Molecular Genetic Characterization of Sahiwal Cattle

The assessment of genetic variability is especially important in highly specialized livestock breeds since the use of assisted reproduction techniques, such

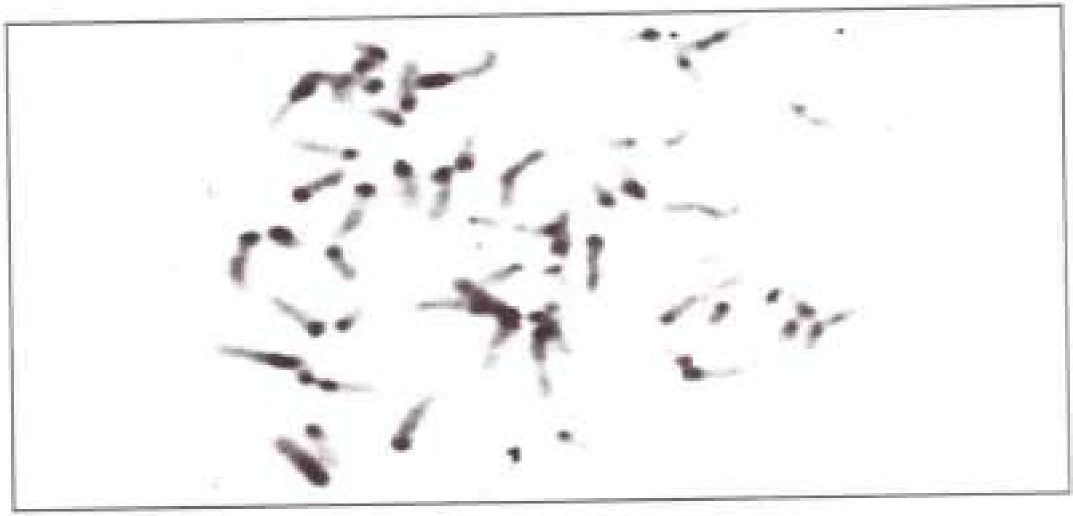

Figure 11 : *C-Banded metaphase spread of a male Sahiwal Cattle*

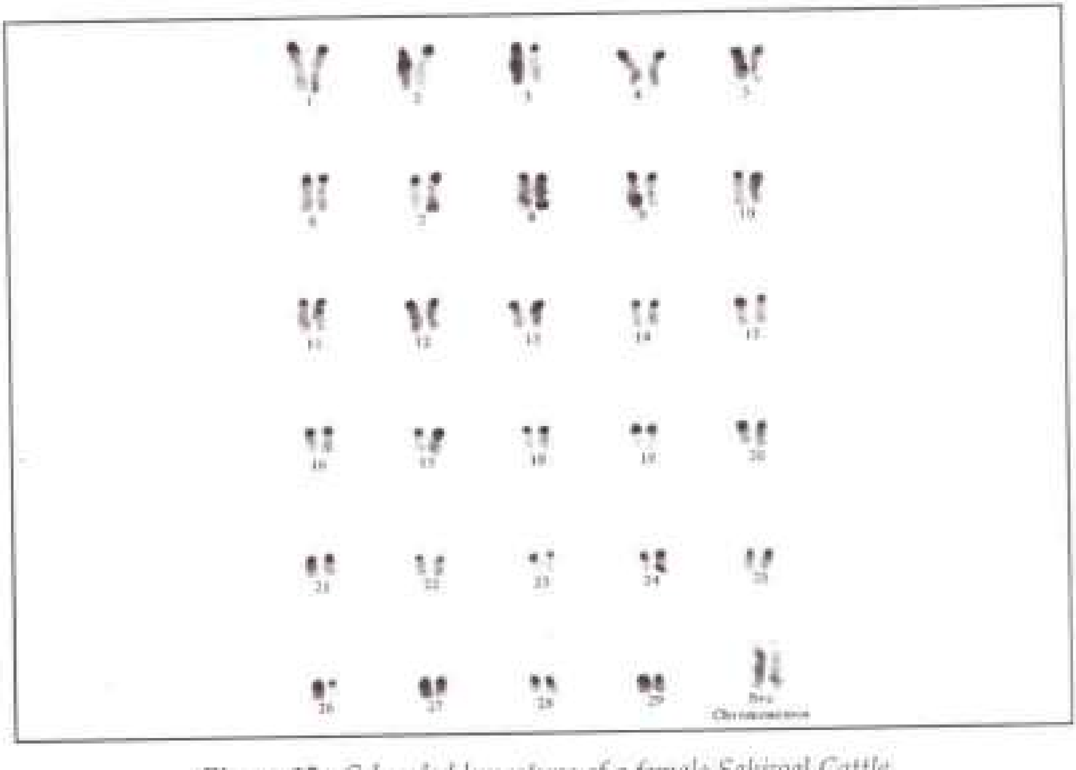

Figure 12 : *C-banded karyotype of a female Sahiwal Cattle*

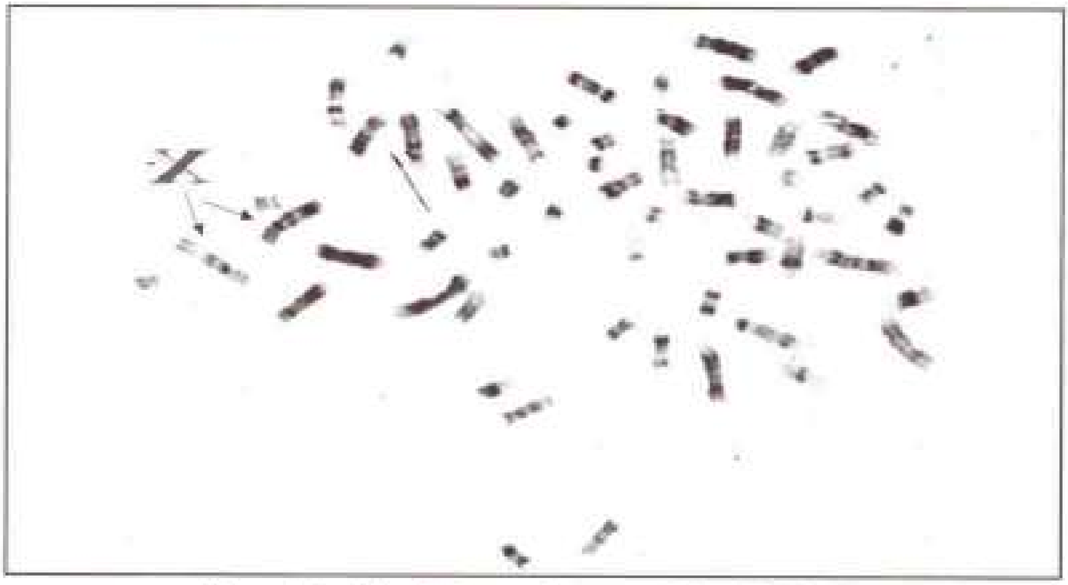

Figure 13 : G-banded metaphase spread of sahiwal cattle

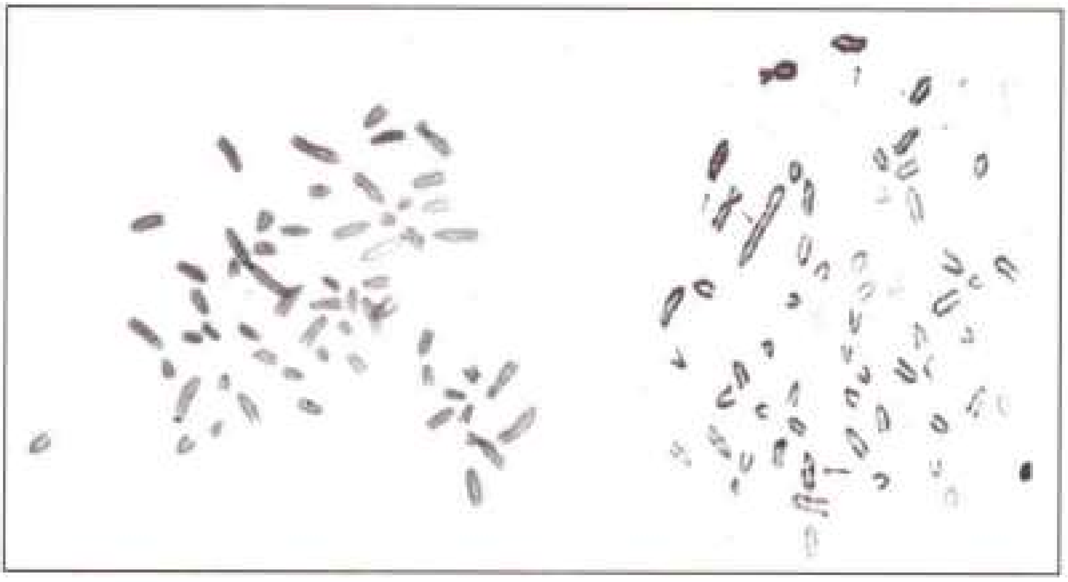

Figure 14 : Metaphase spreads of Sahiwal Cattle showing silver stained NORs

as artificial insemination and embryo transfer, to maintain these breeds can rapidly reduce the genetic variability of the population. Molecular markers have been widely used to access this variability since they provide information on every region of the genome, regardless of the level of gene expression. RFLP and microsatellites (highly polymorphic simple sequence repeats) are currently the most widely used molecular markers, mainly because of the possibility of combining their analysis with the polymerase chain reaction (PCR). These markers have been used to explain bovine domestication and migration patterns and to characterize cattle populations (MacHugh et al., 1994; Tambasco et al., 2000).

Another application of molecular markers is in uncovering parentage mistakes. This is especially important for guaranteeing the accuracy of breeding programs in which the relationship between individuals is used to estimate breeding value. For this application, the frequencies of each marker in the population must be known.

Genetic characterization of the native breeds is the first step, in identifying genetically unique breeds so that they may be prioritized for breed conservation purposes. The characterising of genetic distance sharpens the scientific rigour of choosing which breeds should be preserved. Genetic distance mapping is, thus, an important activity, to follow on the primary characterization of each animal breed.

Sampling and DNA isolation

Genomic DNA from whole blood sample was isolated from 50 genetically unrelated animals of Sahiwal using proteinase-K digestion followed by standard phenol-chloroform extraction procedure. A panel of 25 bovine specific microsatellite markers (except ILST002) recommended in MoDAD project of FAO (1998) for cattle genetic diversity was selected for typing in Sahiwal breed (BM1818, ETH3, ETH10, ETH152, ETH 185, ETH225, HEL1, HEL5, HEL9, ILSTS005, ILSTS006, ILSTS011, ILSTS030, ILSTS033, ILSTS034, ILSTS054, INRA005, INRA035, INRA063, MM8, CSSM60, CSSM66, HAUT24, HAUT27, ILST002).

