CHARACTERISATION AND EVALUATION OF THE DWARF CATTLE OF KERALA

By

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THESIS

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1994

DECLARATION

I hereby declare that the thesis entitled "Characterisation and Evaluation of the Dwarf Cattle of Kerala" is a bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award to me of any degree, diploma, associateship, fellowship or other similar title of any other University or Society.

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CERTIFICATE

Certified that the thesis entitled **"Characterisation and Evaluation of the Dwarf Cattle of Kerala"** is a record of research work done independently by **Smt. C.R. Girija**, under my guidance and supervision and that it has not previously formed the basis for the award of any degree, fellowship or associateship to her.

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INTRODUCTION

Cattle were domesticated at a very early stage of human civilization. They served through ages as objects of worship and mythology. Drawings and carvings on the walls of caves in India and Egypt depict cattle as beasts of burden. The excavations of Mohanjodaro and Harappa indicate the use of cattle in India as early as 5000 years ago. The Great Ox or Aurochs, which Caesar mentioned in his writings is considered to be one of the progenitors of the modern dairy breeds.

Livestock husbandry has been practiced in India from very ancient times and such a long association with the art of rearing of animals and the widely varying agro-ecological conditions of our country and origin of livestock has resulted in great deal of diversity in livestock genetic resources over the years. Over time, however, there has been deterioration in the quality of livestock especially because of increase in number without corresponding increase in feed resources and organisations to undertake systematic genetic improvement.

In India, cattle play a vital role in rural economy. Bullocks are still an important source of motive power in agricultural operations although they are fast being replaced by machines. Milk is the major source of animal protein in

the diet of a large number of people. Among the various milch animals, the cow is the animal of choice as the environmental conditions are generally favourable for its upkeep. India has not only the largest population of cattle and buffaloes but also the world's best breeds of draught cattle and dairy buffaloes. Further, they are adapted to tropical heat and resistant to most of the tropical diseases.

The indigenous zebu cattle (Bos indicus) differ from Bos taurus found in Europe and North America in body conformation. The zebu is characterised by a prominent hump, a long face, upright horns, drooping ears, a dewlap and slender legs. The colour varies from white to grey and black. Zebus have relatively lower basal metabolic rate, better capacity for heat dissipation through cutaneous evaporation and thus, adapted to tropical heat and resistant to diseases.

In India, majority of cattle (about 75-80 per cent) are non-descript and most of the zebu cattle are of the draft type. There are 26 breeds of Indian cattle which can be classified as milch, draught and dual purpose breeds. It is estimated that only about 15 to 25 per cent of these cattle in India belong to these definite breeds. These breeds have evolved in various agroclimatic and ecological regions of the country according to the regional needs. The policy of the various State Governments and Central Government was to

conserve these breeds by establishing State Government farms (Gurnani et al., 1985).

According to the quinquennial Livestock Census, 1987, the cattle population has been 34.24 lakhs which consists of 17.22 lakhs of desi cattle and 17.02 lakhs of improved cattle in Kerala. The native cattle of Kerala which have been evolved through several generations of natural breeding against high humidity due to heavy rainfall, the soil poor in essential minerals and hot climate, have not found a place in the list of recognised breeds of cattle in India. They have been treated as non-descript animals always, although they posses some special features. Kerala Agricultural University has felt the need to conserve the local cattle and started a project for the purpose. Characterisation and evaluation of these cattle is therefore imperative to explore the genetic diversity within and between breeds. Among the dwarf cattle of Kerala, Vechur cattle were very popular in Central Travancore until 30 years back. They had their origin in Vechur, a small place by the side of Vembanad lake near Vaikkom. The Vechur cattle and other dwarf variety of cattle in the high ranges are small in size and highly adapted to the local conditions. Velu Pillai (1940) has stated that out of the local breeds of Travancore, the Vechur breed excelled for its milking capacity. Crossbreeding of local cattle with

exotic cattle and mass castration of local bulls led to the quick disappearance of these native cattle from most of the areas and consequently resulted in near extinction of these cattle.

Conservation is the management of the biosphere so that it may yield greatest benefits to the present generations while maintaining its potential to meet the needs and aspirations of future generations. It is a positive endeavour directed ultimately at the preservation, maintenance, sustainable utilisation, restoration and enhancement of natural resources.

With the emergence of crossbred population of cattle, the traditionally reared local cattle have gradually suffered genetic erosion. Under this circumstance, the present work was undertaken with the following objectives.

1. To characterise and evaluate the germplasm of local dwarf cattle of Kerala.

2. To study the Karyotype and to establish the morphology of chromosomes using G-banding.

3. To study the population structure by means of the gene frequencies of different blood proteins.

4. To study the growth and production traits.

Characterisation and evaluation would help in finding out the genetic differences of the dwarf cattle of Kerala and the evolutionary differences if any can be found out. This will help in deciding about the conservation of their germplasm as a reserve for the future.

The study will also shed light on the genetic potential and perhaps the unutilised genetic potential of the Kerala cattle which has been ignored till now.

Review of Literature

REVIEW OF LITERATURE

The characterisation and evaluation of a breed or type is generally carried out through cytogenetic, immunogenetic and polymorphism studies reinforced by the description of growth and production traits. Since,no scientific study has been conducted in the local cattle, information on this aspect is scanty. In view of comparing the results, the work done on the above aspects in Indian and exotic breeds of cattle are reviewed here under the following heads.

2.1 Cytogenetic studies

2.1.1 Karyotype and morphology of chromosomes

A karyotype is a systematised presentation of the metaphase chromosomes characteristic for an individual animal or species. The chromosomal studies pertaining to domestic animals was initiated by Makino (1944) who reported that the diploid chromosome number of the cattle was 60 using the testicular tissue cultures. He could not observe any difference between the karyotypes of Bos taurus and Bos indicus. The X and Y chromosomes were described to be acrocentric in both sub-species.

The diploid chromosome number in cattle was found to be 60 with X chromosome as submetacentric and all the autosomes as acrocentric (Chiarelli et al., 1960).

Crossley and Clarke (1962) conducted experiments with peripheral blood leucocyte culture and muscle tissue cultures and confirmed the diploid chromosome number of cattle to be 60. They described the autosomes as acrocentric and X and Y as large and small submetacentric respectively.

Gustavsson (1966) conducted studies in Bos taurus animals of Sweden. Eighty eight per cent of the animals appeared to have 60 chromosomes, 122 animals having 59 chromosomes with one abnormal autosome and four bulls with only 58 chromosomes per cell. All the animals appeared normal and used for artificial insemination purposes also. The abnormal chromosomes found in these cattle was explained to be as a result of interspecific chromosomal polymorphism. This type of variation, either centric fusion or translocation of Robertsonian type, is common in invertebrates but not in animals. This Robertsonian type of chromosome translocation described in cattle was the first type of rearrangement observed in domestic animals.

Basrur and Moon (1967) compared the Chromosome complements of domestic cattle, Bos taurus and American bison

(Bos bison) with those of their hybrid, the cattalo. The diploid numbers were 60 and the autosomes and the X chromosomes were morphologically similar in cattle and bison, however, the Y chromosome in these two species differed in that it was a small metacentric, in bison. The diploid number of cattalo was 60 consisting of 58 acrocentric autosomes and two metacentric sex chromosomes which were indistinguishable from those of cattle.

Kieffer and Cartwright (1968) conducted the studies on pure Brahman, Santa Gertrudis or crosses in which the sire was a Brahman and found that the metaphase chromosomes of Bos indicus male possessed subterminal centromeres and the X was submetacentric. The Y chromosome in all the cases was morphologically similar to 58 autosomes in the position of the centromere. The individuals that were either members of Bos taurus species or sired by a number of Bos taurus species had Y chromosome with submedian centromeres. The X chromosome of both the species had identical morphology. The karyotype construction and chromosome replication patterns indicate that the Bos indicus Y to be similar in overall size to Bos taurus Y. The difference in position of centromere of the two species could have originated through a pericentric inversion.

Potter et al. (1979) conducted a cytogenetical study using metaphase chromosomes from cultured lymphocytes of 2

Banteng (Bibos banteng) steers, 218 bulls representing 13 pure breeds (Bos taurus type, Bos indicus type and Sanga) and 7 cross-breds. Studies were made using photographic karyotypes of Giemsa stained and C-banded chromosomes in each breed and G-banded chromosomes from 3 breeds of Bos indicus and one crossbreed (Australian Friesian Sahiwal) cattle. The relative lengths of chromosomes of Bos taurus and Bos indicus bulls were compared and significant difference in relative lengths of X chromosome were noted between these two species. There was difference in morphology of the Y chromosomes; Sanga, Banteng, and Bos taurus type breeds had a small submetacentric Y chromosomes, except for the Jersey which had a metacentric Y chromosome. All Bos indicus type bulls had an acrocentric Y chromosome but the Drought master breed had two forms of the Y chromosome (submetacentric and acrocentric). The G-banding patterns of Bos indicus resembled those of Bos taurus and enabled pairing of homologous chromosomes. Centromeres of autosomes were unstained but those of the sex chromosomes were darkly stained.

Sahai (1982) described the relative length of chromosomes in zebu cattle. In Red Sindhi, it ranged between 1.76 to 5.61 and in Hariana the range was from 1.76 to 5.68 between the largest and shortest chromosomes. In both these

breeds, the largest chromosome was X with 5.61 and 5.68 relative lengths, respectively.

Yadav et al. (1984) reported that the chromosomal screening of 165 male cattle revealed 86.7 per cent with normal chromosome complement such as 29 pairs of acrocentric autosomes and a submetacentric X. The Y chromosome was acrocentric in zebu and metacentric in exotic and crossbred ones.

Stranzinger et al. (1987) screened 52 bulls of different breeds and confirmed the distinct morphological difference in the Y chromosome between Bos taurus and Bos indicus cattle. In Bos indicus the Y chromosome was telocentric whereas in Bos taurus it was metacentric.

Raghunandanan (1988) conducted a study in four groups of cattle such as local non-descript, half bred Jersey, half bred Holstein Friesian and Jersey cattle and found that the normal cattle possessed a diploid chromosome number of 2n = 60 with 29 pairs of autosomes and one pair of sex chromosomes. The males were heterogametic. All the autosomes were acrocentric in all groups whereas the X chromosome was biarmed, large and submetacentric. The Y chromosome was polymorphic being acrocentric in local and submetacentric in exotic bulls.

The relative length of the largest and smallest autosomes were 6.5080 and 1.3473 per cent in local, 6.4735 and 1.2250 per cent in half-bred Jersey, 6.2190 and 1.3788 per cent in half-bred Friesian and 6.9125 and 1.3096 per cent in Jersey, respectively. The difference in relative length of autosomes between different genetic groups was not significant. The relative length of X chromosome was 7.2838 per cent and 7.0313 per cent 6.5138 per cent and 6.3166 per cent in local, half-bred Jersey, half-bred Friesian and pure Jersey respectively with significant difference between the genetic groups. The X chromosome occupied the first position with respect to relative length. The relative length of Y chromosome was 2.9415 per cent 2.5745 per cent and 2.9375 per cent in local, Jersey and Holstein Friesian respectively. The difference was not significant. In the karyotypic array the Y chromosome occupied a position between the 15th and 16th pair of autosomes, in local and Holstein Friesian whereas in Jersey it was between 15th and 20th pair. The arm ratio of X chromosome was 2.043, 1.986, 1.739 and 1.690 in local, half-bred Jersey, half-bred Friesian and Jersey respectively. In local cattle the centromere was located away from mid point compared to other genetic groups. The arm ratios of the Y chromosome of Jersey and Holstein Friesian were 1.21 and 1.66 respectively. The centromere index of X chromosome was 0.365, 0.329, 0.338

and 0.372 in local, half-bred Jersey, half-bred Holstein Friesian and Jersey respectively.

2.1.2 G-banding patterns of chromosomes

Conventional staining techniques failed to identify the individual autosome pairs with the exception of the largest (chromosome 1) and the smallest (chromosome 29) in the genome. With the advancements in banding techniques several investigators have attempted to carry out unequivocal identification of bovine chromosomes. The first demonstration of differential staining of chromosomes was achieved by Quinacrine fluorescence analysis by Caspersson et al. (1970). The standard system of nomenclature adopted should clearly adhere to the system developed for the description of human banded chromosomes laid down in the Paris (1971) conference proceedings.

The description of the G-banded chromosomes proceed from the general to the particular in order of whole chromosomes, parts or segments down to individual bands. The focal point for the descriptions of the G-banded patterns is the centromere (centric region) since the definitions emanate from that point. The chromatid arms of the chromosomes were given the normal designation of p (for the shorter arms) and q (for the longer arms). Generally the chromatid arms were

subjectively subdivided into two parts the proximal part which is the area from the centric region to the centre of the chromatids and a distal part which consists of the terminal regions. In some cases where there was a characteristic banding pattern towards the centre of the chromosome arm, a third part, the central part was interjected between the proximal and distal parts. The chromosomes were visualised as consisting of a series of light and dark areas. The terms light bands and dark bands were qualified by the use of the term narrow, faint, broad, distinct and prominent. The particular arm area of the band is specified by the use of proximal, central and distal. Two further descriptions of location were used, near to or adjacent to centromere and terminal.

Hensen (1972) reported the identification of 28 out of 30 chromosome pairs by the quinacrine fluorescent technique.

Schnedl (1972) reported that all the chromosome pairs in cattle can be identified by their banding patterns using Giemsa staining procedure.

Several studies have indicated that identification of all individual homologous chromosome pairs can be obtained by employing the G-banding techniques (Evans et al., 1973;

Gustavsson, 1973; Hageltorn and Gustavsson, 1974; Eldridge, 1975; Gustavsson et al., 1976; Halnan, 1976).

Lin et al. (1977) developed a reliable trypsin Giemsa banding technique for producing clearly differentiated G-bands on bovine chromosomes which provided unequivocal identification of individual bovine chromosomes. A total of 310 bands were assigned in the bovine karyotype from the study conducted in the Simmental breed.

Potter et al. (1979) observed no difference in the G-banding pattern of the autosomes and sex chromosomes of Bos taurus and Bos indicus, except for the Y chromosome of Bos indicus. When the G-banded Y chromosomes of Bos taurus and Bos indicus were compared, both the centromeres and the proximal sections of the long arms stain darkly and the short arms of Bos indicus were significantly shorter than those of Bos taurus. They concluded that the degree of similarity of Giemsa banding of chromosomes of the two cattle types was not surprising as fertile progeny result from crossbreeding.

Pathak (1979) explained the rise of various banding techniques and found that for longitudinal differentiation of mammalian chromosomes one can use either G-banding or the Q-banding and if possible the R-banding technique.

Ford et al. (1980) in the International Conference on Standardisation of banded karyotypes of domestic animals numbered the chromosome pairs of cattle Bos taurus 1 to 29 in order of decreasing size with description of the X and Y chromosome coming last. The identifying features of the chromosomes were reported from the banding pattern.

The second international conference on standardisation of domestic animal karyotypes formulated the international system for cytogenetic nomenclature of domestic animals (ISCNDA, 1989).

The descriptions of the banded karyotypes of cattle Bos taurus were given. The numbering of regions and bands was based on the International System for Human Cytogenetic Nomenclature (ISCN, 1985). The schematic representations of chromosomes corresponded approximately to 410 G-bands. The number of regions and bands in each chromosome pair are presented in Table 1.

2.2 Biochemical polymorphism systems

Biochemical diversity popularly known as biochemical polymorphism is the occurrence of varieties attributed to biochemical differences which are under genetic control. Biochemical polymorphism can be used in describing the relations and origin of populations and the gene frequency

Table 1. The number of regions and G-bands in the different chromosome pairs of Bos taurus (ISCNDA, 1989)

Chromosome pair	No. of regions	No.of G-bands
1	4	21
2	4	20
3	3	15
4	3	19
5	3	15
6	3	17
7	2	13
8	2	16
9	2	17
10	3	17
11	2	14
12	2	11
13	2	11
14	2	15
15	2	13
16	2	12
17	2	11
18	2	11
19	2	10

Contd.

Table 1 (Contd.)

Chromosome pair	No. of regions	No.of G-bands
20	2	11
21	2	11
22	2	9
23	2	10
24	2	12
25	2	9
26	2	7
27	2	10
28	1	9
29	1	9
Xp	2	8
Xq	4	17
Yp	1	3
Yq	1	7

provides an index to the breed structure (Naik, 1975). The biochemical polymorphic genetic characters considered in the present study are haemoglobin and transferrin.

2.2.1 Haemoglobin

Haemoglobin, the oxygen carrying component of blood called as the respiratory protein belong to the class of heme proteins. They are conjugates of proteins with heme, an iron - porphyrin compound. The protein part of haemoglobin is called globin and consists of four polypeptide chains, each composed of about 140 animo acids. Various species differ in their haemoglobin structure. These differences are related to the variations in the amino acids of the globin part of the molecule.

Pauling et al. (1949) initiated the studies on haemoglobin and other protein variants, by employing paper electrophoresis.

Haemoglobin variation in cattle was first described by Cabannes and Serain (1955) with the use of paper electrophoresis. These workers found three haemoglobin phenotypes in Algerian cattle. Of the 80 Algerian cattle typed 64 had a single band, 15 had a second faster migrating component also and one possessed the faster component alone.

Genetically determined variability for bovine haemoglobins was first established in Algerian and Gir cattle. Two variants viz. Hb-A (slower) and Hb-B (faster) were recognised (Bangham, 1957).

Salisbury and Shreffler (1957) supported the theory of Bangham and designated the adult bovine haemoglobin types as Hb^A and Hb^B, the slow and fast moving types respectively. The variant which was found only in animals less than 80 days of age with a wide range of mobility and diffuse band was designated as foetal haemoglobin or Hb^F.

The occurrence of foetal haemoglobin in the foetus and new-born was also reported by Grimes et al. (1958). They studied the postnatal persistence and relationship of foetal haemoglobin with that of adult haemoglobin and could find that the variant Hb^F was replaced by Hb^A in Holstein Friesian, Brown Swiss and Ayreshire breeds but in Guernseys and Jerseys and disappearance was obscured by Hb^B. The Hb^F was found to have the electrophoretic mobility as that of Hb^B.

Bangham and Blumberg (1958) reported that Bovine Hb^B occurred only in Jersey, Guernsey and South Devon breeds of Britain and this was consistent with one of the suggested ancestral line of the Jersey breed i.e., from African breeds of cattle.

According to the observations of Lehmann and Rollinson (1958) Hb^A was relatively less frequent in the pure-bred zebu cattle in Africa than in other breeds.

A fourth type of haemoglobin avian Hb^C was reported by Vella (1958) in cattle of Bos indicus origin. The mobility of Hb^C was found to be in between Hb^A and Hb^B.

Shreffler and Salisbury (1959) studied the distribution and inheritance of haemoglobin variants in American cattle. The gene frequency estimated for HB^B was 0.33 for Jersey as compared to 0.116 and 0.117 for Guernsey and Brown-Swiss respectively. They pointed out the practical application of electrophoretic studies of the haemoglobin variants viz., parentage determination, tracing of breed origins and adaptation of phenotypes to climatic conditions.