PCR Based Genotyping

Polymerase chain reaction (PCR) was carried out in 25 ml reaction volume containing 1.5 mM $MgCl_2$, 200 mM dNTPs, 50 ng of each primer, ~100 ng of template DNA and 0.5 U of Taq DNA polymerase using PTC-100 thermocycler. The PCR products were analyzed on ethidium bromide (1.5 mg/ml) stained 2% agarose gel for amplification. The denatured samples were electrophoresed on to standard 6 % Urea-PAGE denaturing sequencing gel Allelic size range was estimated using 10 bp sequencing ladder and is depicted in Table 28. The resolved bands of DNA / alleles were visualized by silver staining procedure (Bassam et al 1991). The representative silver stained polyacrylamide gel showing allelic resolution at one of the microsatellite loci is depicted in Figure 15.

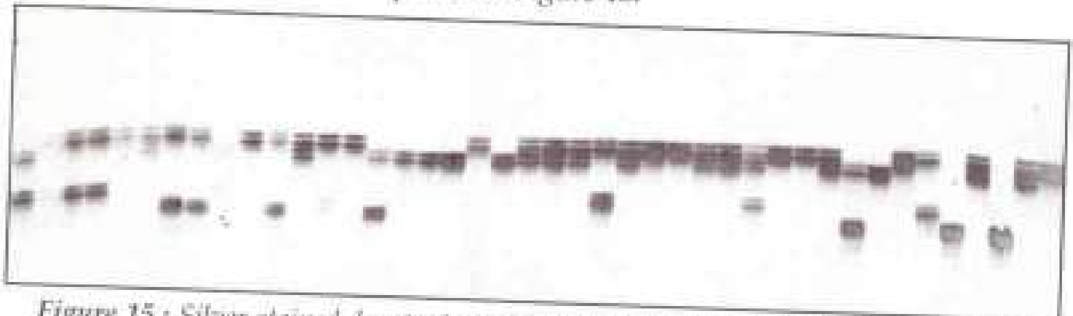

Figure 15 : *Silver stained denaturing urea- polyacrylamide gel (6%) showing allelic resolution at microsatellite locus ETH 225 in Sahiwal cattle*

Different measurements of within breed genetic variations viz. number of alleles, allelic frequencies, effective number of alleles (N_e), observed heterozygosity (H_o), expected heterozygosity (H_e) were estimated using POPGENE software package (Yeh et al. 1999) to assess the variability at DNA level in Sahiwal cattle. All the loci were found to be effective in detecting polymorphism in the investigated breed of cattle. Allele frequency distribution for each of the microsatellite marker is presented in Figure 16. Different genetic measures used to assess intra breed variability in terms of observed and effective number of alleles; observed and expected heterozygosity; PIC at each marker loci are presented in Table 28. The allele size range observed in the Sahiwal cattle was in agreement with that of European, Belgian and African cattle breeds (Mac Hugh et al.1997; Canon et al. 2001).

In total, 130 alleles were detected across the 25 loci with mean of 5.20 alleles (MNA) per locus. The number of alleles per locus was in close agreement with the values reported earlier in European cattle breeds (Blott and Williams 1998). The observed and effective number of alleles ranged from 2 to 10 and 1.04 to 6.65 at locus ETH3 and ILSTS006 respectively. The number of alleles at different marker loci and their frequencies are indicators of genetic variability and also form the basis of all the diversity indices for estimation of genetic distances and construction of phylogenetic trees. The range for observed and expected heterozygosity values across the 25 loci was 0.04 (ETH3) to 0.86 (HEL9) and 0.04 (ETH152) to 0.85 (ILSTS006) with a mean value of 0.43 and 0.60 respectively. The higher values of expected heterozygosity indicated that the population has retained the presence of several alleles, although at a small frequency. This implies a high amount of genetic variability in Sahiwal, an important milch breed. Polymorphism information content (PIC) values which ranged from 0.03 (ETH3) to 0.81(ILSTS006) with a mean of 0.54 revealed the polymorphic

Table 28. Number of observed (No) and effective alleles (Ne), size range, observed (Ho) and expected (He) heterozygosity, polymorphism information content (PIC) at 25 loci in Sahiwal cattle

Locus	Size range	Observed no. of alleles (No)	Effective no. of alleles (Ne)	Observed heterozygosity (Ho)	Expected heterozygosity (He)	PIC
BM1818	254-294	5	1.66	0.25	0.40	0.35
ETH3	109-133	2	1.04	0.04	0.04	0.03
ETH10	210-246	5	2.50	0.23	0.61	0.55
ETH152	204-212	3	1.35	0.23	0.26	0.25
ETH185	210-246	6	2.75	0.37	0.64	0.56
ETH225	130-170	5	2.79	0.58	0.64	0.58
HEL1	102-112	4	2.20	0.49	0.75	0.64
HEL 5	145-165	4	2.19	0.23	0.54	0.44
HEL 9	144-170	9	4.64	0.86	0.78	0.73
ILSTS002	122-138	5	2.26	0.61	0.56	0.49
ILSTS005	182-198	6	2.68	0.55	0.63	0.56
ILSTS006	276-296	10	6.65	0.33	0.85	0.81
ILSTS011	250-270	4	2.86	0.30	0.65	0.60
ILSTS030	158-184	4	3.47	0.26	0.71	0.64
ILSTS033	132-154	4	2.62	0.57	0.62	0.57
ILSTS034	148-210	5	2.47	0.33	0.60	0.53
ILSTS054	126-156	6	2.93	0.52	0.66	0.63
INRA005	132-146	4	2.60	0.28	0.62	0.53
INRA035	102-114	7	3.26	0.70	0.69	0.64
INRA063	170-188	3	2.03	0.60	0.51	0.41
MM8	132-148	3	2.14	0.06	0.53	0.43
CSSM66	177-209	7	4.80	0.74	0.79	0.74
CSRM60	182-202	8	5.33	0.71	0.81	0.79
HAUT24	109-133	5	3.24	0.40	0.69	0.64
HAUT27	160-190	6	2.02	0.45	0.51	0.46
Mean		5.2	2.88	0.43	0.60	0.54