The association of HB^B gene with Bos indicus led Lehmann (1959) to examine the haemoglobin of Indian Zebu Cattle. He found the gene frequencies of Hb^A and Hb^B to be equal in the Gir cattle and there was also an excess of heterozygous phenotypes. He also suggested that in Gir cattle natural selection favoured heterozyotes.

In a study on adaptation of zebu and British breeds of cattle to subtropical environments in relation to erythrocyte

characters Evans (1963) found that Hb^B was associated with tolerance to tropical climate.

The fifth variant Hb^D was observed by Efremov and Braend (1965) in cattle of African origin. This variant had a mobility slower than that of Hb^A and occurred either independently or in combination with Hb^A or Hb^B.

Work carried out in several breeds of Indian cattle by Naik and Sanghvi (1965) led to the discovery of a new but very rare haemoglobin type Hb - Khillari in the Khillari breeds of India (Malvi, Kankrej and Dangi).

Srivasthava (1965) reported that Hb^A occurred only in Holstein crosses and was absent in Jersey, Brown-Swiss and Sindhi crossbreds. The gene frequency for Hb^B was greater in cattle of Sindhi lineage than European crosses.

Balakrishnan and Nair (1966) conducted electrophoretic studies of haemoglobin in agar-gel tubes in Sindhi, Sahiwal and Tharparkar breeds. Though some breed differences could be noticed in the gene frequency of Hb^A and Hb^B alleles, they could find no significant difference with sex.

In a study of some African breeds of cattle like Muturu (West African dwarf short horn) and N'Dama, Braend *et al*. (1966) reported a new allele Hb^D in addition to Hb^A and

Hb^B. The gene frequency of Hb^D varied from 0.13 to 0.26 in different breeds while all the N'Dama animals were of Hb AA type.

Naik et al. (1969) reported a rare haemoglobin variant Hb^X which was similar to Hb^C with a low frequency in some Indian zebu cattle viz., Khillari, Rathi and Kumaoni Hill cattle.

Khanna et al. (1970) reported a new haemoglobin phenotype, Hb BC in Hariana cattle,in addition to BB, BA, CA and AA. Age and sex of animals were found to have no effect on the distribution of haemoglobin types in cattle.

Braend (1971) carried out a comparative study on all cattle haemoglobin variants reported till then. He concluded that the Hb^C reported by different workers in different breeds could be classified into three groups depending upon their electrophoretic mobility. He found a new haemoglobin variant, Hb^G in three of the 101 East African Zebu cattle with a gene frequency of 0.01. Its migration was slower than any cattle haemoglobin variant, previously reported.

Khanna et al. (1972) discovered a rare haemoglobin variant tentatively designated as Hb^E Muk, in four pure-bred Afghan cattle, six Afghan x Kumaoni crossbreds and one Afghan x Jersey crossbred adult lactating cow. The new variant was

not observed in pure Kumaoni cattle and in Red Sindhi and Sahiwal breeds.

Schwellnus and Guerin (1977) compared the Hb^C variant in Brahman and indigenous South African cattle breeds. They suggested that the fast moving variant in Brahman cattle be called Hb^C and the slower migrating type of South African breed be called as Hb^I.

A rare variant Hb^A Cuttack was found in an aged Red-Sindhi cow (Singh and Bhat, 1979).

Nandakumaran et al. (1979) observed three haemoglobin phenotypes Hb AA, Hb AB and Hb BB controlled by two alleles Hb^A and Hb^B in Hariana crossbreds. No significant differences could be noticed between different populations with respect to gene frequencies. They also reported that the population was in agreement with the observed and expected phenotype frequencies.

Haemoglobin polymorphism among 23 different herds belonging to pure bred and crossbred Indian cattle (Singh and Bhat, 1980a, 1980b) revealed a trend to increase in heterozygosity in crossbred cattle over the respective parental population.

Starch gel electrophoresis for haemoglobin polymorphism in three grey cattle breeds of India carried out by Singh and Bhagi (1981) revealed good agreement between observed and expected values of genotype frequencies. The results obtained were comparable to that of earlier reports in Hariana breed. They observed a very high frequency of heterozygote phenotype which was attributed to the adaptation of heterozygotes towards some environmental factors.

Studies by Singh et al. (1981) on the average heterozygocity at haemoglobin locus for pure breds and crossbreds revealed that the same was only 19.6 to 33.6 per cent in pure breds as compared to 35.3 to 42.7 per cent in corssbreds.

Nandakumaran et al. (1982) estimated the genetic variability in four crossbred populations using gene frequencies at six polymorphic loci. The heterozygocity observed in the four populations at the haemoglobin locus was 0.3956 (Holstein x Hariana), 0.4401 (Brown-Swiss x Hariana), 0.4873 (Jersey x Hariana) and 0.3787 (pooled crossbreds having 3/4 exotic blood).

Shanker and Bhatia (1982) observed three haemoglobin alleles (Hb^A, Hb^B and Hb^C) with five different genotypes viz., Hb AA, Hb AB, Hb BB, HB AC and Hb BC in Sahiwal and Jersey

cattle. The genotype frequency in most of the breeds was highest for Hb AA followed by Hb AB and Hb BB. Tharparkar, Red-Sindhi and Holstein-Friesian breeds had only two alleles viz. Hb^A and Hb^B.

In the Friesian herds in India, Singh et al. (1983) observed relatively higher frequency of Hb AB genotype. The high incidence of Hb^A allele was consistent with earlier reports on Friesian herds. The low incidence of Hb AB observed in the military farm, Meerut was attributed to the low diffusion of zebu genes among Friesians.

Singh and Bhat (1983) reported significant differences between breeds and between herds within breeds for the gene frequencies of alleles at haemoglobin locus in breeds such as Gir, Hariana, Kangayam, Kankrej, Ongole, Red-Sindhi, Sahiwal and Tharparkar.

Polymorphic studies in Bali cattle by Bell et al. (1990) revealed a second variant Hb^C Bali in addition to the B variant. This new variant occurred in Bali cattle either as homozygotes or heterozygotes, the mobility of which was intermediate between those of the common A and B variants but closer to B. This appeared to be similar to the variant C of Khillari and C of Asian cattle, differing from those of Kenyan cattle, Rhodesian cattle and Mithun.

Electrophoretic studies on haemoglobin locus in different breeds of Indian and exotic cattle by several workers revealed differences in gene frequencies of the haemoglobin alleles between herds and between breeds (Table 2).

2.2.2 Transferrin

Transferrin (Tf) is a β_1-globulin of approximate MW 80000. It is a glycoprotein and is synthesised in the liver. More than 20 polymorphic forms of Transferrin have been found. It plays a central role in the body's metabolism of iron because it transports iron (2 moles of Fe^{3+} per mole of Tf) in the circulation to the sites where iron is required. Each transferrin molecule consisted of two similar polypetide chains either of which contains a functionally identical metal binding site (Efremov et al., 1971).

The existence of gene determined transferrin polymorphism with 3 variants viz., Tf - A, Tf - D and Tf - E was established by Ashton (1957) by starch electrophoresis.

Genetically controlled differences were reported in the B - globulins of British breeds of dairy cattle by Smithies and Hickman (1958) and Ashton (1958). Giblett et al. (1959) had shown that these globulins were transferrins, the iron binding proteins. In the original studies a number of

Table 2. Haemoglobin gene frequencies in different cattle breeds

Author(s)	Breeds of cattle	Hb^A	Hb^B	Hb^C	Other variants
Naik et al. (1963)	Jersey	0.556	0.444		
Sen et al. (1966)	Hariana	0.578	0.422		
	Deshi	0.705	0.295		
	Gir	0.569	0.431		
	Tharparkar	0.700	0.300		
	Sahiwal	0.625	0.375		
	Red Sindhi	0.824	0.176		
Balakrishnan and Nair (1966)	Red Sindhi	0.700	0.300		
	Sahiwal	0.707	0.293		
	Tharparkar	0.897	0.103		
Naik et al. (1969)	Malvi	0.543	0.454	0.003	
	Khillari	0.518	0.478	0.002	Hb Khillari 0.001
	Dangi	0.512	0.485	0.003	
	Gir	0.509	0.491		
	Kankrej	0.587	0.410	0.003	
	Rath	0.581	0.412	0.007	
	Kumaoni	0.735	0.244	0.021	
Khanna et al. (1970)	Hariana	0.430	0.570		

Contd.

Table 2 (Contd.)

Author(s)	Breeds of cattle	Hb^A	Hb^B	Hb^C	Other variants
Singh and Khanna (1971)	Hariana	0.538	0.462		
	Hariana x HF	0.796	0.204		
	Hariana x Jersey F_1	0.586	0.414		
	Hariana x Jersey F_2	0.658	0.342		
Singh *et al.* (1972)	Ongole	0.780	0.220		
	Hariana	0.380	0.620		
	Kankrej	0.440	0.560		
	Gir	0.450	0.550		
	Sahiwal	0.570	0.430		
	Rath	0.730	0.270		
Singh and Khanna (1973)	Kumaoni	0.708	0.276	0.016	
Singh and Bhat (1979)	Indian Zebu Cattle	0.625	0.375		
	½ Friesian Crossbred	0.787	0.213		
	3/4 triesian Crossbred	0.886	0.114		
	Friesian	1.000			
Nandakumaran *et al.* (1979)	Hariana Crossbreds	0.580-746	0.245-0.420		

Contd.

Table 2 (Contd.)

Author(s)	Breeds of cattle	Hb^A	Hb^B	Hb^C	Other variants
Singh and Bhat (1980 a&b)	Hariana	0.429	0.571		
	Sahiwal	0.807	0.193		
	Friesian	1.000			
	Kankrej	0.619	0.381		
	Ongole	0.750	0.250		
	Red Sindhi	0.557	0.443		
	Kangayan	0.645	0.355		
	Gir	0.530	0.470		
	Tharparkar	0.731	0.269		
Singh and Bhagi (1981)	Hariana	0.479	0.521		
	Malvi	0.693	0.310		
	Naguri	0.521	0.479		
Shankar and Bhatia (1982)	Sahiwal	0.748	0.249	0.003	
	Tarparkar	0.859	0.141		
	Red Sindhi	0.702	0.298		
	Holstein Friesian	0.900	0.100		
	Jersey	0.548	0.404	0.480	
Han and Lee (1982)	Korean Cattle	0.890	0.077	0.014	

Contd.

Table 2 (Contd.)

Author(s)	Breeds of cattle	Hb^A	Hb^B	Hb^C	Other variants
	Holstein Friesian	1.000			
Singh et al. (1983)	Friesian	1.000			
Khanna and Tandon (1987)	Mithun		0.040	0.960	
	Mithun hybrid with cattle	0.400	0.130	0.470	
	Local zebu cattle	0.810	0.190		
	Local zebu x exotic (crossbred cattle)	0.750	0.250		
	Pooled crossbred (Hariana x Exotic)	0.710	0.290		
Al-Timemi and Al-Murrani (1990)	Sharabi (Iraq)	0.640	0.460		
	Holstein	1.000			
John (1992)	Holstein Friesian crossbred	0.83	0.17		
	Jersey crossbred	0.67	0.33		
	Brown Swiss	0.66	0.34		

different transferrin phenotypes, observed by the technique of starch gel electrophoresis were reported. These were explained by the action of three allelic genes, Tf^A, Tf^D and Tf^E. Each transferrin type was migrating in the starch gels as four protein band pattern (Ashton, 1959a). In another publication, Ashton (1959b) reported that the cattle transferrins were controlled by five allelic genes called Tf^A, Tf^B, Tf^D, Tf^E and Tf^F in the order of decreasing mobility in starch gel electrophoresis. The variations in the frequency of these alleles proved to be quite informative about breed origin, structure and relationships. The Tf^B and Tf^F alleles were confirmed to the Zebu cattle, Tf^E allele was absent in Jersey, Guernsey and South Devon breeds while Tf^E allele occurred rarely in most of the other European breeds. This allele had, however, a high frequency in the Zebu cattle.

Improved techniques based upon discontinuous buffer system made further distinctions possible between transferrin phenotypes (Kristjansson, 1962). The transferrin bands previously assigned to the action of one allele Tf^D were subdivided and explained by two genes. This report presented evidence which indicated that the band pattern of Tf^D allele could be sub-divided into two types controlled by two alleles which produce different transferrin bands. These were indistinquishable when the original starch

gel elctrophoresis procedures were employed. These variants were called as Tf^{d1} and Tf^{d2} by Jamieson (1965).

Braend and Khanna (1967) described a rare transferrin phenotype Tf N in the Norwegian cattle.

The transferrin types Tf^{B} and Tf^{F} have so far been reported in African and Indian cattle by (Ashton, 1959b; Osterhoff and Van Heerden, 1965; Ashton and Lampkin, 1965a,b; Braend and Khanna, 1968). These transferrin genes have not been found in Bos taurus. The frequency of Tf^{E} allele was quite high in the Indian cattle as compared to the American and European cattle in which it was found to range from nil to very low frequency (Jamieson, 1965).

Osterhoff and Van Heerden (1965) described an additional transferrin allele called Tf^{G}. Sartore and Bernoco (1966) reported an allele called Tf^{H} having the fastest mobility.

At least a series of 10 codominant autosomal alleles at transferrin locus have been described (Jamieson, 1965; Braend and Khanna, 1967; Bouw and Oosterlee, 1969). These are Tf^{H}, Tf^{A1}, Tf^{A2}, Tf^{B}, Tf^{D1}, Tf^{D2}, Tf^{F}, Tf^{N}, Tf^{E} and Tf^{G} in order of decreasing mobility in the starch gel at alkaline pH.

Singh et al. (1972) reported 22 phenotypes representing combinations of the Tf^{A1}, Tf^{A2}, Tf^{B}, Tf^{D1}, Tf^{D2}, Tf^{E}, Tf^{F}, and Tf^{G} in four Indian cattle breeds viz., Hariana, Ongole, Gir and Kankrej. In this study Tf^{F} and Tf^{E} were found to be the most frequent allele in all the four breeds, followed by Tf^{A2}, Tf^{D2}, Tf^{B} and Tf^{G}.

Sixteen transferrin phenotypes controlled by six alleles Tf^{A}, Tf^{B}, Tf^{D1}, Tf^{D2}, Tf^{F} and Tf^{E} in order of decreasing mobility towards anode were observed in Hariana crossbreds (Nandakumaran, 1976).

Singh (1978) confirmed a rare occurrence of Tf^{A1} and Tf^{G} alleles among different indigenous breeds.

Komissarenko (1979) found 6 transferrin types in Ayreshire cows and were typed as DD (46.3%), AD (23.64%), AA (16.5%), DE (6.65%), AE and EE (3-4%). The number of homozygotes (66.74 per cent) prevailed over the heterozygotes.

Singh and Bhat (1981a) studied phylogenetic relationship between 8 Indian cattle breeds on the basis of biochemical polymorphic alleles. The results indicated a closeness of short-horned grey cattle breeds viz., Hariana, Tharparkar and Ongole while Karkrej stood distinctly different from them.

The gene frequencies of different Zebu breeds studied are furnished in the Table 3 (Singh and Bhat, 1981b).

Prasad et al. (1983) reported six allelic genes Tf^{A}, Tf^{B}, Tf^{D1}, Tf^{D2}, Tf^{E} and Tf^{F} in order of decreasing mobility. The alleles Tf^{B} and Tf^{F} were confined to Zebu breeds and Tf^{E} is absent in Bos taurus animals, but its frequency was high in zebu. The frequency of Tf^{B} allele was low in all the breeds studied. It was suggested that Tf^{E} might be associated with tolerance and climatic extremes.

Ashok Singh et al. (1989) observed ten transferrin phenotypes viz., AA, DD, EE, AD, AB, DF FB, BE AF and DE controlled by five transferrin alleles Tf^{A}, Tf^{B}, Tf^{D}, Tf^{F} and Tf^{E}. In Sahiwal, Tf^{E} and Tf^{D} were most frequent whereas in crossbreds Tf^{A} and Tf^{D} were most frequent followed by the other three alleles.

Ashok Singh and Choudhari (1989) reported that seven transferrin allelomorphic variants Tf^{A}, Tf^{B}, Tf^{D1}, Tf^{D2}, Tf^{F}, Tf^{E} and Tf^{G} in the order of decreasing mobility were observed so far in Indian cattle breeds.

2.3 Growth studies

Body weight and measurements give an indication of the

Table 3. Gene frequencies of transferrin alleles, in different types of zebu cattle

Tf System	Breeds of cattle							
	Gir	Hariana	Kankrej	Kangayam	Ongole	Red Sindhi	Sahiwal	Tharparkar
Tf^{A}	0.138to 0.220	0.085to 0.179	0.201to 0.205	0.066	0.115to 0.171	0.016to 0.156	0.020to 0.318	0.253to 0.410
Tf^{B}	0.002to 0.020	0.000to 0.051	0.000to 0.018	0.040	0.004to 0.020	0.016	0.000to 0.896	0.000to 0.033
Tf^{D1}	0.000to 0.015	0.000to 0.025	0.000	0.000	0.000	0.000	0.000to 0.061	0.000
Tf^{D2}	0.030to 0.091	0.013to 0.127	0.009to 0.057	0.000	0.004to 0.015	0.009	0.000to 0.133	0.000to 0.022
Tf^{F}	0.450to 0.495	0.384to 0.410	0.154to 0.491	0.536	0.364to 0.399	0.435	0.695to 0.375	0.423
Tf^{E}	0.265to 0.271	0.289to 0.428	0.226to 0.629	0.349	0.414to 0.427	0.382	0.339to 0.660	0.266to 0.340

adult performance and hence it is very important in the economy of dairy cattle production.

Study of growth rate of 145 Hariana calves of first calvings by Kohli et al. (1962) revealed that male calves were heavier than females at birth. There was an increase of 100 per cent, 150 per cent and 200 per cent over the birth weight at the age of 3, 6 and 9 months respectively irrespective of the sex of calves. The age of the calf had significant effect on the weight of the calves.

The growth rate of Red Sindhi male and female calves maintained at N.D.R.I., Karnal was studied by Mudgal and Ray (1966). The birth weight of male and female calves were 21.14 ± 2.16 kg and 20.07 ± 2.19 kg respectively. The coefficient of regression of growth from birth to 6 months per fortnight was 6.43 ± 1.48 kg in male and 5.17 ± 1.20 kg in female calves. A greater reduction was observed in growth rate from 7 to 12 months of age. Irrespective of age group the male calves gained a higher rate than female calves.

Taneja and Bhat (1971) studied the growth rate of Sahiwal females maintained at Military dairy farms. The growth rate was slow from birth to 19th week (0.458 kg/day when compared to that from 19th to 26th week (0.526 kg/day). The average daily gain from 27th to 52 week was 0.411 kg.

The growth rate of Hariana female calves in relation to the birth weight and season of birth was analysed by Agarwal and Tomar (1972). The growth rate was maximum upto 6 months of age, thereafter the general trend in growth declined. The growth rate observed at 6, 12, 18 and 24 months of age varied significantly. The season of birth has no significant effect on growth rate.

Chawla and Mishra (1981) concluded from a study conducted in 689 Sahiwal, 639 Brown-Swiss x Sahiwal and 3802 Holstein Friesian x Sahiwal to find out the role of exotic genes on growth rate of zebu crosses that body weights at various intervals of age had relationship with the increase of HF inheritance from 1/8 to 7/8 except at birth and at 2 months of age where it was linear. Crossbreds with various levels of Brown-Swiss and Holstein Friesian inheritance showed maximum growth rate during 4 to 6 months of age.

The growth rate of different crossbred calves i.e., Holstein Friesian (HF) x Deoni, HF x Rath and HF x (Deoni x Gir) were studied by Kulkarni et al. (1982). The mean growth rate at 3, 6, 9 and 12 months of age were 0.50, 0.4, 0.44 and 0.40 kg for 82 males and 0.46, 0.44, 0.42 and 0.40 kg for females. The effect of sire, breed of dam, sex and pregnancy duration (duration of intrauterine life on animals under study) on growth rates were significant.

Srivasthava et al. (1986) analysed the factors affecting body weight and measurements at birth in three breed croses. The birth weight averaged 28.23, 25.54, 29.75 and 24.28 kg respectively in H.F. (B.S. x Hariana), H.F. x (J x Hariana), B.S. x (H.F. x Hariana and J.H.F. x Hariana). Heights at withers were 68.61, 68.35, 69.06 and 66.14 cms and body length averaged 69.73, 68.42, 70.80 and 65.83 cms respectively in the four groups. Birth weight was significantly correlated with the body measurements.

The non-genetic and genetic factors affecting birth weight and linear body measurements in Jersey x Gir F2 calves at birth were studied by Ashok Singh and Parekh (1986). The mean birth weight (in kg) and body measurements such as length height and heart girth and paunch girth (in cm) at birth were 24.19 $\pm$ 0.25, 59.27 $\pm$ 0.66, 67.24 $\pm$ 0.25, 67.55 $\pm$ 0.24 and 68.17 $\pm$ 0.30 respectively. The season, year, parity, sire and sex had highly significant effect on the birth weight, length, height and heart girth, while season, year, sire and sex did not affect paunch girth and parity and sire, the body weight.

The averages of adult body weights and body measurements of the recognised Indian breeds of cattle (Dairy India, 1987) are presented in Table 4.

Table 4. The adult body weights and measurements of Indian breeds of cattle

Breed		Weight	Body measurements (Metres)		
			Height	Length	Girth
AMRITMAHAL	M	498.9	1.3	1.5	1.9
	F	317.5	1.3	1.3	1.7
BACHAUR	M	385.5	1.4	1.2	1.8
	F	317.5	1.0	1.2	1.7
BARGUR	M	340.0	1.2	1.4	1.8
	F	295.0	1.0	1.3	1.7
DANGI	M	362.9	1.3	1.4	1.5
	F				
DEONI	M	589.7	1.5	1.7	2.0
	F	340.2	1.3	1.5	1.7
GAOLAO	M	431.0	1.5	1.2	1.9
	F	340.2	1.3	1.3	1.7
GIR	M	544.0	1.4	1.5	1.8
	F	385.5	1.3	1.7	1.7
HALLIKAR	M	453.5	1.4	1.5	1.7
HARIANA	M	499.0	1.4	1.5	2.0
	F	-	-	-	-
KANGAYAM	M	317.5	1.4	1.0	1.9
	F	294.8	1.4	1.4	1.7
KANKREJ	M	589.6	1.6	1.6	2.0
	F	430.9	1.3	1.4	1.8
KENKATHA	M	344.5	1.3	1.2	1.8
KHERIGARH	M	476.0	1.3	1.2	1.8
	F	317.5	1.3	1.3	1.5

Contd.

Table 4 (Contd.)

Breed		Weight	Body measurements (Metres)		
			Height	Length	Girth
KHILLARI	M	499.0	1.4	1.4	2.0
	F	344.0	1.3	1.1	1.7
KRISHNA VALLEY	M	499.0	1.5	1.5	1.9
	F	340.2	1.2	1.3	1.5
MALVI	M	499.0	1.4	1.5	2.0
	F	340.2	1.3	1.4	1.7
MEWATI (KOSI)	M	385.6	1.6	1.8	1.9
	F	326.6	1.2	1.3	1.6
NAGORI	M	408.0	1.5	1.5	2.0
	F	340.0	1.4	1.3	1.9
NIMARI	M	390.0	1.6	1.8	1.8
	F	317.5	1.4	1.3	1.6
ONGOLE	M	567.6	1.5	1.6	2.1
	F	431.0	1.3	1.1	1.8
PONWAR	M	317.5	1.4	1.4	1.6
	F	294.8	1.3	1.3	1.6
RATHI	M	385.5	1.5	1.5	2.0
	F	326.6	1.2	1.4	1.5
RED SINDHI	M	454.0	1.3	1.4	1.8
	F	317.0	1.2	1.4	1.4
SAHIWAL	M	544.0	1.7	1.5	1.9
	F	408.3	1.3	1.4	1.7
SIRI	M	453.5	1.3	1.5	1.9
	F	362.9	1.2	1.3	1.8
THARPARKAR	M	544.3	1.3	1.4	1.9
	F	340.2	1.2	1.3	1.5

Dhangar and Patel (1990a) studied the growth performance of intersomated Jersey x Kankrej half bred calves upto six months of age. The overall body weight gain during birth to 4 months and 4-6 months were 376.99 ± 9.2 and 517.06 ± 16.79 g/day respectively. The association between birth to 4 and birth-6 months was significant. The birth weight did not contribute towards daily gain from birth to 6 months period. Season significantly influenced body weight gain of calves. Relative gainwas maximum during 5-12 week period.

Dhangar and Patel (1990b) attempted to generate prediction equations for estimation of body weight from different body measurements. For birth weight, prediction equation with body length gave the highest accuracy (R^2 = 74.72%). The prediction equation with heart girth along with body length/height at withers covered variation to the extent of 75.12-80% for body weight at 4 and 6 months of age. Both the linear and exponential equation covered equal variation to predict growth rate of calves.

2.4 Production performance

The milk production performance of the Indian cattle and the crossbreds were studied extensively. The performance of Brown Swiss crossbreds maintained at the Indo Swiss Project, Madupetty was reported by Nair (1973) as 1958.0 ±

53.4 kg. Katpatal (1977) reported a 305 day lactation milk yield of 1411 kg for Jersey crossbreds. Nair and Kelath (1977) studied the first lactation yield of Brown Swiss x Zebu crossbreds maintained at the farmers' homesteads and found it to be 1611.40 ± 12.79 l.

Girija and Nair (1984) studied the lactation and peak yield in crossbred cows of the three livestock farms of Kerala Agricultural University. The total lactation yields in Jersey and Brown Swiss Crossbreds were 1673.66 ± 49.97 kg and 1979.73 ± 101.78 kg respectively. The lactation period in Jersey crossbreds was 423.4 ± 29.58 days and that for Brown Swiss crossbreds was 349.7 ± 10.64 days. The Jersey x Zebu crossbreds attained peak yield by 44.75 ± 1.23 days and the Brown Swiss x Zebu crossbreds by 49.86 ± 3.06 days. The mean peak yields were 7.91 ± 0.15 kg and 7.70 ± 0.31 kg in Jersey and Brown Swiss crossbreds respectively. There were highly significant correlations between peak yield and total lactation yield.

The average first lactation 305 day milk yield for Brown Swiss crosses was 1445.5 ± 77.9 kg (Iype et al., 1985).

Stephen et al. (1985) found the first lactation milk yield for 305 days in Jersey half breds as 1359.2 ± 57.4 kg and Brown Swiss half breds as 1482 ± 19.7 kg.

The production parameters in Indian cattle and crossbreds (Dairy India, 1987) are presented in Table 5.

Iype et al. (1993) reported the 305 day lactation milk yield of 1479.5 ± 10.3 l predicted on the basis of milk recording at fortnightly intervals in cross bred cattle of Trichur district in Kerala.

Table 5. The lactation yield and lactation length of Indian cattle and crossbreds

Breed	lactation yield (kg)	Lactation length (days)
Indian breeds		
Devangi	615.9 ± 34.9	292.5 ± 11.5
Deogir	1423.1 ± 60.5	313.2 ± 08.7
Deoni	879.2 ± 23.6	270.0 ± 04.6
Gir	1403.0 ± 31.1	257.4 ± 0.46
Gaolao	534.5 ± 15.2	295.2 ± 05.2
Hallikar	541.9 ± 61.1	285.1 ± 10.1
Hariana	1136.7 ± 34.0	232.5 ± 04.3
Kangayam	643.6 ± 10.5	212.0 ± 30.0
Kankrej	1850.0 ± 51.4	351.0 ± 08.0
Khilari	214.7 ± 12.2	255.0 ± 03.1
Ongole	613.1 ± 60.5	217.0 ± 08.9
Rathi	1931.0 ± 53.0	331.0 ± 04.2
Red Sindhi	1605.0 ± 24.7	284.0 ± 02.4
Sahiwal	1718.7 ± 36.0	283.5 ± 01.8
Tharparkar	1659.2 ± 53.3	280.1 ± 06.0
Umblachery	323.9 ± 18.5	233.7 ± 09.1
Non-descript	534.7 ± 14.3	303.0 ± 06.2

Contd.

Table 5 (Contd.)

Breed	lactation yield (kg)	Lactation length (days)
Crossbred cattle (Bos indicus F x Bos taurus M)		
H x F	3195.5 ± 205.0	340.0 ± 05.1
H x BS	2785.5 ± 163.2	336.0 ± 24.5
H x J	2868.0 ± 215.5	308.0 ± 04.2
G x J	2713.0 ± 225.5	326.0 ± 06.2
G x F	2254.5 ± 097.5	288.2 ± 06.0
RS x F	2326.2 ± 094.3	283.8 ± 08.3
RS x RD	2213.8 ± 115.5	267.0 ± 09.4
RS x J	1501.7 ± 082.3	305.8 ± 07.2
R x J	2801.6 ± 096.4	321.0 ± 08.4
T x F	1501.7 ± 049.5	311.1 ± 17.8
S x F	2801.6 ± 020.0	294.6 ± 05.1
S x J	2600.0 ± 029.0	314.0 ± 16.8
J x BS	2188.0 ± 607.0	292.0 ± 12.9
L x J	1151.0 ± 045.0	328.6 ± 04.0

Materials and Methods

MATERIALS AND METHODS

The local dwarf cattle maintained under the ICAR scheme on "Conservation of germplasm of Vechur cattle of the coastal area and the dwarf cattle of the high ranges of Kerala" formed the material for the present study (Fig.1-5).

3.1 Cytogenetic studies

3.1.1 Karyotype and morphology

The Karyotype analysis was carried out using peripheral blood leucocyte culture technique described by Halnan (1977) and Halnan (1989) with suitable modifications.

Culture medium

The basal medium used for lymphocyte culture was RPMl-1640 (SIGMA). The composition of the medium is as follows.

RPMl 1640	-	1 g
Sodium bicarbonate (3.5 per cent)	-	1.06 ml
Penicillin (10,000 IU/ml)	-	0.25 ml
Phytohemagglutinin solution (2000 ug/ml) - SIGMA	-	0.75 ml
Double distilled water (autoclaved) upto	-	100 ml

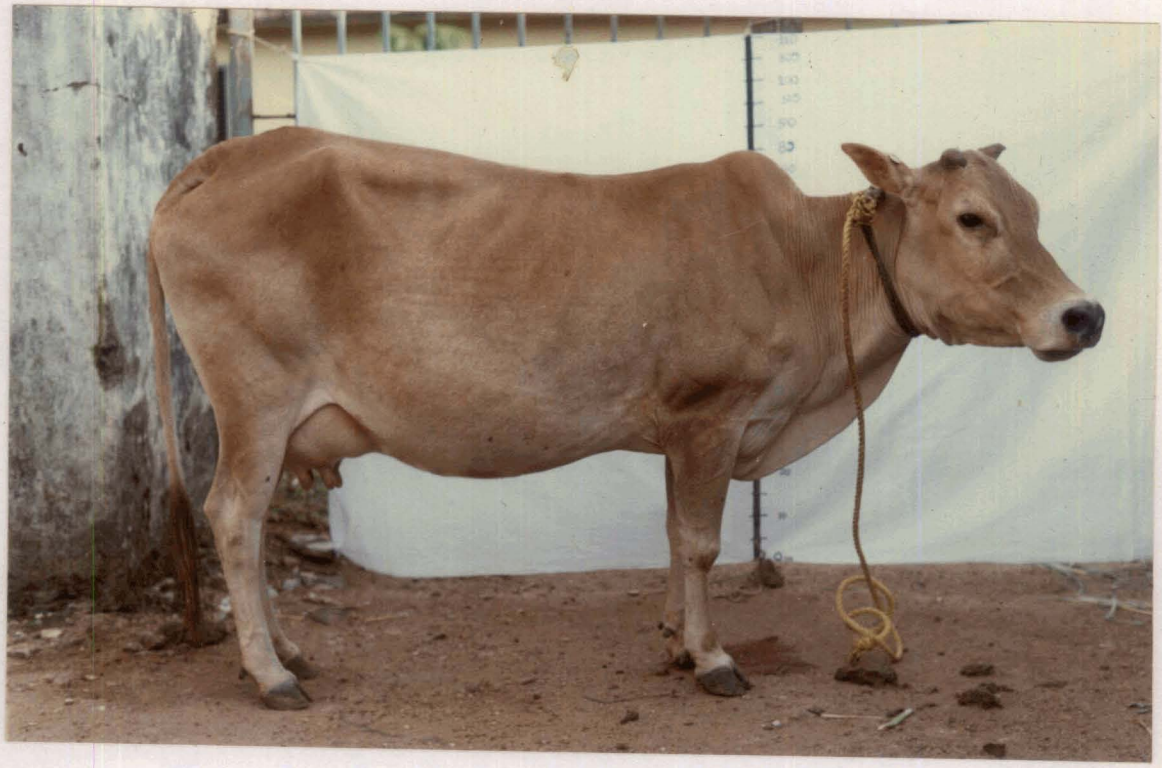

Fig.2. Adult male dwarf cattle

Fig.3. Female calf of dwarf cattle

Fig.4. Male calf of dwarf cattle

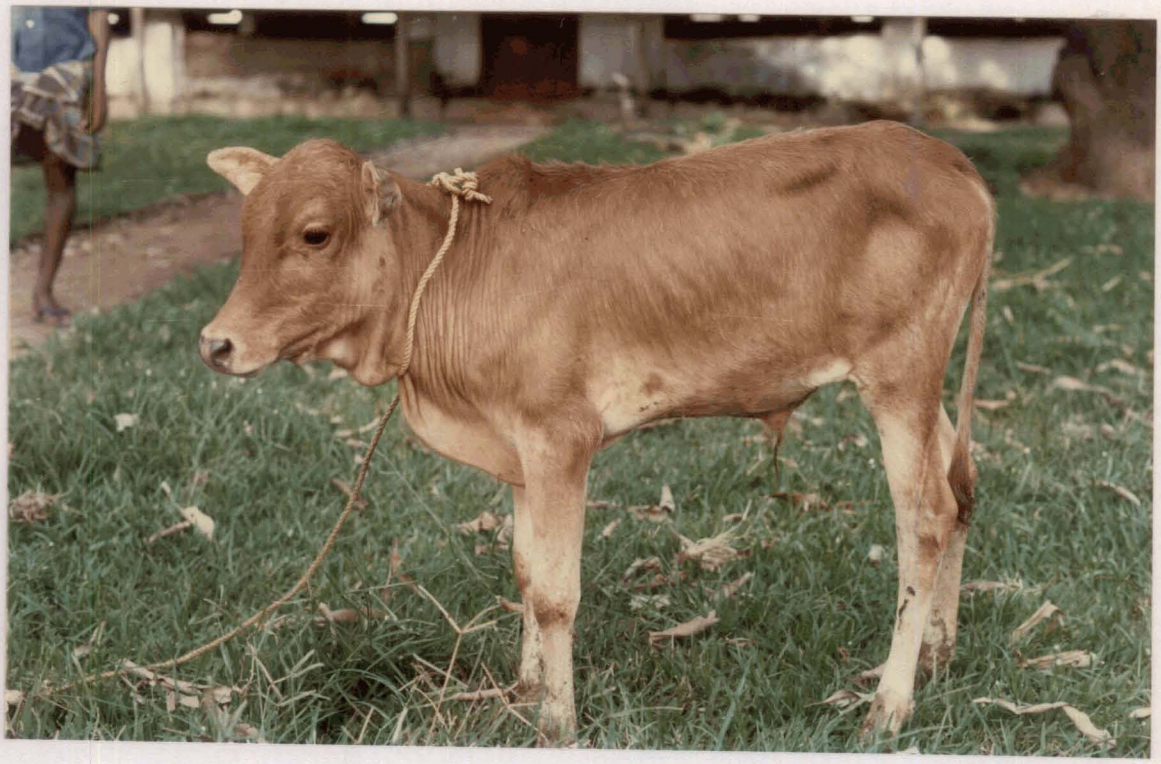

Fig.5. A herd of dwarf cattle

Into the culture vial containing 5 ml of the medium and 2 ml of autologous plasma, 0.7 ml of whole blood was added and incubated at 37°C for 70 hours. At the 70th hour of incubation 0.05 ml of Colchicine solution (10 ug/ml), was added as a mitotic arrester and the incubation was continued for 45 minutes. Hypotonic treatment with prewarmed KCl solution (0.075 M) was performed for swelling the cells with subsequent dispersion of chromosomes. Fixation of the cells was done using freshly prepared fixative containing methanol and acetic acid (3:1). Slides of metaphase spreads were prepared and stained with Giemsa (4%).

Karyotypes were prepared and the morphology of each chromosome was studied. The morphometric studies included relative length, arm ratio and centromeric index. The measurements were taken as per the Denver conference in 1960 on human chromosomes. The length of chromosomes in the karyotype was measured using a set of calipers with fine points.

The size of the chromosome was represented as the relative length. It is the ratio of the length of the chromosome to the total length of the haploid set of chromosomes containing the X chromosome.

$$\text{Arm ratio} = \frac{\text{Length of the long arm}}{\text{Length of the short arm}} = \frac{q}{p}$$

$$\text{Centromeric index} = \frac{\text{Length of the short arm}}{\text{Total length}} = \frac{p}{p+q}$$

3.1.2 G-banding

The G-banding technique used was the one described by Thiagarajan (1993) which was a combination of the techniques of Sumner et al. (1971) and Seabright (1971).

3.2 Biochemical polymorphism

3.2.1 Haemoglobin

Haemoglobin polymorphism was studied by polyacrylamide gel electrophoresis (Gahne et al., 1977) with suitable modifications.

Buffers and solutions

(a) Composition of the electrode buffer

Tris	-	40.4 g
EDTA	-	4.0 g
Boric acid	-	3.0 g
Distilled water	-	ad - 2 L
pH	-	8.9

(b) Acrylamide stock solution (A)

Acrylamide (SISCO)	-	32 g
N^1 - N^1methylene bisacrylamide (Sisco)	-	0.8 g
Distilled water	-	100 ml

(c) Gel buffer stock solution (B)

To 12.5 ml of 1.5 M Tris solution(2.27 g of tris hydroxy methyl amino methane in 12.5 ml distilled water) was added 11.25 ml of distilled water, 0.075 ml of NNNN tetra methylane diamine (TEMED) and 0.04 ml of β mercapto ethanol. The pH was adjusted to 8.3 with conc. H_2SO_4 and the final volume was adjusted to 25 ml with distilled water.