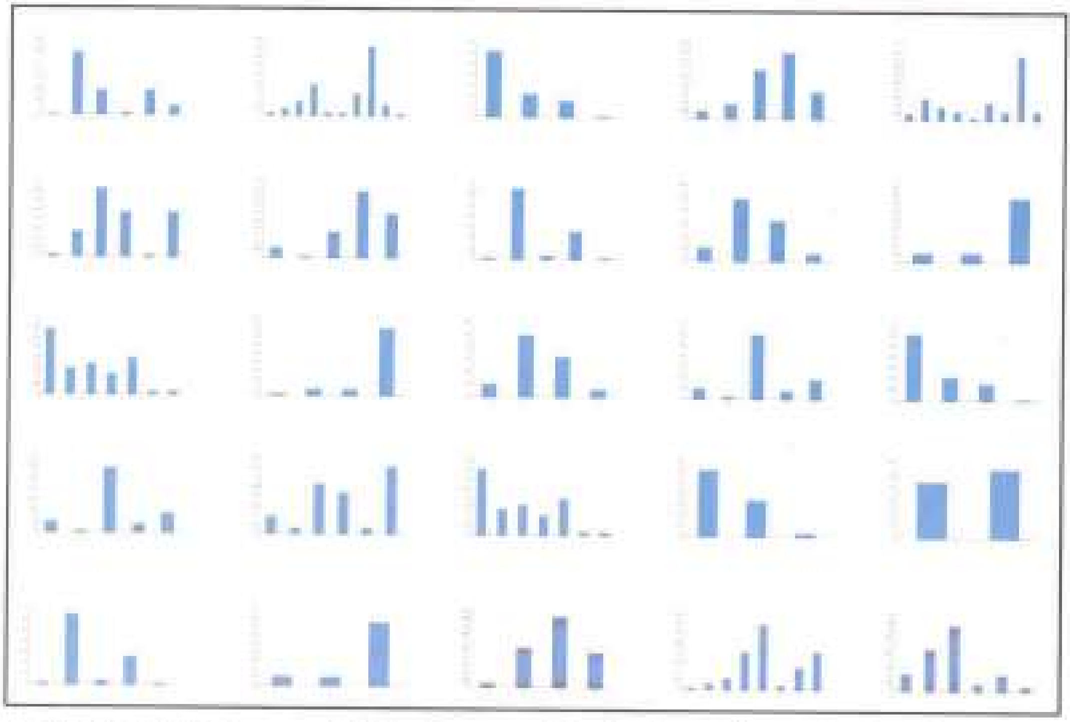

Figure 16 : Allelic frequency distribution across the 25 microsatellite markers in Sahiwal cattle

nature and suitability of the used set of microsatellite markers for the measurement of within breed diversity. The extension of such microsatellite based genotyping in other native cattle breeds would assist in their prioritization for conservation by establishing genetic relationships. The microsatellite loci exhibited high levels of genetic diversity estimates. The mean diversity indices across the 25-microsatellite loci in Sahiwal cattle are summarized in Fig 17.

The within-population-inbreeding estimates ($f = F_{IS}$) at each microsatellite loci were estimated using FSTAT version 2.9.3.2 computer programme (Goudet, 2002). The level of significance ($P < 0.05$) was determined from permutation test with the sequential Bonferroni procedure applied over all loci. There was a significant deficit of heterozygotes and the average F_{IS} values for most of the loci were significantly different ($P<0.05$) from zero. This shortage of heterozygotes and excess of homozygotes in Sahiwal cattle ($F_{IS}>0$) might be attributed to a number of factors viz., sample relatedness, linkage with loci under selection (genetic hitchhiking), population heterogeneity or null alleles (non-amplifying alleles). However, the foremost rationale for significant F_{IS} values in both the populations seems to be relatedness of few samples otherwise deemed unrelated (samples may be having common ancestors).