(d) Ammonium per sulphate (C)

Ammonium per sulphate 100 g was dissolved in 50 ml distilled water.

The above solutions were prepared and used on the same day.

Working gel solution

The working gel solution was prepared at the time of use and the composition of the solution was as follows:

Acrylamide (A)	- 6.64 ml
Gel buffer (B)	- 5.32 ml
Distilled water	- 4.00 ml
TEMED	- 0.03 ml
Ammonium per sulphate (C)	- 5.32 ml

(e) Fixing solution

Methanol	- 250 ml
Acetic acid	- 60 ml
Distilled water	- 1000 ml

(f) Staining solution

Coomassie brilliant blue R 250	- 1.25 g
Methanol	- 227 ml
Glacial acetic acid	- 46 ml
Distilled water	- 227 ml

The dye was dissolved in the solution of methanol and distilled water. Acetic acid was then added and stored in dark bottles.

(g) Destaining solution

Ethanol	- 1500 ml
Acetic acid	- 500 ml
Distilled water	- 5000 ml

(h) Preserving solution

Ethanol	- 300 ml
Acetic acid	- 100 ml

Glycerol - 100 ml

Distilled water to make up 1000 ml

The working gel solution was prepared just before use with addition of ammonium per sulphate at the last. After mixing, the solution was poured into the cell through the funnel at the top. Air bubbles if any were removed by tapping. Polymerisation reaction was completed in 30 minutes.

Twenty microlitres of each sample was charged into the slots made on the gel, using a micro syringe as quickly as possible to avoid diffusion of the initial samples.

The samples were subjected to electrophoresis at 250 v at 15 mA. Once a clear separation of the protein variants was observed which usually occurred within 1½ to 2 hours, the electrophoresis was discontinued.

Gel fixation and staining

The gel was then transferred to the fixative and kept in the fixing solution for one or two hours. This avoids loss of soluble proteins and minimises the diffusion. The gel was kept in the staining solution for two hours.

Destaining

The gel was then transferred to the destaining solution and kept 3 to 4 hours. The solution was frequently

changed until the bandless portion of the gel become colourless.

The gels were preserved in the preserving solution for sufficiently long duration.

The genotype and gene frequencies were estimated by direct counting method.

The heterozygocity at haemoglobin locus was estimated as per the method described by Nei and Roy Choudhari (1974).

The population was tested for genetic equilibrium at the haemoglobin locus by employing X^2 test of significance.

3.2.2 Transferrin

Transferrin polymorphism was also studied by polyacrylamide gel electrophoresis as described by Gahne et al. (1977). These gels allowed the simultaneous phenotyping of transferrin, post transferrin albumin and post albumin in the blood serum of cattle. The method was similar to that for haemoglobin except for the differences in the composition of the solutions used. The serum separated from the blood was used for the elctrophoresis.

(a) Composition of the electrode buffer

Tris	- 16 g
Boric acid	- 4 g
Distilled water	- 2000 ml

(b) Acrylamide stock solution for 12 gels (Solution A)

Acrylamide	- 160 g
Bisacrylamide	- 4 g

Dissolved in 350 ml distilled water and made up the volume to 500 ml and filtered using Whatman filter paper No.54.

(c) Gel buffer stock solution (Solution B)

Stock Tris	- 45 g	Tris in 250 ml distilled water
Stock citric acid	- 10 g	citric acid in 250 ml distilled water

Twenty ml of stock tris, 200 ml stock citric acid and 1.2 ml TEMED and 400 ml of B mercaptoethanol were mixed.

(d) Ammonium per sulphate (Solution C)

0.8 g of ammonium per sulphate dissolved in 400 ml distilled water.

Casting of gels

The quantity of solutions required for the different layers of the gel are given in Table 6.

Table 6. The quantity of solutions required for the different layers of the gel.

Solutions	I layer 12% (3 gels)	II layer 6% (12 gels)	III layer 8% (12 gels
Distilled water	28 ml	100 ml	45 ml
Solution A	84 ml	45 ml	30 ml
Solution B	56 ml	35 ml	15 ml
Solution C	56 ml	60 ml	30 ml
TEMED	--	60 ul	60 ul

Twenty microlitres of serum was filled in the slots and electrophoresis was done as in the case of haemoglobin at 20 mA and voltage was adjusted to 250 v. Total time for electrophoresis was 6 hours. Gel fixation, staining, destaining and preservation of gels were done as in the case of haemoglobin.

The frequency of different alleles and genotypes were studied as in the case of haemoglobin.

3.3 Growth studies

The body weight and measurements such as length, chest girth and height were taken for all the adult animals. The birth weight and body measurements and subsequent fortnightly body weights and measurements of the calves upto one year of age were recorded. The averages of these values separately and for the four periods i.e. fortnights 0-6, 7-12, 13-18 and 19-24 were estimated and statistical analysis of the data was done by the method suggested by Snedecor and Cochran (1967). From the fortnightly averages on body weights and measurements graphs were plotted. The average daily weight gain was calculated.

3.4 Production performance

Weekly morning and evening milk yields were recorded. The averages of the weekly yields were taken and graph was plotted. The averages of the total lactation yield, lactation length, daily yield, peak yield and days to attain peak yield were calculated (Snedecor and Cochran, 1967).

Results

RESULTS

4.1 Cytogenetic studies

4.1.1 Chromosome number and morphology

The metaphase spreads and karyotypes of the male and female dwarf cattle were prepared (Figures 6 to 9). The karyotype analysis of 52 animals revealed a diploid chromosome number of 60 comprising of 58 autosomes and two sex chromosomes. The chromosomes were arranged within the karyotype in the descending order of the size from left to right in five rows of six pairs each, with the sex chromosomes occupying the last position. The females were with XX and males XY sex chromosomes.

All the 29 pairs of autosomes were acrocentric in appearance. The X chromosomes in both sexes showed a biarmed submetacentric appearance. The Y chromosomes were acrocentric.

4.1.2 Morphometric studies

4.1.2.1 Relative length

The relative length of chromosomes are presented in Fig.10. The relative length of autosomes ranged from 1.758

Fig.6. Metaphase spread of the female dwarf cattle

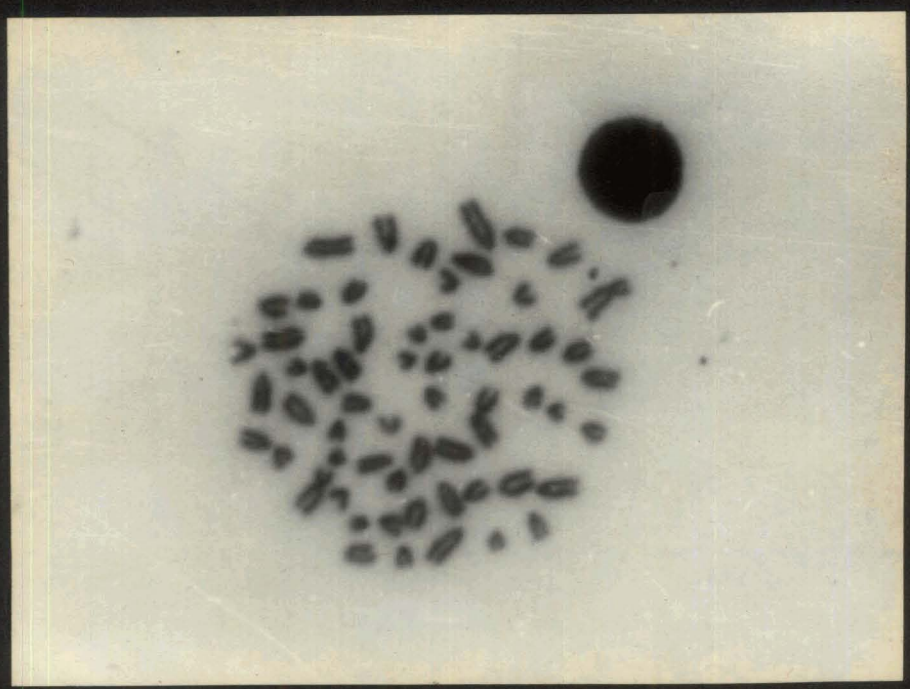

Fig.7. Karyotype of the female dwarf cattle

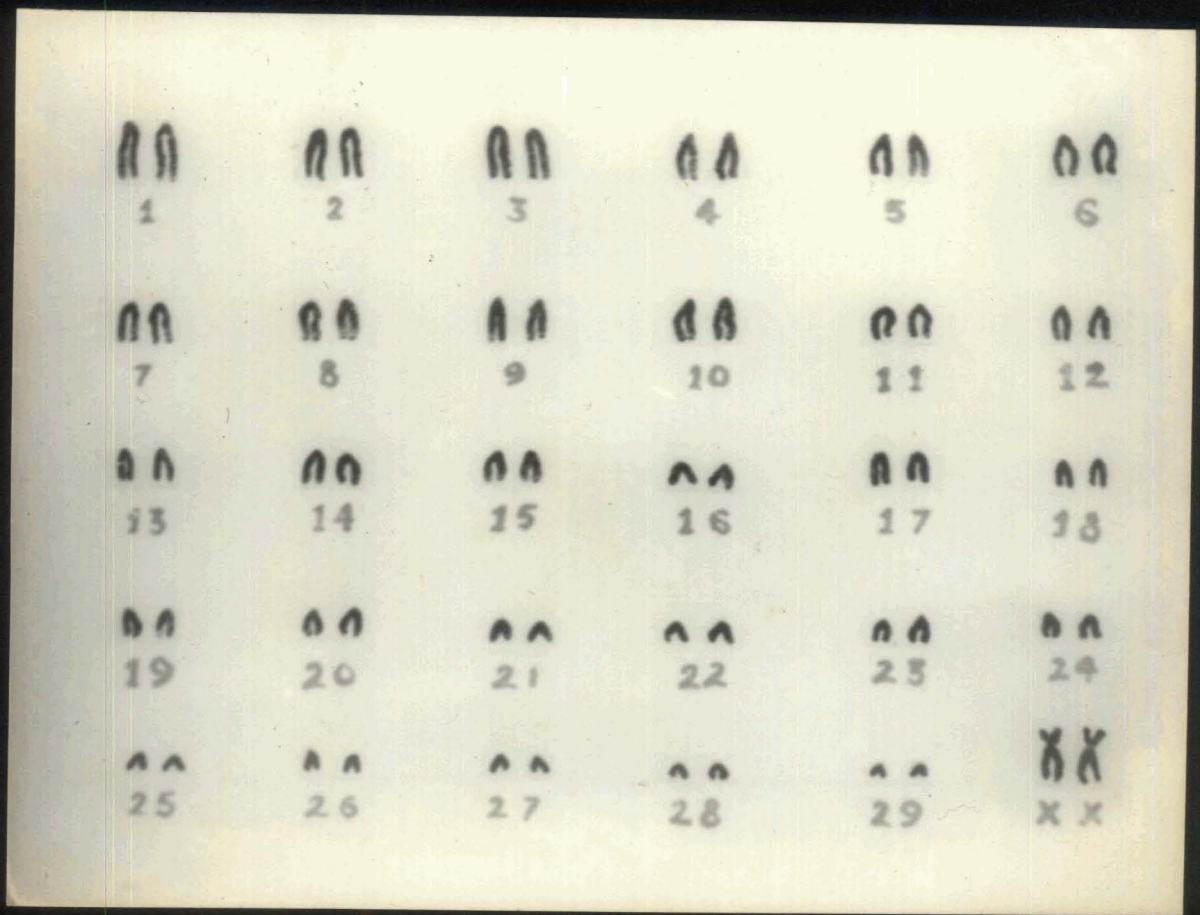
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Fig.8. Metaphase spread of the male dwarf cattle

Fig.9. Karyotype of the male dwarf cattle

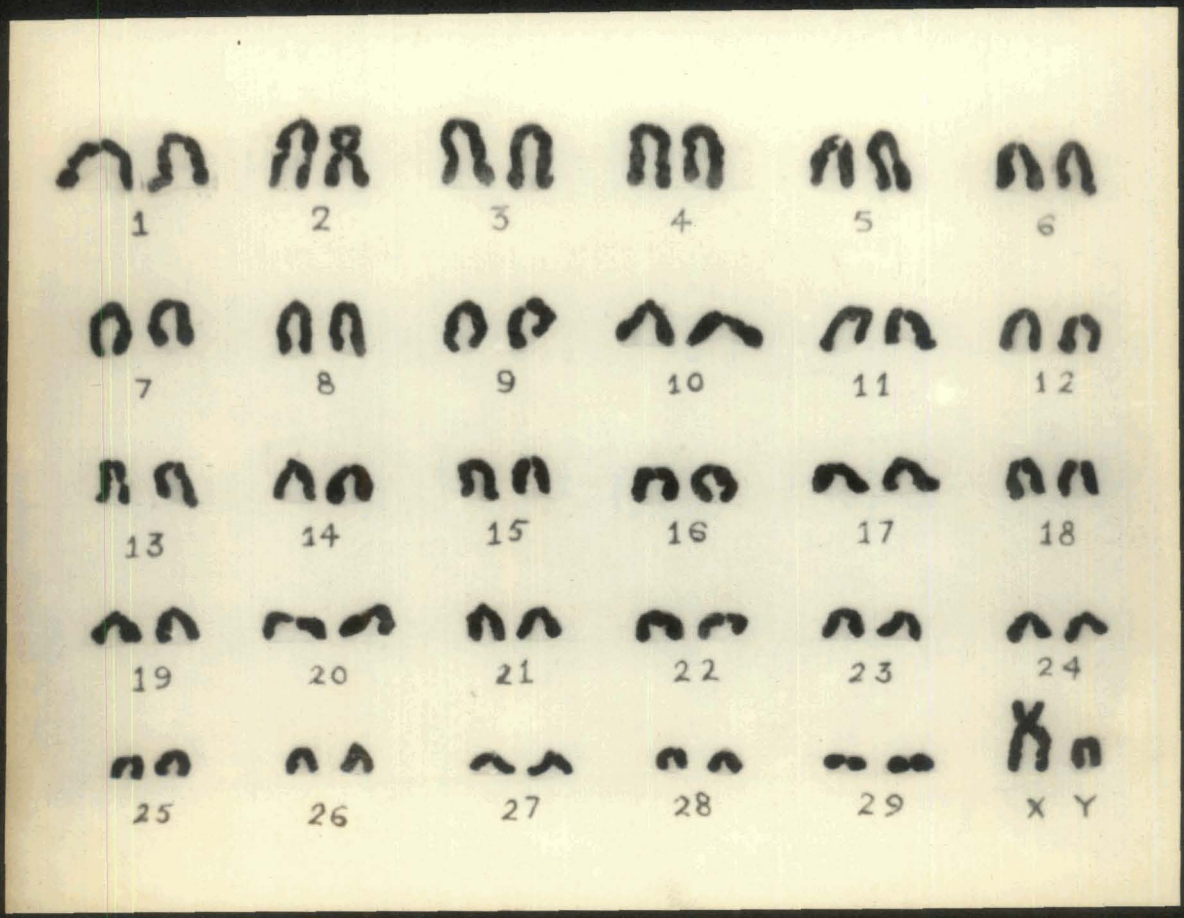
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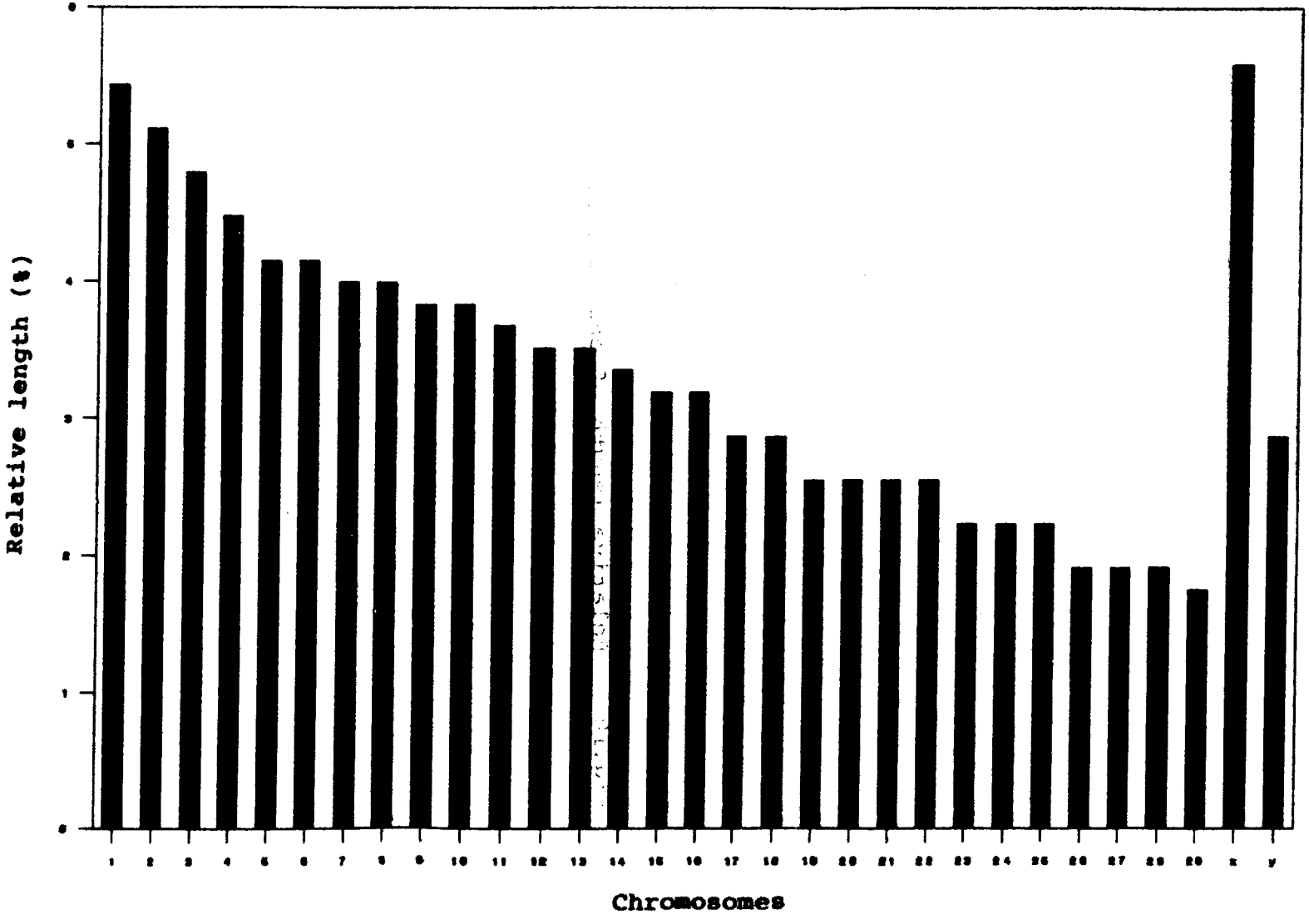
Fig.10. Relative length of chromosomes

Fig.10 Relative length of chromosomes



to 5.431 per cent. The relative length of X chromosome was found to be 5.591 per cent and that of the Y chromosome was 2.875 per cent. In the karyological array, the X chromosome occupied the first position.

4.1.2.2 Arm ratio

All the autosomes and Y chromosome were acrocentric and hence measurements were available only for one arm, the arm ratio for autosomes as well as Y chromosome could not be estimated.

The X chromosome was biarmed and the arm ratio was found to be 2.182.

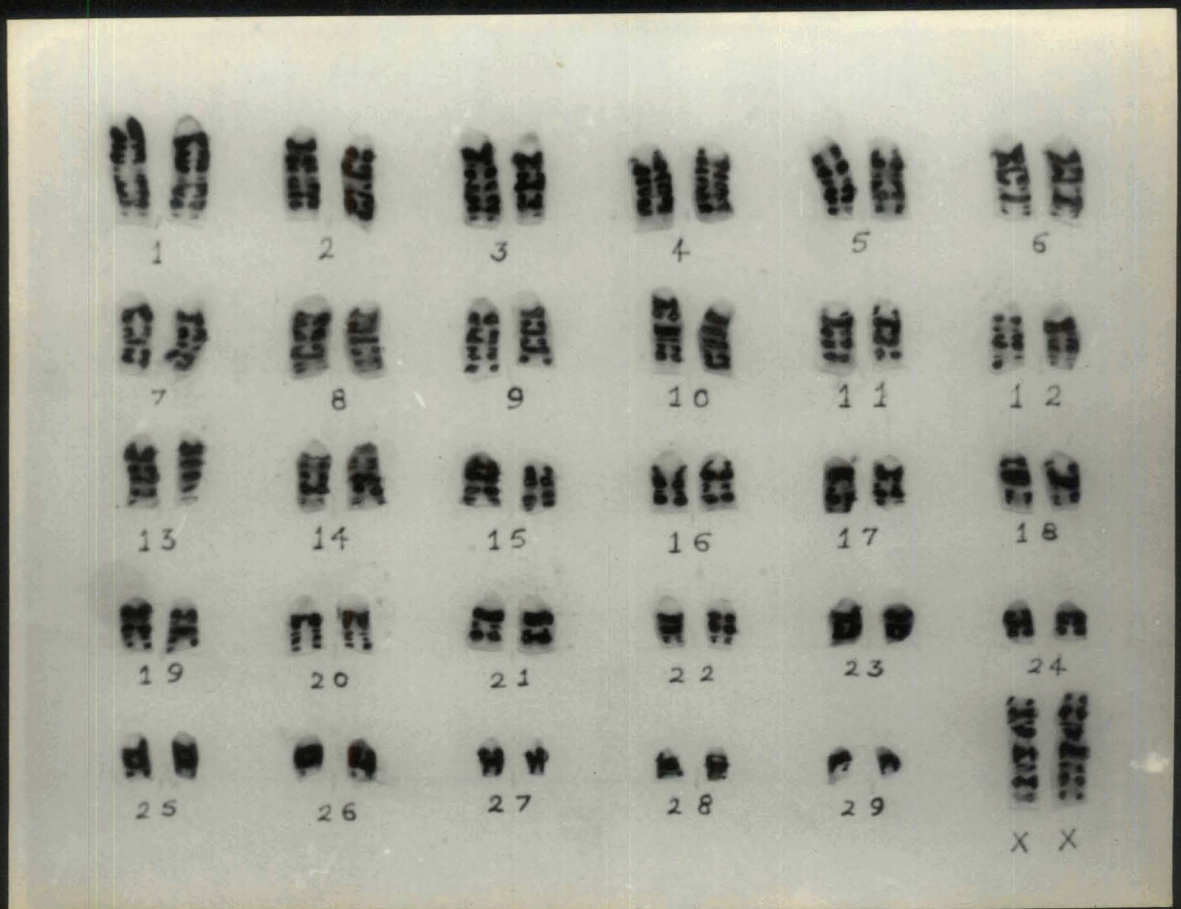
4.1.2.3 Centromeric index

The autosomes and Y chromosomes were found to be acrocentric and hence the centromeric indices were zero. Only the X chromosome had centromeric index of 0.314.

4.1.3 G-banding pattern of chromosomes

The morphology of the chromosomes were studied in detail using the G-banding technique. The G-banded karyotypes of the male and female dwarf cattle are given in the Figures 11 and 12. Idiograms were prepared for the G-banded chromosomes and presented in Figures 13 and 14.

Fig.11. G-banded karyotype of the female dwarf cattle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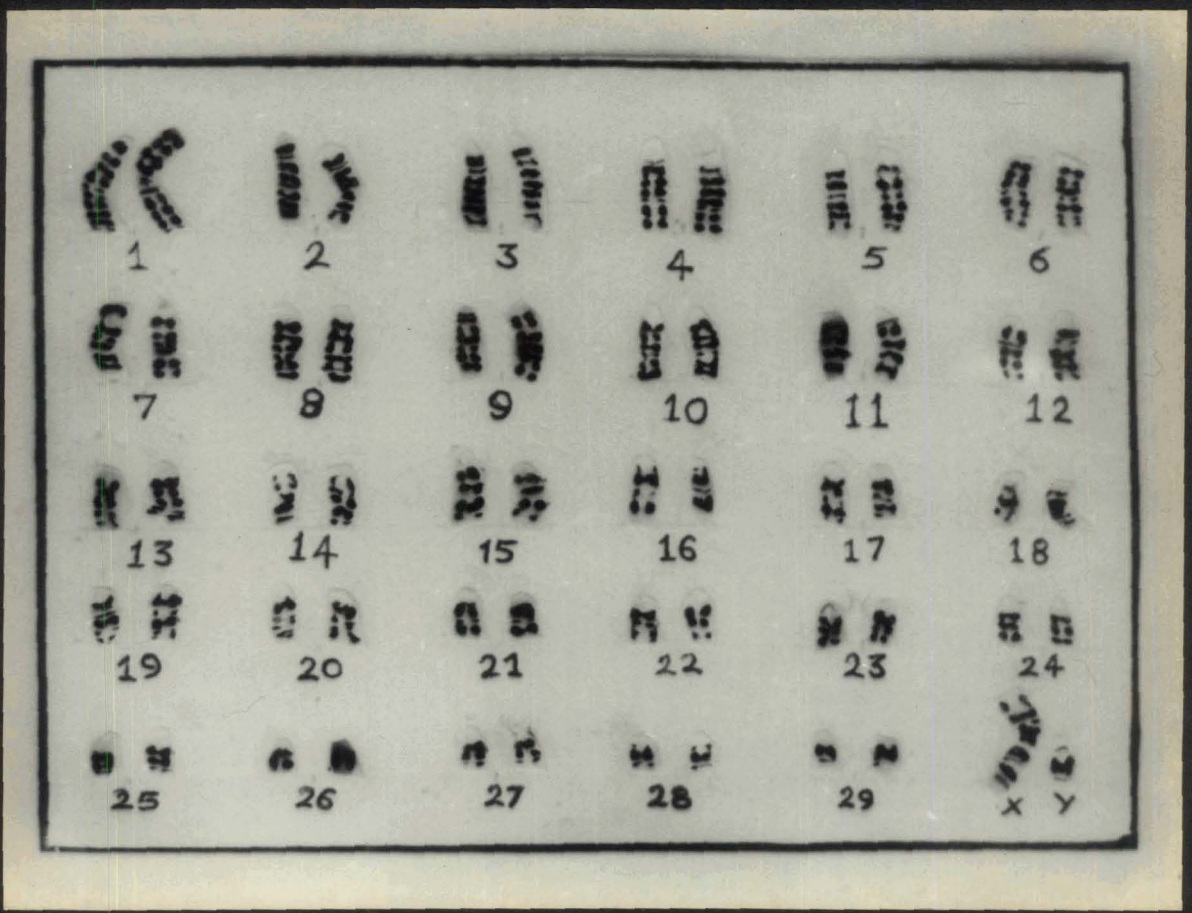
X X

Fig.12. G-banded karyotype of the male dwarf cattle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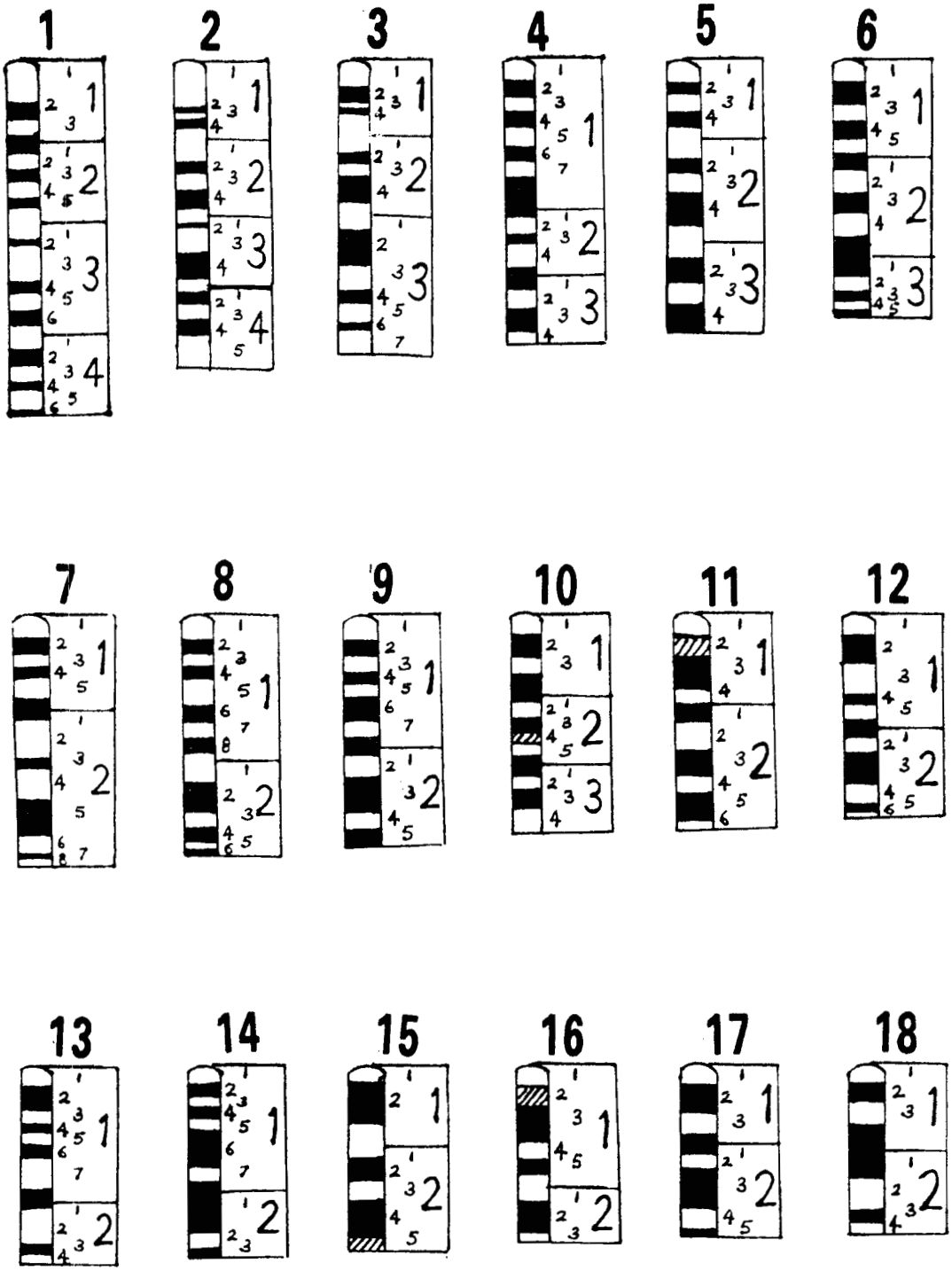
Y

Fig.13. Idiogram of the G-banded chromosomes 1-18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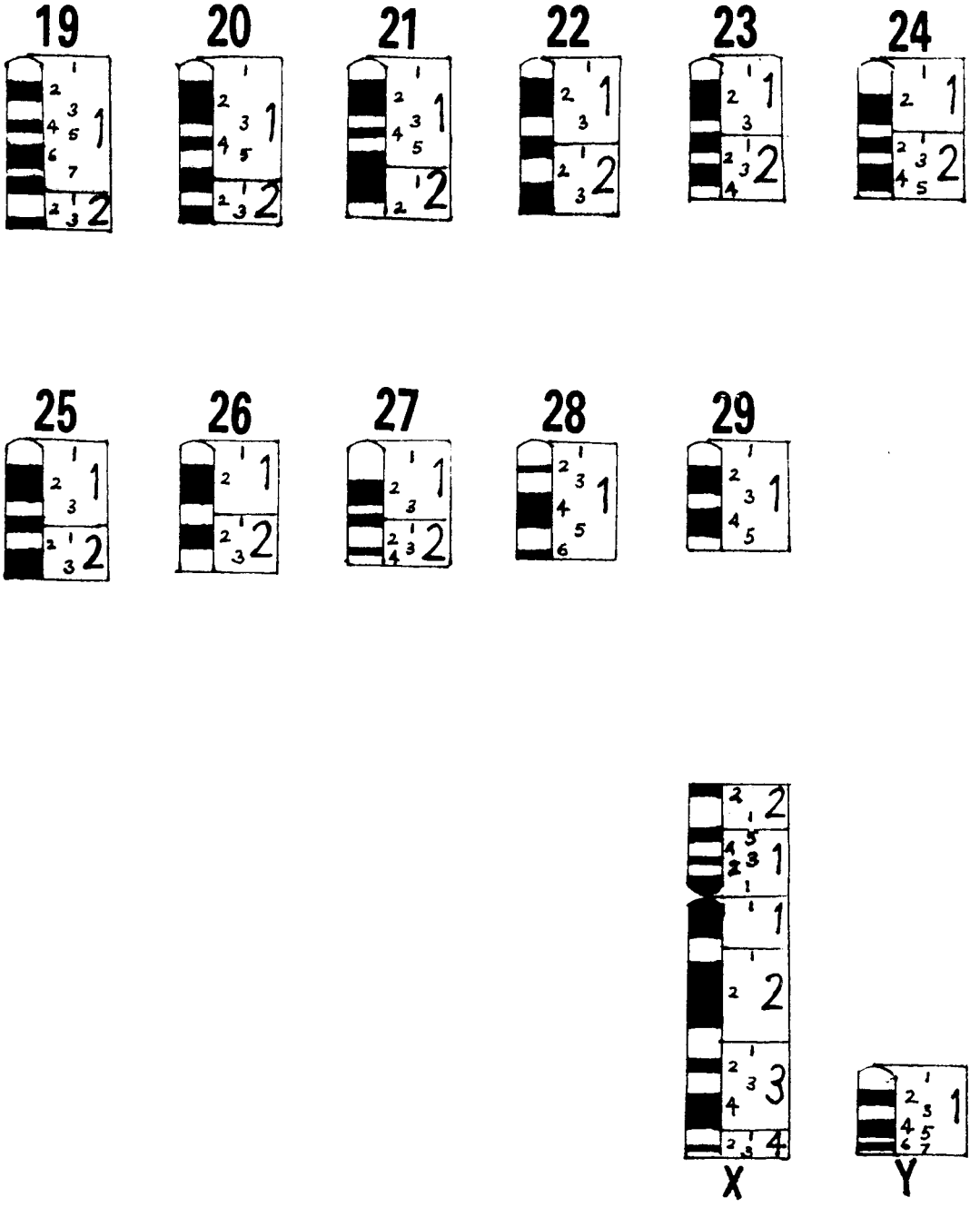
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X
Y

A total of 72 regions and 314 G-bands were observed in the karyotype of the dwarf cattle. The regions of the chromosomes were identified as per the standard nomenclature for Bos taurus. Based on the G-banding pattern, the chromosomes of the dwarf cattle are as follows.

Chromosome 1 - Four regions, 20 G-bands, 10 positive bands. Distal positive band.

Chromosome 2 - Four regions, 17 G-bands, 8 positive bands. Distal negative band.

Chromosome 3 - Three regions, 15 G-bands, 8 positive bands. Distal negative band.

Chromosome 4 - Three regions, 15 G-bands, 7 positive bands. Distal negative band.

Chromosome 5 - Three regions, 12 G-bands, 6 positive bands. Distal positive band.

Chromosome 6 - Three regions, 14 G-bands, 7 positive bands. Distal positive band.

Chromosome 7 - Two regions, 13 G-bands, 6 positive bands. Distal negative band.

Chromosome 8 - Two regions, 14 G-bands, 7 positive bands. Distal positive band.

Chromosome 9 - Two regions, 12 G-bands, 6 positive bands. Distal positive band.

Chromosome 10 - Three regions, 12 G-bands, 6 positive bands. Distal negative band.

Chromosome 11 - Two regions, 10 G-bands, 5 positive bands. Distal negative band.

Chromosome 12 - Two regions, 11 G-bands, 5 positive bands. Distal negative band.

Chromosome 13 - Two regions, 11 G-bands, 5 positive bands. Distal negative band.

Chromosome 14 - Two regions, 10 G-bands, 5 positive bands. Distal positive band.

Chromosome 15 - Two regions, 7 G-bands, 4 positive bands. Distal positive band.

Chromosome 16 - Two regions, 8 G-bands, 4 positive bands. Distal negative band.

Chromosome 17 - Two regions, 8 G-bands, 4 positive bands. Distal positive band.

Chromosome 18 - Two regions, 7 G-bands, 3 positive bands. Distal negative band.

Chromosome 19 - Two regions, 10 G-bands, 5 positive bands. Distal positive band.

Chromosome 20 - Two regions, 8 G-bands, 4 positive bands. Distal positive band.

Chromosome 21 - Two regions, 7 G-bands, 3 positive bands. Distal negative band.

Chromosome 22 - Two regions, 6 G-bands, 3 positive bands. Distal positive band.

Chromosome 23 - Two regions, 7 G-bands, 3 positive bands. Distal negative band.

Chromosome 24 - Two regions, 7 G-bands, 3 positive bands. Distal negative band.

Chromosome 25 - Two regions, 6 G-bands, 3 positive bands. Distal positive band.

Chromosome 26 - Two regions, 5 G-bands, 2 positive bands. Distal negative band.

Chromosome 27 - Two regions, 7 G-bands, 3 positive bands. Distal negative band.

Chromosome 28 - One region, 6 G-bands, 3 positive bands. Distal positive band.

Chromosome 29 - One region, 5 G-bands, 2 positive bands.

Chromosome Xp - Two regions, 7 G-bands, 4 positive bands. Distal positive band.

Chromosome Xq - Four regions, 10 G-bands, 5 positive bands. Distal negative band.

Chromosome Yq - One region, 7 G-bands, 3 positive bands. Distal negative band.