To find out whether Sahiwal population has experienced a recent reduction in the effective population size or genetic bottleneck, three different tests, namely a "sign test", a "standardized differences test" and a "Wilcoxon sign-rank test" were employed under different models of microsatellite evolution like the Infinite Allele Model (IAM), Stepwise Mutation Model (SMM), Two-phased model of mutation (TPM). The computer programme Bottleneck ver1.2.02 (Cornuet and Luikart, 1996) was used for these calculations. This programme works on the principle that any populations that have experienced a recent reduction in their effective population size exhibit a correlative reduction of the allele numbers (k) and gene diversity (He, or Hardy-Weinberg heterozygosity) at polymorphic loci. But the allele numbers is reduced faster than the gene diversity. Thus, in a recently bottlenecked population, the observed gene diversity is higher than the expected equilibrium gene diversity (Heq), which is computed from the observed number of alleles (k), under the assumption of a constant-size (equilibrium) population. The outcome supported for the absence of any bottleneck in Sahiwal cattle. Another powerful test of qualitative geographical method based on mode -shift distortion was utilized to visualize the allele frequency spectra as a check for genetic bottleneck. No Mode shift was detected in the frequency distribution of alleles and a normal L- shaped curve was observed, where the alleles with the lowest frequencies (0.01-0.1) were found to be most abundant (Fig-18).

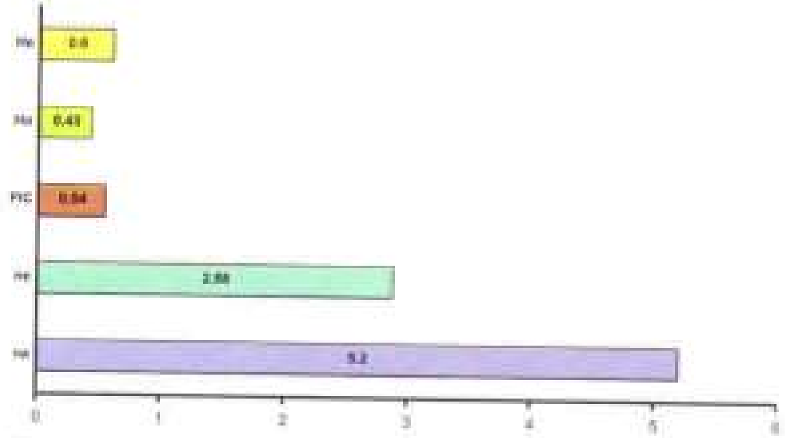

Figure 17 : Mean diversity indices across 25 microsatellite markers

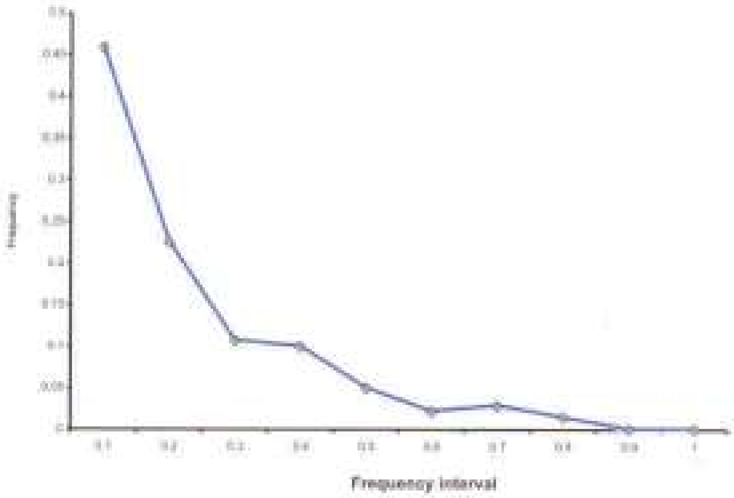

Figure 18 : Mode shift analysis for test of bottleneck in Sahiwal cattle

Recent Published information on microsatellite based studies in Sahiwal cattle

Many reports are now available globally, describing the use of microsatellites in measurement of genetic variation between breeds/populations, defining the population structure and identifying the genetically unique population. However, not much information was available on genetic characterization and diversity analysis of Indian cattle breeds. Recently, Mukesh et al (2004a) tried to assess the genetic variation and establish the relationship amongst the three Indian zebu cattle breeds viz. Sahiwal, Hariana and Deoni using 20 bovine-specific microsatellite markers. A total of 136 unrelated DNA samples from the three breeds of cattle were genotyped to estimate within and between breed genetic diversity indices. The estimated mean allelic diversity was 5.2, 6.5 and 5.9 in SC, HC and DC, respectively, with a total of 167 alleles. The average observed and expected heterozygosity for the population varied from 0.42 in Sahiwal to 0.59 in Deoni, and from 0.61 in Sahiwal to 0.70 in Deoni, respectively. Low values of genetic variability estimates were observed in Sahiwal when compared with Deoni and Hariana, indicating some loss of variability because of its relatively small population size (Nivsarkar et al. 2000). From global F-statistics a significant deficit of heterozygotes of 24.2% ($p < 0.05$) was observed for each one of the analysed breeds whereas the total population had a 32.8% ($p < 0.05$) deficit of heterozygotes.

The F_{ST} estimates demonstrated that approximately 88.7% of the total genetic variation was because of the genetic differentiation within each breed. Pair-wise breed differentiation, Nei's standard and D_A genetic distance estimates revealed relatively close genetic similarity between Hariana and Deoni in comparison with Sahiwal. In the UPGMA-based phylogenetic tree constructed from the genetic distances, Hariana and Deoni were grouped together in one cluster and Sahiwal in the other (Figure 19). The estimated time of divergence suggested a separation time of approximately 776 years between Deoni and Hariana, and a comparatively longer period (1296 years) between Deoni and Sahiwal.