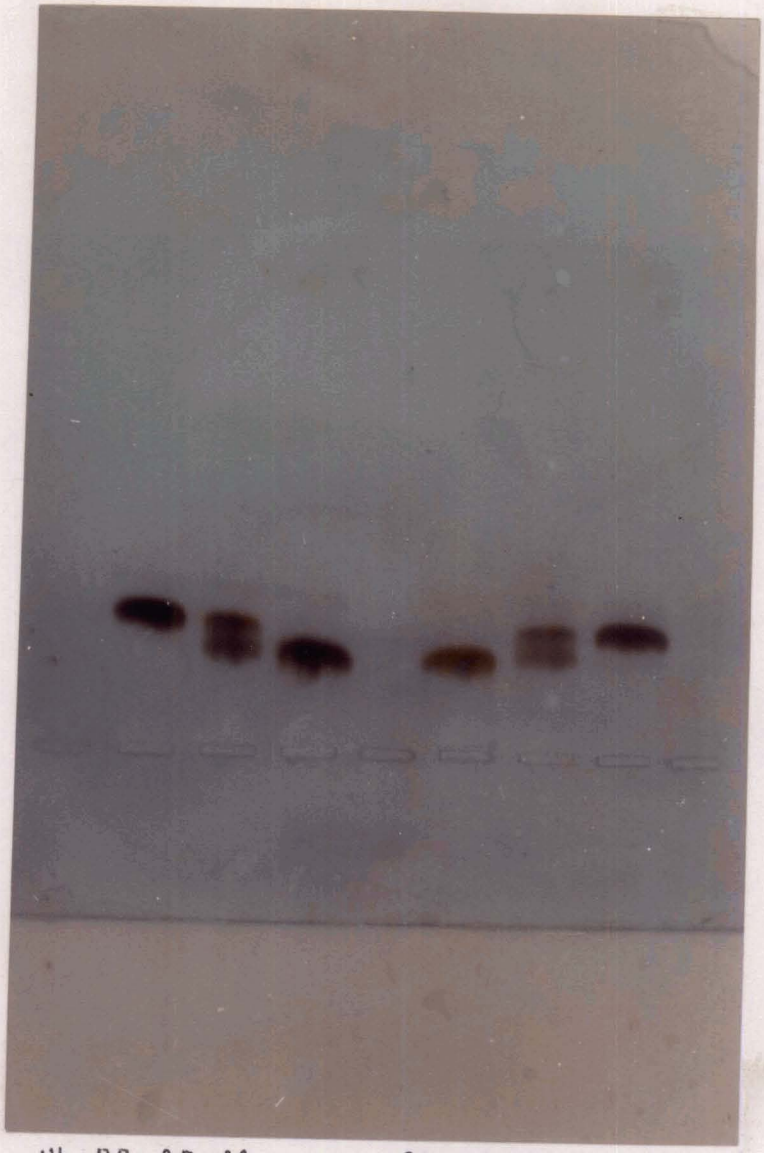
Pale or dark distal positive G-bands were observed in chromosome numbers 1, 5, 6, 8, 9, 14, 15, 17, 19, 20, 22, 25, 28 and the 'p' arm of X. Distal negative G-bands were seen in chromosome numbers 2, 3, 4, 7, 10, 11, 12, 13, 16, 18, 21, 23, 24, 26, 27, 29 and the q arm of X. The Y chromosome had the q arm only with seven G-bands.

4.2 Biochemical polymorphism

4.2.1 Haemoglobin

Fifty two animals were typed for the haemoglobin variants. They were found to possess two types of haemoglobin variants - the fast moving B and the slow moving A type. Three phenotypes viz. Hb AA, Hb AB and HbBB were observed (Fig.15).

Fig.15. Haemoglobin polymorphism of the dwarf cattle


Hb BB AB AA AA AB BB

The phenotypic and gene frequencies were estimated. The frequencies of HbAA, HbAB and HbBB are 0.404, 0.384 and 0.212 respectively. The gene frequency of HbA allele was found to be 0.596 and that of Hb^B allele was 0.404.

The genetic variability of the population at the haemoglobin locus was measured by heterozygocity which came to 0.4815.

The population was tested for genetic equilibrium at the Hb locus. The observed numbers and the expected numbers were given in the Table 7. The expected number of heterozygotes was more than the observed and in the case of homozygotes it was less. But the difference was not statistically significant.

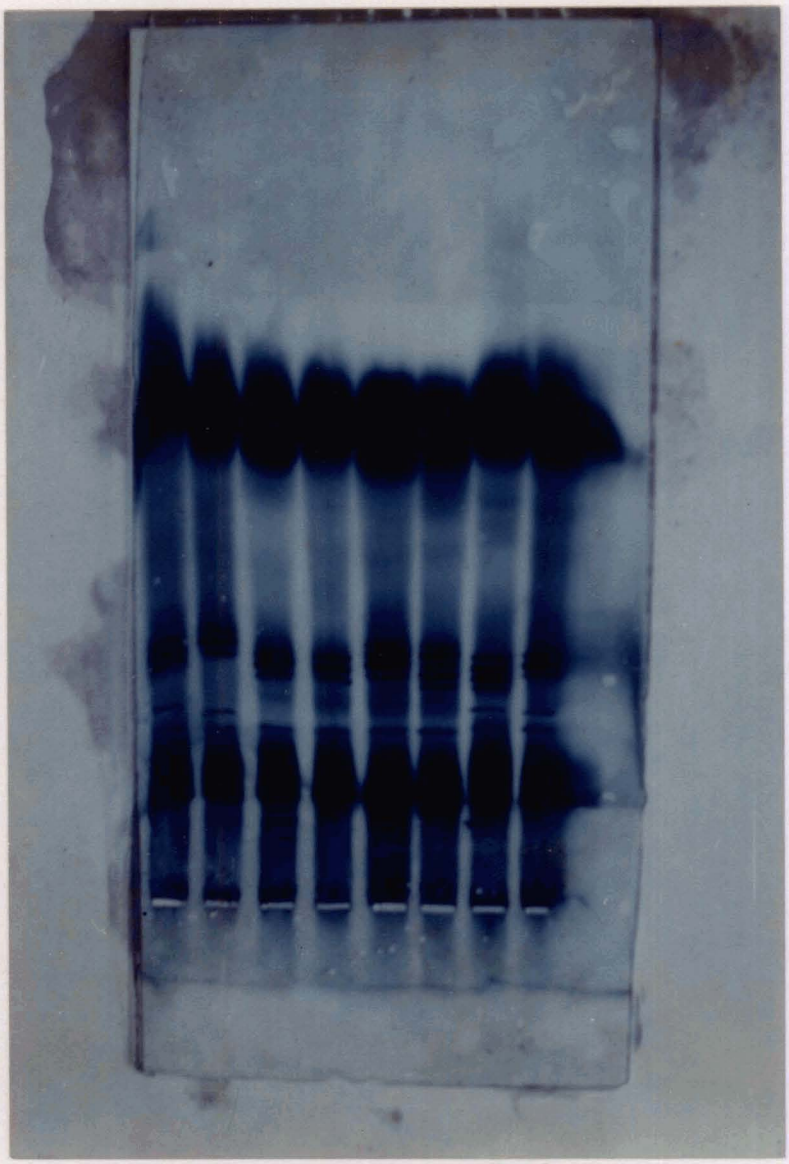
4.2.2 Transferrin

Six transferrin phenotypes, Tf AA, Tf DD, Tf EE, Tf AD, Tf AE and Tf DE controlled by -3 alleles, Tf^A, Tf^D, Tf^E in order of decreasing mobilities towards the anode were observed on typing 52 animals (Fig.16). Each allele exhibited four electrophoretically distinct bands, the fastest of these four bands being the weakest. The number of bands in a heterozygous individual depended upon the mobilities of the bands of two alleles for which it was heterozygous.

Table 7. The observed and expected number of haemoglobin phenotypes in the dwarf cattle

	Hb. Phenotypes			
	AA	AB	BB	X^2 value (df.2)
Observed No.	21	20	11	
Expected	18.49	25.04	8.48	2.10

Fig.16. Transferrin polymorphism of the dwarf cattle



Tf. DD AA EE EG AD AE DE DD

The phenotypic and gene frequencies were estimated. The frequencies of Tf AA, Tf DD, Tf EE, Tf AD, Tf AE and Tf DE were 0.031, 0.563, 0.125, 0.031, 0.031 and 0.219 respectively.

The gene frequencies of Tf^A, Tf^D and Tf^E were 0.063, 0.578 and 0.359 respectively.

4.3 Growth studies

4.3.1 Calves

The body measurements such as length, heart girth and height and body weights of 31 calves were studied. The recordings were done at fortnightly intervals from birth to one year of age. The birth weights and body measurements of calves are presented in Table 8. Male calves had higher weight and body measurements at birth. The mean birth weight in females and males were 10.78 $\pm$ 0.40 kg with a coefficient of variation of 15.02 per cent and 12.55 $\pm$ 0.31 kg with a coefficient of variation of 7.86 per cent respectively.

The mean body weights and measurements from birth to one year of age at fortnightly intervals for males and females are presented in figures 17 and 18. From the graph it is clear that the girth and body weight shows a positive correlation from birth to the 24th fortnight. The average fortnightly body weights of female and male calves

Table 8. The mean birth weight and body measurements of calves of the dwarf cattle

Parameter	Females		Males		Overall	
	Mean	CV%	Mean	CV%	Mean	CV%
Birth weight (kg)	10.78 ± 0.40 (16)	15.02	12.55± 0.31 (15)	7.85	11.46 ± 0.32 (31)	14.41
Length (cm)	45.93 ± 0.74 (16)	6.46	46.3 ± 0.51 (15)	3.48	46.07 ± 0.49 (31)	5.51
Heart girth (cm)	53.03 ± 0.62 (16)	4.69	53.8 ± 0.89 (15)	5.24	53.32 ± 0.51 (31)	4.96
(Height (cm)	53.46 ± 0.54 (16)	4.09	55.1 ± 0.74 (15)	4.25	54.09 ± 0.45 (31)	4.41

Number of observations given in parenthesis

Fig.17 Body weight and measurements in male calves

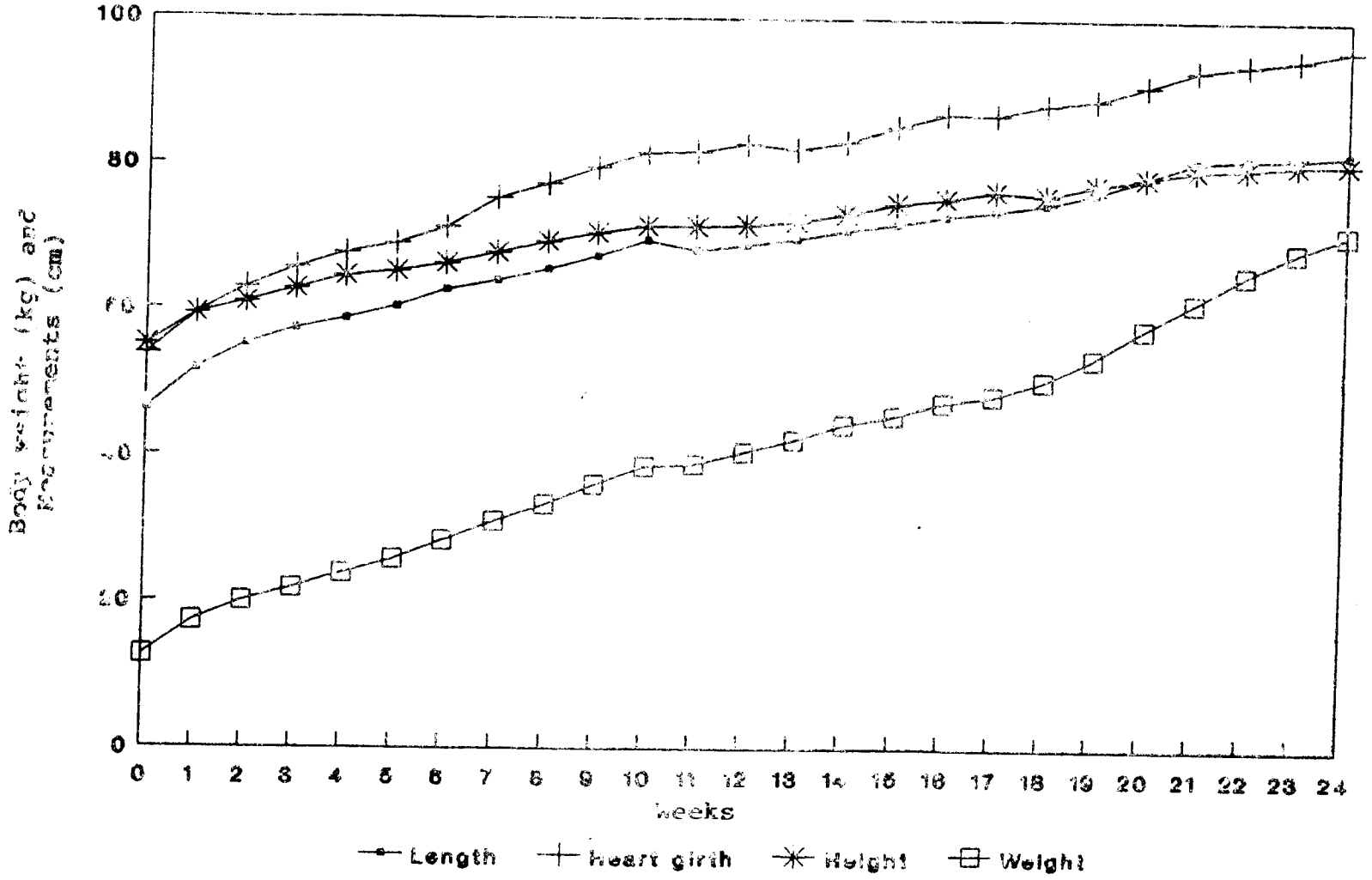
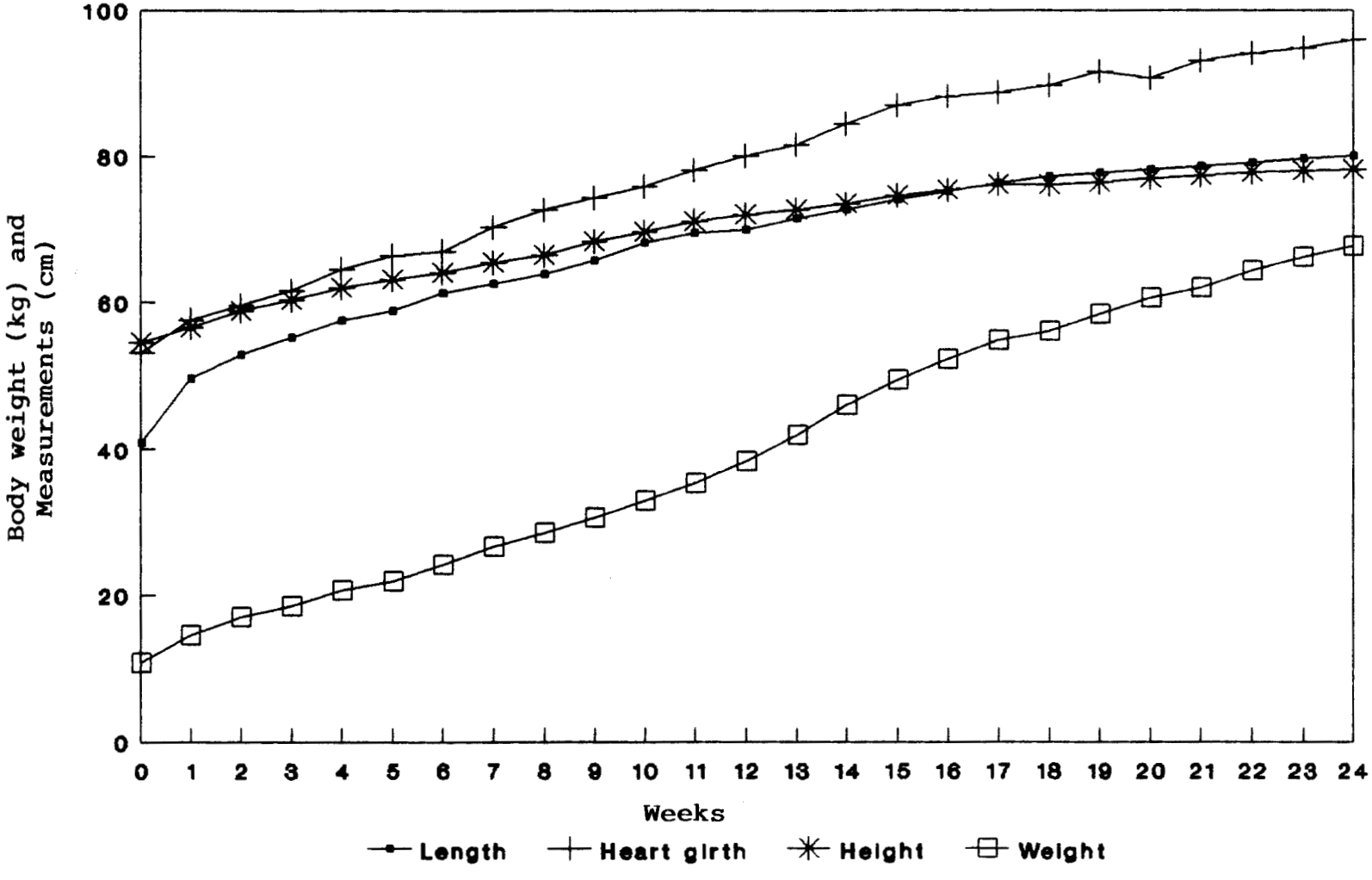


Fig.18 Body weight and measurements in female calves



upto one year of age are presented in Table 9. There is a 100 per cent increase in birth weight by the 5th fortnight and a three fold increase by the 10th fortnight. The average length, girth and height of calves at fortnightly intervals are presented in Tables 10, 11 and 12 respectively.

The weight gain for four periods i.e. fortnights 0-6, 7-12, 13-18 and 19-24 of female and male calves were estimated. The gain in weight for the above periods expressed as a percentage of the initial weight was also estimated (Table 13).

4.3.2 Adults

The mean body weights and measurements of 30 adult animals are presented in Table 14. The average body weights of females and males were 126.90 ± 3.56 kg and 210.5 ± 15.74 kg respectively.

4.4 Production performance

The weekly milk yields(28 cows)were recorded from the first to the 44th week. The mean lactation yield, lactation length, peak yield, days to attain peak yield and daily yield were estimated and presented in Table 15. The mean total lactation yield was 471.68 ± 38.72 kg with C.V. of 45.29 per cent in an average lactation length of 217 ± 16.5 days with a

Table 9. Average body weights (kg) of calves of the dwarf cattle at fortnightly intervals

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
(At birth weight)				
0	10.78 ± 0.40	15.02	12.55 ± 0.31	7.86
1	14.56 ± 0.54	14.33	17.15 ± 0.83	15.31
2	17.00 ± 0.75	16.48	19.88 ± 0.71	10.71
3	18.46 ± 1.13	22.09	21.68 ± 1.03	14.26
4	20.61 ± 1.17	20.62	23.77 ± 1.19	15.06
5	21.91 ± 1.21	19.12	25.66 ± 1.63	19.08
6	24.12 ± 1.18	17.00	28.33 ± 1.57	16.63
7	26.63 ± 1.32	16.42	30.87 ± 1.73	15.82
8	28.54 ± 1.38	16.04	33.25 ± 1.62	13.76
9	30.63 ± 1.41	15.26	36.00 ± 1.58	12.42
10	32.95 ± 1.55	15.55	38.50 ± 1.47	16.78
11	35.18 ± 1.51	14.27	38.94 ± 2.64	20.63
12	38.18 ± 1.95	16.96	40.55 ± 2.79	20.69
13	41.81 ± 1.91	15.11	42.33 ± 2.96	21.00
14	45.90 ± 2.14	15.44	44.44 ± 3.07	20.76
15	49.44 ± 2.74	16.59	45.57 ± 4.19	24.31
16	52.22 ± 2.73	15.70	47.42 ± 4.28	23.90

Contd.

Table 9 (Contd.)

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
17	54.83 ± 2.49	13.67	48.28 ± 4.43	24.29
18	56.00 ± 2.87	15.38	50.28 ± 3.97	20.87
19	58.44 ± 3.13	16.07	53.42 ± 4.22	20.91
20	60.55 ± 3.44	17.03	57.42 ± 4.41	20.32
21	62.00 ± 3.28	15.91	61.14 ± 4.29	18.57
22	64.33 ± 3.18	14.85	65.00 ± 4.91	19.99
23	66.16 ± 3.16	14.33	68.21 ± 5.23	20.27
24	67.66 ± 3.21	14.24	70.57 ± 5.69	21.34

Number of observations in females = 16

Number of observations in males = 15

Table 10. Average length (cms) of calves of the dwarf cattle at fortnightly intervals

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
(At birth)				
0	45.93 ± 0.74	6.46	46.30 ± 0.51	3.49
1	49.73 ± 0.83	6.46	51.70 ± 1.04	6.36
2	52.78 ± 0.99	6.99	55.11 ± 0.87	4.72
3	55.23 ± 1.16	7.55	57.22 ± 0.72	0.76
4	57.46 ± 1.05	6.60	58.55 ± 0.70	3.61
5	58.83 ± 1.03	6.08	60.33 ± 0.75	3.75
6	61.33 ± 1.14	6.43	62.66 ± 1.21	5.78
7	62.63 ± 1.31	6.95	64.75 ± 1.30	5.74
8	63.90 ± 1.51	7.82	65.50 ± 1.03	4.45
9	65.81 ± 1.52	7.67	67.25 ± 1.34	5.65
10	68.18 ± 1.35	6.56	68.52 ± 2.01	8.84
11	69.54 ± 1.26	5.99	68.88 ± 1.98	8.61
12	70.00 ± 1.34	6.36	69.50 ± 0.94	3.81
13	71.54 ± 1.94	5.54	69.77 ± 1.91	8.21
14	72.72 ± 1.39	6.34	71.00 ± 2.02	8.55
15	74.11 ± 1.74	7.04	71.85 ± 2.33	8.59
16	75.22 ± 1.67	6.63	73.00 ± 2.20	7.99

Contd.

Table 10 (Contd.)

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
17	76.33 ± 1.88	7.38	73.71 ± 2.12	7.50
18	77.33 ± 1.69	6.54	74.57 ± 2.36	8.39
19	77.66 ± 1.68	6.48	76.14 ± 2.62	9.11
20	78.22 ± 1.64	6.29	78.28 ± 2.50	8.44
21	78.66 ± 1.58	6.02	80.57 ± 2.74	9.00
22	79.11 ± 1.70	6.43	81.00 ± 2.68	8.75
23	79.66 ± 1.89	7.10	81.14 ± 2.64	8.60
24	80.11 ± 1.99	7.45	81.71 ± 2.56	8.29

Number of observations in females = 16

Number of observations in males = 15

Table 11. Average heart girth (cms) of calves of the dwarf cattle at fortnightly intervals

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
(At birth)				
0	53.03 ± 0.62	6.22	53.80 ± 0.89	5.24
1	57.60 ± 0.74	4.98	59.30 ± 0.83	4.40
2	59.57 ± 0.84	5.30	62.88 ± 0.91	4.33
3	61.57 ± 1.13	6.62	65.67 ± 1.03	4.69
4	64.53 ± 1.20	6.70	67.66 ± 1.33	5.91
5	66.41 ± 1.28	6.66	69.65 ± 1.40	6.11
6	67.00 ± 1.43	7.41	71.33 ± 1.56	6.58
7	70.27 ± 0.80	3.79	75.25 ± 1.34	5.05
8	72.72 ± 0.95	4.35	77.25 ± 1.40	5.13
9	74.36 ± 1.00	4.45	79.50 ± 1.70	6.07
10	75.90 ± 1.12	4.88	81.62 ± 1.91	6.62
11	78.09 ± 1.21	5.14	82.11 ± 2.32	8.49
12	80.09 ± 1.44	5.96	82.77 ± 2.51	9.33
13	81.63 ± 1.50	6.07	82.88 ± 2.65	9.59
14	84.45 ± 1.40	5.52	83.22 ± 2.08	7.51
15	87.74 ± 1.47	5.08	85.28 ± 2.44	7.57
16	88.22 ± 1.58	5.36	87.75 ± 2.41	7.32

Contd.

Table 11 (Contd.)

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
17	88.77 ± 1.61	5.41	87.85 ± 2.61	7.94
18	89.66 ± 1.87	6.26	88.28 ± 2.86	8.56
19	91.55 ± 2.00	6.56	89.77 ± 2.80	8.32
20	92.66 ± 1.90	6.27	90.85 ± 2.82	8.22
21	93.11 ± 1.91	6.17	93.14 ± 2.71	7.69
22	94.11 ± 2.08	6.62	93.85 ± 2.87	8.08
23	94.88 ± 2.08	6.56	94.71 ± 3.08	8.59
24	96.00 ± 2.00	6.33	96.00 ± 3.07	8.46

Number of observations in females = 16

Number of observations in males = 15

Table 12. Average height (cms) of calves of the dwarf cattle at fortnightly intervals

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
(At birth)				
0	53.46 ± 0.55	4.10	55.10 ± 0.74	4.25
1	56.60 ± 0.63	4.32	59.30 ± 0.69	3.70
2	58.78 ± 0.66	4.18	60.88 ± 0.84	4.13
3	60.30 ± 0.87	5.18	62.77 ± 0.66	3.17
4	62.00 ± 0.92	5.33	64.44 ± 0.65	3.02
5	63.16 ± 0.95	5.20	65.22 ± 0.60	2.78
6	64.08 ± 0.95	5.15	66.33 ± 0.63	2.84
7	65.45 ± 1.02	5.18	67.75 ± 0.70	2.93
8	66.54 ± 1.05	5.22	69.25 ± 0.79	3.21
9	68.36 ± 1.00	4.84	70.50 ± 0.87	3.47
10	69.72 ± 0.71	3.35	71.50 ± 0.61	2.42
11	71.09 ± 0.74	3.47	71.80 ± 1.35	5.71
12	72.00 ± 0.79	3.65	72.22 ± 1.62	6.81
13	72.72 ± 0.77	3.52	72.82 ± 1.84	7.56
14	73.54 ± 0.65	2.92	73.22 ± 1.67	6.96
15	74.55 ± 0.77	3.10	74.71 ± 2.46	8.72
16	75.44 ± 1.00	3.96	75.42 ± 1.95	6.83

Contd.

Table 12 (Contd.)

Fortnights	Females		Males	
	Mean	CV %	Mean	CV %
17	76.11 ± 1.01	3.99	75.42 ± 1.95	6.83
18	76.20 ± 1.18	4.64	75.85 ± 1.87	6.51
19	76.44 ± 1.19	4.66	77.28 ± 1.84	6.29
20	77.00 ± 1.15	4.98	78.28 ± 1.69	5.70
21	77.44 ± 1.10	4.27	79.14 ± 1.35	4.50
22	77.77 ± 1.23	4.73	79.71 ± 1.26	4.17
23	78.00 ± 1.21	4.64	80.28 ± 1.40	4.60
24	78.22 ± 1.18	4.54	80.42 ± 1.43	4.69

Number of observations in females = 16

Number of observations in males = 15

Table 13. Growth rate of male and female calves of the dwarf cattle

Fortnights	Actual daily gain in weight (kg)		Weight gain as a percentage of the initial weight (%)	
	Female	Male	Female	Male
0-6	0.160 ± 0.011	0.188 ± 0.023	124.3	125.7
7-12	0.167 ± 0.018	0.145 ± 0.016	58.3	43.1
13-18	0.212 ± 0.011	0.116 ± 0.025	46.7	25.0
19-24	0.139 ± 0.015	0.242 ± 0.049	20.8	40.4

Number of observations in females = 16

Number of observations in males = 15

Table 14. The mean body weight and measurements of adult dwarf cattle

Parameter	Females		Males	
	Mean	CV%	Mean	CV%
Body weight (kg)	126.90 ± 3.56 (26)	16.39	210.5 ± 15.74 (4)	14.95
Length (cm)	97.50 ± 1.12 (26)	5.85	111.5 ± 3.76 (4)	6.76
Heart girth (cm)	115.60 ± 1.32 (26)	5.82	146.0 ± 2.92 (4)	3.99
(Height (cm)	87.53 ± 0.82 (26)	4.80	107.5 ± 1.35 (4)	2.50

Number of observations given in parenthesis

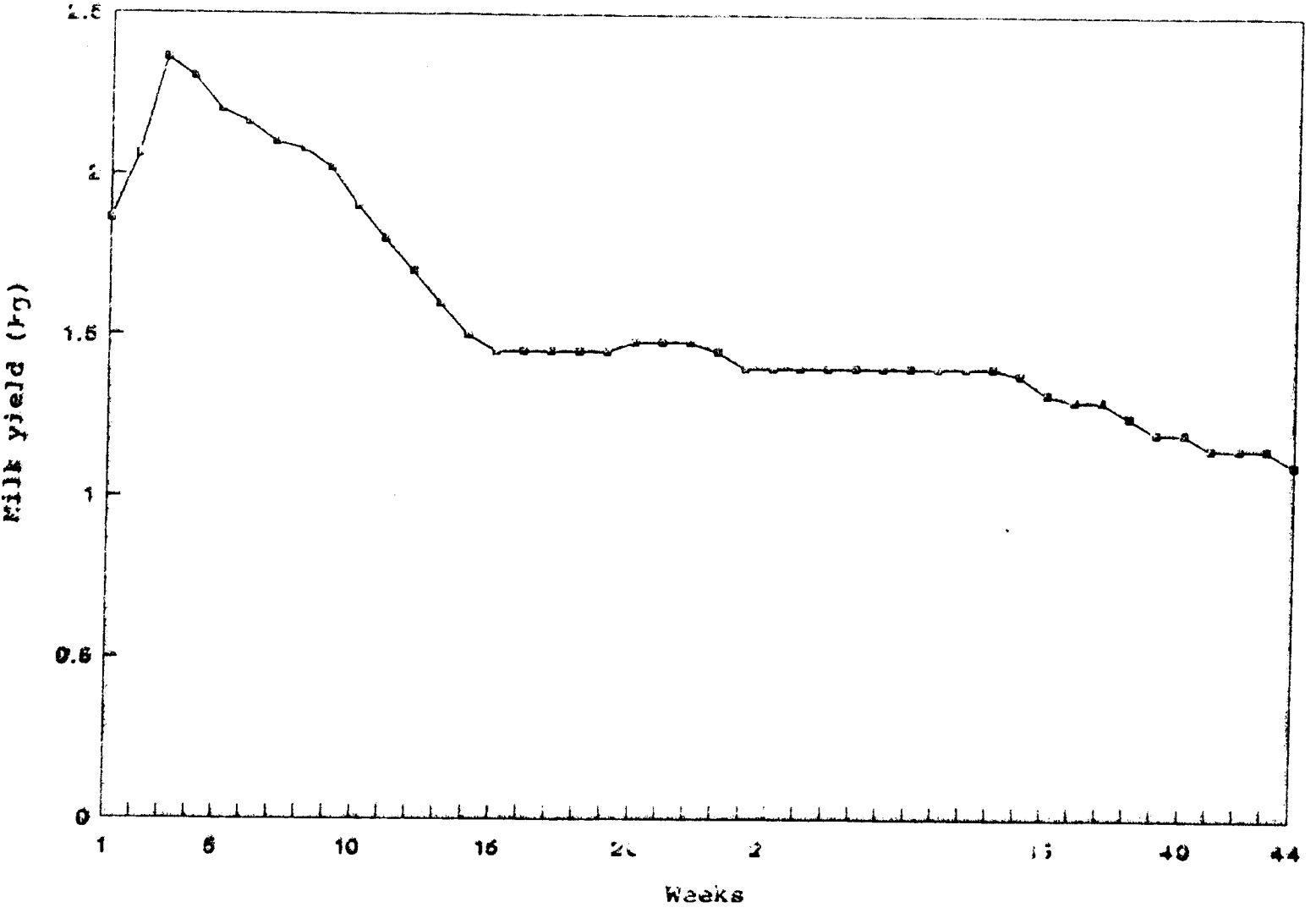
Table 15. The mean production performance of the dwarf cattle

Parameter	No. of cows	Mean	C.V.%
Total lactation yield (kg)	28	471.68 ± 38.72	45.29
Lactation length (days)	28	217.00 ± 16.50	32.20
Daily yield (kg)	28	2.17 ± 0.11	29.48
Peak yield (kg)	28	3.71 ± 0.16	21.51
Days to attain peak yield	28	23.23 ± 1.70	37.38

C.V. of 32.2 per cent. The average daily yield was 2.17 ± 0.11 kg (CV. 27.48%). The dwarf cattle attained a mean peak yield of 3.71 ± 0.16 kg (C.V. 21.51%) in 23.23 ± 1.70 days (C.V. 37.38%).

A graph was plotted with the average weekly yields Fig.19. It shows that by the 3rd week peak production is attained and thereafter the production drops showing a less persistent trend.

Fig. 18 A[illegible]ge daily [illegible]uction
performance of [illegible] (kg)



Discussion

DISCUSSION

5.1 Cytogenetic studies

5.1.1 Chromosome number and morphology

The diploid chromosome number of the dwarf cattle was found to be 60 (Fig. 6-9) which agreed with those reported by Chiarelli *et al*. (1960), Crossley and Clarke (1962), Gustavsson (1966), Basrur and Moon (1967) and Raghunandanan (1988).

All the 29 pairs of autosomes were acrocentric. The X chromosomes in both sexes showed a biarmed submetacentric appearance and the Y chromosomes were acrocentric. These observations were in agreement with those of Kieffer and Cartwright (1968), Potter *et al*. (1979), Yadav *et al*. (1984), Strazinger *et al*. (1987) and Raghunandanan (1988) in *Bos indicus* cattle. There had been extensive use of exotic bulls since 35 years in the area from where the dwarf cattle were collected and the probability of inheritance from an exotic sire in the parent generation or earlier generation is quite high. But the acrocentric Y points to the fact that the bulls studied had their inheritance from local dwarf cattle. This showed that the chromosome profile of the dwarf cattle

resembled that of the Bos indicus group. As suggested by Kieffer and Cartwright (1968), it can be concluded that the position of the centromere of the Y chromosome might have originated through a pericentric inversion. Kieffer and Cartwright (1968) and Potter et al. (1979) reported similarity in the overall size of the chromosomes of Bos indicus and Bos taurus.

5.1.2 Morphometric studies

5.1.2.1 Relative length

The relative length of autosomes ranged from 1.757 to 5.431 per cent. The largest of the chromosome was the X chromosome with a relative length of 5.591 per cent. This was in agreement with the reports of the studies conducted in the zebu cattle by Sahai (1982) and Raghunandanan (1988).

5.1.2.2 Arm ratio

Since all the autosomes and Y chromosome were acrocentric the measurements were available only for one arm and hence the arm ratio could not be estimated. For X chromosome the arm ratio was estimated to be 2.182. This finding is in agreement with those reported by Raghunandanan (1988) in local cattle.

5.1.2.3 Centromeric index

The centromeric index was found to be zero for the autosomes and Y chromosomes as they were acrocentric. The centromeric index of 0.314 estimated in the present study is comparable to that of Raghunandanan (1988) reported in local cattle (0.365).

5.1.3 G-Banding pattern of chromosomes

The use of the banding pattern is essential for the accurate identification of individual chromosomes. The G-banding technique described, produced a characteristic banding pattern in each chromosome and allowed pairing of homologous chromosome pairs in the dwarf cattle genome. The resolution afforded by the banding pattern is dependent on the number of bands, their size, staining intensity and relative disposition in the chromatid. Banding pattern resulted from the hydrolysis of discrete areas of the protein component of chromatin by trypsin, thus allowing Giemsa stain to react with the exposed DNA (Potter et al., 1979).

The pale or dark positive distal bands of the chromosomes 1, 8 and 19 (Fig. 13 and 14) agreed to the descriptions of Lin et al. (1977) and the standard bands of Bos taurus (ISCNDA, 1989).

The dark or pale positive distal bands of chromosomes, 5, 6, 9, 14, 15, 17, 20, 22 and 25 are similar to those observed by Lin et al. (1977) in Bos taurus. The distal negative bands of the chromosomes 2, 3, 4, 7, 10, 11, 16, 18, 21, 24, 26, 27, 29 and the 'q' arm of the X agree with those reported by Lin et al. (1977) and the standard G-bands of Bos taurus (ISCNDA, 1989). The distal negative bands of chromosomes 12 and 13 and the 'q' arm of Y resembled those of Bos taurus (ISCNDA, 1989) whereas that of chromosome 23 resembled the band obtained by Lin et al. (1977).

The G-banding pattern of chromosomes 3, 7, 13 and 19 were similar to the standard bands of Bos taurus described in ISCNDA (1989). All the other autosomes and the 'X' chromosome resembled the G-bands of Bos taurus reported by Lin et al. (1977).

The G-bands of Y chromosomes were similar to those of the 'q' arm of Bos taurus (ISCNDA, 1989).

Potter et al. (1979) reported that the G-banding pattern of Bos indicus and Bos taurus are similar except in the case of Y chromosome which is acrocentric in Bos indicus and submetracentric in Bos taurus. It is also reported that the acrocentric Y chromosome of Bos indicus and the long arm of the submetacentric Y chromosome of Bos taurus are similar

in the G-banding pattern. Seven G-bands in the Y chromosome of Bos indicus was reported by Halnan (1989). The total number of G-bands (314 Nos.) obtained in dwarf cattle were lesser than those of Bos taurus (410 Nos.) as per the ISCNDA (1989), but more than that reported by Lin et al. (1977) in Simmental breed.

5.2 Biochemical polymorphism

5.2.1 Haemoglobin

There were two haemoglobin variants Hb^A and Hb^B and three phenotypes viz. HbAA, HbAB and HbBB observed in the population (Fig.15). This was in agreement with the findings of Sen et al. (1966), Balakrishnan and Nair (1966), Khanna et al. (1970), Singh et al. (1972), Singh and Bhat (1979), Singh and Bhat (1980 a&b), Singh and Bhagi (1981) and Khanna and Tandon (1987) in Sahiwal, Red Sindhi, Tharparkar, Gir and other Indian breeds and crossbreds. Other variants like Hb^C, Hb^D and Khillari were not observed in the population studied. These variants were reported in Malvi, Khillari, Dangi, Kankrej Rath, Kumaoni and Shahiwal breeds by Braend et al (1966), Naik et al. (1969), Singh and Khanna (1973) and Shankar and Bhatia (1982). The absence of these variants in the present population studied showed that these animals did not get any gene from the above mentioned breeds.