The population structure and microsatellite based genetic variability in Sahiwal cattle was assessed using 25 FAO recommended (FAO 1998) bovine specific microsatellite markers (Mukesh et al.2004b). In a comprehensive study by Kumar et al. (2004), admixture analysis of South Asian cattle i.e., influence of *Bos Taurus* ancestry in the cattle breeds of Indian subcontinent was carried out. Their study has revealed low number of alleles and heterozygosity in Sahiwal as compared to Hariana and other cattle breeds. The similar low values of gene diversity in Sahiwal cattle were also observed as compared to other Indian breeds (Hariana and Tharparkar) included in an extensive study on microsatellite variation and phylogeography of taurine and zebu cattle (Mac Hugh et al.1997). These studies indicated some loss of variability in Sahiwal cattle and that could be attributed to its relatively smaller population size. More efforts are now being extended in a more concerted manner for molecular inventorization and determining the overall relationship of Sahiwal cattle in relation to other indigenous breeds of cattle.

Figure 19 : *UPGMA dendrogram based on D_A genetic distance showing the genetic relationship of Sahiwal breed with Deoni and Hariana.*

DNA Fingerprinting

Shashikant and Yadav (2004) screened Sahiwal, Hariana and Tharparker breeds with a synthetic oligonucleotide $(GTG)_5$ in combination with HaeIII, HinfI, AluI and MboI for producing DNA fingerprints of randomly selected animals of the three breeds. Highly polymorphic multilocus fingerprints were obtained from all the four combinations of probe and enzymes. The average number of bands, average band sharing values and the mean allelic frequencies of the fingerprints were 14.90 ± 2.7, 0.55 ± 1.0, 0.32 for Sahiwal; 14.95 ±1.30, 0.48 ± 0.11 and 0.27 for Hariana and 13,72 ±1.95, 0.49 ±0.16, 0.28 for Tharparkar breeds respectively. The probability of getting two identical fingerprint pattern between two unrelated animals were 9.7×10^{n} for Sahiwal, 4.5×10^{n} for Hariana and 3.7×10^{n} for Tharparkar cattle. Within breed variation was highest in Hariana followed by Sahiwal and Tharparkar breeds. Sahiwal breed was found to be genetically more distant to Hariana as compared to Tharparkar.

MHC-DRB 3 Locus

Yadav (2001) analysed the MHC-DRB 3 Locus of sahiwal cattle using PCR-RFLP technique. The analysis revealed polymorphism in the MHC-DRB 3 Locus. Restriction enzymes RSm1, BstYI and HaeIII showed heterozygote as well as homozygote patterns. The three enzymes revealed 10,3 and 3 patterns, respectively with a total of 144 alleles in Sahiwal cattle. The results of the studies are summarized as:

- PCR-RFLP revealed polymorphism at MHC-DRB 3 Locus
- A total of 14 MHC-DRB 3 alleles distinguished.
- Revealed 10 distinct fragments for RsaI, 4 Bst YI and 4 HaeIII patterns.
- Revealed homozygosity in 10 and heterozygosity in 53 animals.
- Bba pattern in 27 animals followed by fba in 16 animals and one animal was heterozygote for lbb.

Bovine Somatotrophin Gene

PCR-RFLP analysis of somatotrophin gene of Sahiwal cattle by Srinivas Raghvan (2002) revealed

- Polymorphism in the Sahiwal somatotrophin gene.
- PCR-RFPL using MspI enzyme exhibited polymorphism.
- PCR-RFPL using EcoR V and Bgl II did not reveal any polymorphism
- Two alleles C and D were detected by MspI
- The D allele in homozygous condition was observed in 29 Sahiwal animals

- CD heterozygote condition was observed in 5 Sahiwal animals
- C allele in homozygous condition was not observed in any of the Sahiwal animals studied
- The gene frequency of D allele was 0.93 and that of C allele as 0.07 in Sahiwal breed

Insulin-like Growth Factor Binding Protein-3 (IGFB - 3)

IGFBP-3 is a protein that specifically binds to insulin growth factor (IGF; growth factors playing key role in tissue and cellular growth) peptides and modifies IGF bioavailability and bioactivity and thus plays a crucial role in the growth and development of animals. A 651 bp of IGFBP-3 gene spanning over a part of exon-2, complete intron 2, exon3 and part of intron 3 was amplified by PCR (Choudhary et al 2005). Digestion of the amplified product with NlaIII restriction enzyme revealed three patterns in Holestein and Jersey cattle breeds and only one allelic pattern (AA) in Sahiwal, Hariana, Gir and Nimari breeds of zebu cattle. Nucleotide sequencing showed that there was a transition in the intron region 2 of the IGFBP-3 gene causing polymorphism in exotic breeds and absence of polymorphism in zebu breeds.

Conservation

Need for Conservation

Lately, prominence in India is transferring from crossbreeding to the conservation and proliferation of zebu milk breeds like Sahiwal, Red Sindhi, Tharparkar, Rathi (containing Sahiwal blood to a large extent) and Kankrej, which have outstanding milk production potential and all together suitably adapted to the local conditions and diseases. Average lactation milk yield in the ranges of 1500 to 2500 Kg have been testified from the organized Sahiwal herds. In properly managed herds highest lactation yields touching 4500 Kg have been achieved from certain cows, thus demonstrating the milk production potential of the breed which has essentially remained unexploited. This warrants an undelayed need to reformulate the breeding and developmental strategies to stop further deterioration and dilution of this valuable germplasm and bring about genetic improvement in the productivity of the breed which is undoubtedly the best indigenous cattle milk breed.

Conservation Practices and their Relevance for Sahiwal cattle

Live animal conservation (in situ) has numerous advantages as compared to cryo preservation (ex situ), but it is very expensive because of the number of animals to be maintained. The advantages include (1) improvement of the breed over the time, 2) purification of the breed from other breeds and from lethals by elimination of unwanted traits, 3) availability of animals for immediate use etc. Nevertheless, it is indispensable to conserve the germ plasm in the shape of semen and embryos (ex situ) also. When it comes down to the conservation of live populations of endangered breeds hardly ever sticks to the textbook blueprint of minimum inbreeding coefficients and classical breeding strategies. In the field, in an in situ project the limitations and priorities are shifted as the lines between breeds and populations, and between conservation and utilization become less obvious.

One of the magnificent strengths of in situ conservation programmes lie in their own diversity. Unlike ex situ projects which involve a minimum level of technological equipment and knowledge, in situ conservation can be implemented at any level, in any country with the expertise and resources already existing. Programmes can be functioned by national or provincial government agencies, by non-government organizations, by private organizations, by cooperative groups of farmers and even by private individuals.

Local indigenous and adapted stocks like Sahiwal cattle are vanishing by dilution and replacement. Farmers and livestock breeders throughout the world are aware of the problem. Often they are also conscious that something of great local value is being exhausted but that as individuals they cannot swim against the tide even if they would like to see more pride in, and the use and development of their own local stocks. There are many examples of individual farmers or groups of farmers who have continued to maintain and breed the last herd of a particular type or breed of livestock because they believed that they had something to offer. In many cases such farmers have ensured the survival of that breed until its value has been recognized.

One such case in point is that of The Maharaj Bir Singh who maintains an important private animal breeding and agricultural research farm in the Sirsa district of Haryana. First established in the early years of this century by his late holiness Sri Satguru Pratap Singh ji, the farm has breeding herds of 300 Sahiwal and 300 Hariana cattle. All the cows are individually identified and excellent records maintained on their breeding, health and production. The current Maharaj believes that these two local breeds have many adaptive characteristics which make them ideal for the local farmers. In particular the exotic European crosses which have become widespread in the past thirty years do generally produce more milk in a single lactation in the first cross. However, their survival rates are considerably lower than the local breeds due to their failure to conceive repeatedly on the very low input diets available, their relatively high susceptibility to prevalent parasites and diseases and their intolerance of the humidity and heat. In addition the male crossbred calves are far less valuable as draught oxen than the local breeds because they will not work in the heat of day and are known to be slow and lazy. In a country where cattle are not slaughtered for meat, this inability to make use of the male calves is a serious financial consideration. Overall, despite their lower milk yield, the economic output of the Sahiwal cows is not in fact inferior to the exotics or their crosses.

Through a programme of recording and selection the Maharaj hopes to be able to be instrumental in ensuring the survival of the Sahiwal and Hariana breeds while making superior animals available to local farmers wishing to return to these traditional breeds. He is now working with a number of university and research farm projects coordinated through the National Bureau of Animal Genetic Resources in Karnal. In such an example the value placed by individual farmers on their breeds has enabled unfashionable or temporarily uneconomic breeds to survive until their potential value could be recognized. This also highlights how important it is to seek information about breeds from farmers and to use farmers as a central part of conservation strategy.

Strategies for Conservation and Improvement of Sahiwal Cattle

Currently only limited pure bred Sahiwal herds are maintained by few tribal cattle breeders still committed to rear Sahiwal on their own, at selected cow stables (Gaushalas), religious charitable trusts, provincial cattle breeding farms and research and development organistions. The first and foremost need is to determine the actual number of Sahiwal cattle in the country by conducting a quick breed survey and liaisoning with various state animal husbandry departments. The quick study should also look into the socio-economic level of Sahiwal breeders/farmers, demographic and geographical spreading, morphological characteristics, functional traits as well as genetic characterization of the breed.

Alarmed at the genetic dilution and population shrinkage of some of the well-known dairy breeds of the country like Sahiwal, Gir, Kankrej, Red Sindhi and Tharparkar, emphasis has now shifted towards conservation and improvement of indigenous zebu breeds of cattle. Though such a realization is yet to take a practical shape, yet the envisaged Sahiwal cattle conservation and improvement plan should allow for the following objectives:

- Maintenance of nucleus herds of superior germplasm of Sahiwal cattle. Adding high producing animals acquired from farmers' herds should further reinforce the existing organized farms
- Registration and recording of institutional and private Sahiwal cattle farms/herds: Over and above the farms listed in Table 1 there are several other farms which maintain Sahiwal animals, though in small numbers. Inventorization of all Sahiwal animals will give a comprehensible picture of the Sahiwal resources available in the country.
- Performance recording for genetic evaluation and herd management: This is most important and indispensable for any successful breed improvement programme.
- Recognition of superior individuals through selection: Multi location progeny testing of bulls linking as many farms/farmers herds will pave the way for long term development of the breed for its sustainable improvement and utilization.
- Collaboration with national and international institutions involved in breed development programmes through research.
- A far-reaching progeny testing programme for evaluating ample number of Sahiwal bulls joining together large breeding herds of Sahiwal kept at different farms in the country must be commenced instantaneously. This will also facilitate the setting up of Sahiwal bull mother farms and germplasm collection centers which will further supply superior germplasm in the form of semen and live bulls to different farms including farmersr:' herds (Joshi et al 2001).