Three haemoglobin phenotypes HbAA, HbAB and HbBB controlled by two alleles Hb^A and Hb^B were observed. The frequency of HB AA individuals was more and HbBB the least and the frequency of the allele Hb^A was more which is in accordance with the reports of Sen et al. (1966), Balakrishnan and Nair (1966), Singh and Khanna (1971) and Singh and Bhat (1979).

The polymorphism in a population reflects genetic variability and the variation provides scope for selection. This was reflected in the present population also with a heterozygosity of 0.4815.

There was no significant difference between the observed and expected genotype frequencies at the haemoglobin locus studied. This showed that the population was in genetic equilibrium with respect to the haemoglobin locus. This was in accordance with the observation of Nandakumaran et al. (1979) and Singh and Bhagi (1981). This was expected as no selection was followed based on the Hb locus.

5.2.2 Transferrin

Six transferrin phenotypes controlled by 3 alleles Tf^A, Tf^D and Tf^E were observed in the dwarf cattle (Fig.16). These alleles and phenotypes were reported by Ashton (1959a) and Jamieson (1965) in European breeds as well as in zebu.

The frequency of Tf^E allele in the dwarf cattle was as high as the frequency of the allele in zebu cattle reported by Ashton (1959b) and in Indian cattle reported by Jamieson (1965), Singh et al. (1972) and Ashok Singh and Chaudhari (1989). The absence of transferrin variants like Tf^F, Tf^H, Tf^N, Tf^G and the higher frequency of Tf^E allele are probably indicative of the genetic isolation of this population from the exotic breeds. The absence of Tf^B and Tf^F alleles, which is present in Gir, Hariana, Kankrej, Kankayam, Ongole, Red Sindhi, Sahiwal and Tharparkar also indicates a separate line of inheritance for the dwarf cattle.

5.3 Growth studies

5.3.1 Calves

The body weights and measurements of calves at birth studied, showed that calves had a very low birth weight (11.46 ± 0.32 kg). It is about one third of that of the crossbred calves and half of the indigenous zebu cattle. Male calves had a body weight higher by 1.8 kg. This agreed with the findings of Kohli et al. (1962) in Hariana calves, and Mudgal and Ray (1966) in Red Sindhi calves. The birth measurements of the calves of the dwarf cattle were also similarly low (Length 46.07 cms, Girth 53.32 cms and Height 54.09 cm). They were much lower than those reported by Mudgal and Ray (1966), Srivasthava et al.

(1986) and Ashok Singh and Parekh (1986). The average daily gain in weight of calves were lesser than those reported by Taneja and Bhat (1971) in Sahiwal cattle, and Kulkarni et al. (1982) in Holstein Friesian crossbred calves. The lesser body weights and measurements in the dwarf cattle may be due to their smaller body size as against the other Indian breeds and crossbreds. The calves were born in the farm and reared under optimum conditions of feeding and management. Still the females weighed only 67.7 kg and males 70.6 kg by 24th fortnight. This clearly brings out the genetic speciality of this type of animal in the case of body weights. The average length of the calves was higher for males upto 9th fortnight but became equal to that of females by 10th fortnight and this continued to be less upto 19th fortnight. From 20th fortnight onwards the length was more for the males. But in the case of heart girth, males had higher heart girth upto 13th fortnight. From 14th fortnight onwards, upto 20th the females had higher girth measurements and thereafter, the measurements in both sexes were similar. Height was more in males upto 13th fortnight but slightly more for females upto the 18th fortnight. Thereafter the males had higher height.

Variability was more with weight compared to length, heart girth and height. Height had the least variability for the different fortnights.

The body measurements were low for the calves as expected and in accordance with the weight. The body weight and heart girth at fortnightly intervals had the maximum association compared to length and height with body weight. The correlation between girth and weight at fortnightly intervals was almost perfect ($r = 0.993$).

The weight gain per day upto the 6th fortnight looked similar for males (0.188 kg) and females (0.162 kg). But from 7-12 the daily weight gain was less for males compared to the females. The males showed a great reduction in the weight gain especially when expressed as a percentage of the initial weight. In fortnights 13th to 18th also, there is a reduction in actual gain in weight compared to the first two periods. But the females showed an actual increase, but as a percentage of the initial weight there was reduction. Percentage wise males showed a greater reduction. The gain in weight for males showed a remarkable improvement during 19th-24th fortnight compared to the previous periods and percentage wise the growth was higher by about 15 per cent compared to the 13th-18th fortnight period. But in the case of females the trend was reverse and less was the weight gain compared to the previous periods.

5.3.2 Adults

The average body weights of the adult females and males were 126.90 ± 3.56 kg (CV 16.39%) and 210.5 ± 15.75 kg (CV 14.95%) respectively. These values were lesser than those reported for the recognised Indian cattle breeds (Dairy India, 1987). The average body measurements also gave the same type of results which were lesser than those reported for the Indian cattle breeds.

The cows weighed only about one third of the recognised breeds of India. Similarly, when the height of the cows of other breeds is around 130 cms, it is surprising that these cows have an average height of only 87 cms. The average length of the cow was found to be 97.5 cm whereas that of the other Indian breeds was around 130 cms. Girth was 115.6 cm, while those of the Indian breeds around 170 cm. This leads to the conclusion that the indigenous cattle of Kerala are the smallest type available in India and perhaps in the world itself.

5.4 Production performance

The total lactation milk production performance of the dwarf cattle (471.68 ± 38.72 kg) excelled certain Indian cattle breeds such as Khillari and Umblachery breeds, which had 214.7 ± 12.2 kg and 323.9 ± 18.5 kg. The average

lactation length of 217 ± 16.5 days observed was similar to that in Ongole breed. The average peak yield was 3.71 ± 0.16 kg which was lesser than the average production reported in crossbreds (Girija and Nair, 1984). The peak yield was attained by the 23rd day of lactation as against the Jersey x Zebu and Brown Swiss x zebu crossbreds which attained peak in 44.75 and 49.86 days respectively. Eventhough the production performance was lesser than the crossbreds or some other recognised Indian breeds, the milk production in comparison with the body size was reasonable. Most of the cows were old and have passed their optimum age for milk production. It is to be assumed that the actual genetic potential of the animal is higher than this. Average peak yield of 3.71 kg is indicative of a higher milk yield. Lactation length is short, i.e. only 217 days, probably due to the advanced age of the animals. Whether these are specific traits of the breed can be ascertained only with studies on young animals coming to production.

It can be concluded that the dwarf cattle of Kerala which include the Vechur cattle has unique characteristics of its own and give separate identity to this group. The genetic characterisation of this type brings out the necessity of conservation of their germplasm.

Summary

SUMMARY

The studies conducted to characterise and evaluate the dwarf cattle of Kerala revealed the following results.

1. The diploid chromosome number of the dwarf cattle was 60, which comprised 58 autosomes and two sex chromosomes. The females were with XX and males XY sex chromosomes.

2. All the 29 pairs of autosomes were acrocentric in appearance. The X chromosomes in both sexes showed a biarmed submetacentric appearance. The Y chromosomes were acrocentric .

3. The relative lengths of autosomes ranged from 1.757 to 5.431 per cent. the relative length of X chromosome was found to be 5.591 per cent and that of Y chromosome was 2.875 per cent. In the karyological array the X chromosome occupied the first position.

4. The X chromosome was biarmed and the arm ratio and centromere index were found to be 2.182 and 0.314 respectively. All other chromosomes were acrocentric and hence the arm ratio and centromere index could not be estimated.

5. A total of 72 regions and 314 G-bands were observed. A pale or dark distal positive G-bands were observed in chromosome numbers, 1, 5, 6, 8, 9, 14, 15, 17, 19, 20, 22, 25 and the 'p' arm of X. Distal negative G-bands were seen in chromosome numbers 2, 3, 4, 7, 10, 11, 12, 13, 16, 18, 21, 23, 24, 26, 27, 29 and the 'q' arm of X. The Y chromosome had only the 'q' arm with seven G-bands.

6. Two types of haemoglobin variants were observed - a fast moving B and the slow moving A type. Three phenotypes viz. Hb^{AA}, Hb^{AB} and Hb^{BB} were observed.

7. The gene frequency of Hb^{A} allele was found to be 0.596 and that of Hb^{B} allele was 0.404. The frequencies of Hb^{AA}, Hb^{AB} and Hb^{BB} were 0.404, 0.384 and 0.212 respectively.

8. The genetic variability of the population at the haemoglobin locus was measured by the heterozygocity which came to 0.4815. The population was in genetic equilibrium with respect to haemoglobin locus.

9. Six transferrin phenotypes Tf^{AA}, Tf^{DD}, Tf^{EE}, Tf^{AD}, Tf^{AE} and Tf^{DE} controlled by 3 alleles, Tf^{A}, Tf^{D} and Tf^{E} in order of decreasing mobilities towards the anode were observed.

10. The genotypic frequencies of Tf^{AA}, Tf^{DD}, Tf^{EE}, Tf^{AD}, Tf^{AE} and Tf^{DE} were 0.031, 0.563, 0.125, 0.031, 0.031 and 0.219 respectively. The gene frequencies of Tf^{A}, Tf^{D} and Tf^{E} were 0.063, 0.578 and 0.359 respectively. The frequency of the Tf^{E} allele in dwarf cattle was as high as frequency of the allele reported in zebu cattle. The absence of transferrin variants like Tf^{F}, Tf^{H}, Tf^{N} and Tf^{G} and higher frequency of Tf^{E} allele are probably indicative of the genetic isolation of the population from exotic breeds. The absence of Tf^{B} and Tf^{F} allele which is present in Gir, Hariana, Kankrej, Kangayam, Ongole, Red Sindhi, Sahiwal and Tharparkar also indicates a separate line of inheritance for the dwarf cattle.

11. The mean birth weight of female and male calves were 10.78 kg $\pm$ 0.40 with a C.V. of 15.02 per cent and 12.55 kg $\pm$ 0.31 with a C.V. of 7.86 per cent respectively. The length, heart girth, and height (in cms) at birth were 45.93 $\pm$ 0.74 (C.V. 6.46%), 53.03 $\pm$ 0.62 (C.V. 4.70%) and 53.46 $\pm$ 0.54 (C.V. 4.10%) respectively in females. The corresponding values in males were 46.3 $\pm$ 0.51 (c.v. 3.49%) 53.8 $\pm$ 0.89 (c.v. 5.24%) and 55.1 $\pm$ 0.74 (c.v. 4.25%) respectively.

12. The heart girth measurement and body weight showed positive correlation from birth to the 24th fortnight ($r = 0.933$). There is a 100 per cent increase in birth weight by the 5th fortnight and a three fold increase by the 10th fortnight.

13. The average daily gain in weight for the four periods i.e., fortnights 0-6, 7-12, 13-18 and 19-24 were 0.160 ± 0.011, 0.167 ± 0.018, 0.212 ± 0.011 and 0.139 ± 0.015 kg respectively for female calves and 0.188 ± 0.023, 0.145 ± 0.016, 0.116 ± 0.025, 0.242 ± 0.049 kg respectively in male calves. During the period from birth to 6th fortnight the growth rates in males and females were similar. The gain in body weight per day during the periods from 7 to 12th and 13 to 18th fortnight was comparatively less for males but the trend reversed during the period of fortnights for 19 to 24th.

14. The average body weights of adult females and males were 126.90 ± 3.56 kg (c.v. 16.39%) and 210.5 ± 15.75 kg (c.v. 14.95%) respectively. The body measurements such as length, heart girth and height (in cms) in females were 97.5 ± 1.12 (c.v. 5.85%), 115.60 ± 1.32 (c.v. 5.82%) and 87.53 ± 0.82 (c.v. 4.82%) respectively. The

corresponding figures in males were 111.5 ± 3.77 (c.v. 6.76%), 146.0 ± 2.92 (c.v. 3.99%) and 107.5 ± 1.35 (c.v. 2.50%) respectively.

15. The mean lactation yield was 471.68 ± 38.72 kg (c.v. 45.29%) in an average lactation length of 217 ± 16.5 days (c.v. 32.2%). The average daily yield was 2.17 ± 0.11 kg (c.v. 27.48%). The dwarf cattle attained a mean peak yield of 3.71 ± 0.16 kg (c.v. 21.51%) in 23.23 ± 1.70 days (c.v. 37.38%).

Considering the morphology of the Y chromosome, the Hb as well as Tf polymorphism and their allelic frequencies, it is to be summarised that the stock of dwarf cattle of Kerala maintained at Kerala Agricultural University is genetically isolated from the exotic breeds and other zebu breeds. The body size and milk production of the cow indicates its suitability for a farmer who requires milk just for home consumption. The study strongly confirms the necessity of conservation of the dwarf cattle of Kerala which is the smallest variety available in India and perhaps in the world itself.

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CHARACTERISATION AND EVALUATION OF THE DWARF CATTLE OF KERALA

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ABSTRACT

The native cattle of Kerala have been treated as non descript animals always eventhough they possess some special features. The dwarf cattle often called as Vechur were very popular in Central Travancore until 35 years back. With the emergence of the crossbred population of cattle the traditionally reared local cattle have gradually suffered genetic erosion. Under this circumstance, the present work was undertaken to characterise and evaluate the germplasm of local dwarf cattle of Kerala by studying (a) the karyotype and morphology of chromosomes using G-banding (b) the population structure by means of gene frequencies of different blood proteins (c) the growth and production performance. The characterisation and the evaluation would help in finding out the genetic differences of the dwarf cattle which will help in deciding about the conservation of their germplasm as a reserve for the future.

The dwarf cattle maintained under the ICAR scheme on "Conservation of germplasm of Vechur cattle of the coastal area and the dwarf cattle of the high ranges of Kerala" formed the material for the study.

The characterisation and evaluation was carried out through the cytogenetic, immunogenetic and polymorphism studies as well as through the description of the growth and production traits. Karyotype analysis was carried out using peripheral blood leukocyte culture technique described by Halnan (1977) and Halnan (1989) with suitable modifications. G-banding of chromosomes were done by the method described by Thiagarajan (1993). Blood protein polymorphism systems such as Haemoglobin and transferrin were studied by poly acrylamide gel electrophoresis in horizontal dimension (Gahne et al. 1977) with suitable modifications. The statistical analysis of the growth and production data were done as suggested by Snedecor and Cochran (1967).

The diploid chromosome number of the dwarf cattle was found to be 60, with 29 pairs of autosomes and one pair of sex chromosomes. All the autosomes and the 'Y' chromosome were acrocentric. The X chromosome was submetacentric. The relative length of the autosomes ranged from 1.757 to 5.431 per cent. The relative length of the X and Y chromosomes were found to be 5.591 per cent and 2.875 per cent respectively. In the karyological array, the X chromosome occupied the first position. The X chromosome was biarmed and the arm ratio and centromere index obtained were 2.182 and 0.314 respectively. The karyotype and morphometric measurements resembled the

finding in Bos indicus group of cattle. The G-banding pattern of chromosomes revealed 72 regions and 314 G-bands. The Y chromosome had 7 G-bands in the 'q' arm which resembled the 'q' arm of Bos taurus described in the international system for cytogenetic nomenclature of domestic animals.

There were two haemoglobin variants Hb^{A} and Hb^{B} and three phenotypes viz. Hb^{AA}, Hb^{AB} and Hb^{BB}, in the population. The heterozygocity was found to be 0.4815. The population was found to be in genetic equilibrium with respect to the Haemoglobin locus.

Six transferrin phenotypes controlled by three alleles Tf^{A}, Tf^{D} and Tf^{E} were observed. The frequency of Tf^{E} (0.359) allele in the dwarf cattle was as high as the frequency of the allele reported in the zebu cattle. The absence of transferrin variants like Tf^{F}, Tf^{H}, Tf^{N} and Tf^{G} and higher frequency of Tf^{E} allele are probably indicative of the genetic isolation of the population from exotic breeds. The absence of Tf^{B} and Tf^{F} allele which is present in Gir, Hariana, Kankrej, Kangayam, Ongole, Red Sindhi, Sahiwal and Tharparkar also indicates that the dwarf cattle has not inherited genes from the above cattle breeds.

The body weights and measurements of calves at birth studied showed that the male calves had a higher body weight

(12.55 ± 0.31 kg with a CV of 7.86 per cent) than female calves (10.78 ± 0.40 kg with a CV of 15.02 per cent). The same trend was observed with regard to the birth body measurements also. The heart girth measurement and body weight showed a positive correlation from birth to the 24th fortnight. There is a 100 per cent increase in the birth weight by the 5th fortnight and a three-fold increase by the 10th fortnight. The average daily gain in weight for the four periods i.e., fortnights 0-6, 7-12, 13-18 and 19-24 were 0.160 ± 0.011, 0.167 ± 0.018, 0.212 ± 0.011 and 0.139 ± 0.015 respectively for female calves and 0.188 ± 0.023, 0.145 ± 0.016, 0.116 ± 0.025, 0.242 ± 0.049 kg respectively in male calves. During the period from birth to 6th fortnight the growth rates in males and females were similar. The gain in body weight per day during the periods from 7 to 12th and 13 to 18th fortnight was comparatively less for males but the trend reversed during the period of fortnights for 19 to 24th.

The average body weights of adult females and males were 126.90 ± 3.56 kg (CV 16.39%) and 210 ± 15.75 kg (CV 14.95%) respectively. The body measurements such as length, heart girth and height (in cms) in females were 97.5 ± 1.12 (CV 5.85%), 115.60 ± 1.32 (CV 5.82%) and 87.53 ± 0.82 (CV 4.82%) respectively. The corresponding figures in males were

111.5 ± 3.77 (CV 6.76%), 146.0 ± 2.92 (CV 3.99%) and 107.5 ± 1.35 (CV 2.50%) respectively. The average body weights and measurements were lesser than those reported in other Indian breeds and crossbred cattle.

The total lactation milk production performance of the dwarf cattle was 471.68 ± 38.72 kg (CV 45.29%) in an average lactation length of 217 ± 16.50 days (CV 32.20%). The average daily yield was 2.17 ± 0.11 kg (CV 29.48%). The dwarf cattle attained a peak yield of 3.71 ± 0.16 kg (CV 21.5%) in 23.23 ± 1.703 days (CV 37.38%). The milk production performance eventhough was lesser than crossbreds or some recognised Indian breeds, the milk production in comparison with the body size was reasonable.

Considering the morphology of the Y chromosome, the Hb as well as Tf polymorphism and their allelic frequencies, it is to be summarised that the stock of dwarf cattle of Kerala maintained at Kerala Agricultural University is genetically isolated from the other cattle breeds of the country and world. The body size and milk production of the cow indicates its suitability for a farmer who requires milk just for home consumption. The study strongly confirms the necessity of conservation of the dwarf cattle of Kerala which is the smallest variety available in India and perhaps in the world itself.