Multiple ovulation and embryo transfer (MOET), a new reproductive biotechnological tool may subsequently be used for boosting the proliferation of superior germplasm from the elite nucleus herd to produce a large number of improved progenies. Taking advantage of this technology, 6-12 progenies can be produced per donor per year and 30-60 progenies in her lifetime (Kurup 1992) corresponding to 4-6 progenies by way of the biological process. Success of MOET, however, requires excellent infrastructure facilities for cryopreservation of semen/embryos and transfer of embryos even at field level.

Sahiwal Breed Association

Breed associations are groups of individual farmers who maintain and produce the same pure breed. They act as a pedigree registration and certification service to their members and as a commercially based breed promotion and marketing service. In normal circumstances they seek to 'improve' their stock by encouraging selective breeding. The combination of the two factors of breed improvement and breed promotion do, therefore, appear to be in direct opposition to the concept of the conservation of genetic variation. There is an urgent necessity of having an active breed association for ensuring that Sahiwal breed survives and propagates. But such breed associations are dependent upon member contributions, and in the case of small associations are normally run by members themselves. It, therefore, often happens that a very rare breed that really needs a breed association cannot sustain by itself. In such a situation, Governmental organizations associated with livestock sector should come forward in providing assistance with basic secretarial, communication and registration services until the members are able to sustain their own breed organizations.

Inter country collaboration among stake holder countries via exchange of superior germplasm will further enlarge the genetic base of the breed. This will eventually render selection more efficient. An associated herd progeny-testing programme resembling the INTERBULL programme of Sweden will further enhance the precision and potency of sire evaluation.

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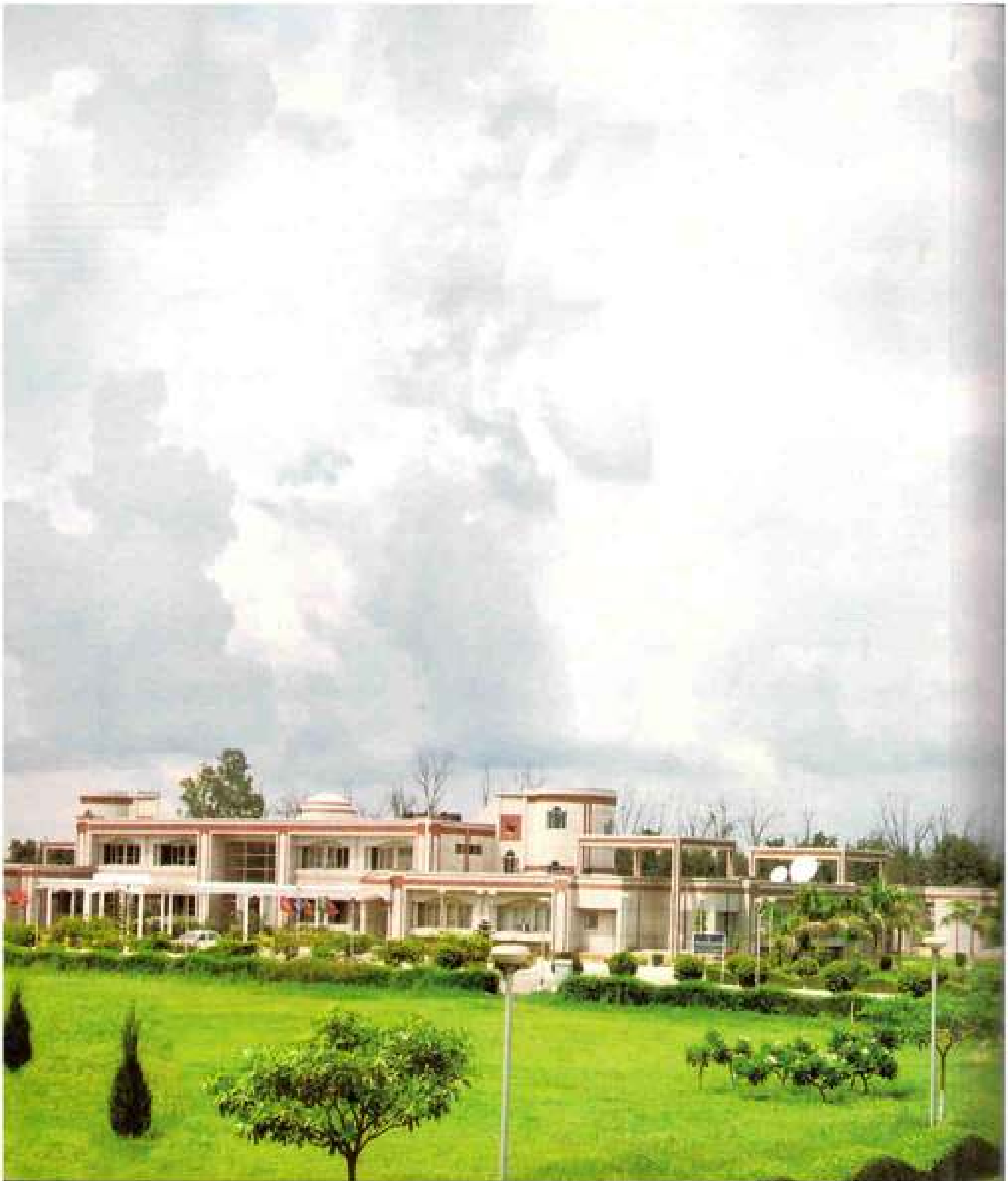

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