Goat Genetic Resources of India

MARWARI

- The Pride of hot-arid region of India

S.P. Dixit
N.K. Verma
R.A.K. Aggarwal
Dinesh Kumar
Rekha Sharma
S.P.S. Ahlawat

National Bureau of Animal Genetic Resources
(Indian Council of Agricultural Research)
P.O. Box No. 129, Karnal (Haryana)

Monograph 14, 2005

Goat Genetic Resources of India

MARWARI

– The pride of hot-arid region of India

S.P. Dixit, N.K. Verma, R.A.K. Aggarwal,
Dinesh Kumar, Rekha Sharma, S.P. S. Ahlawat

National Bureau of Animal Genetic Resources

(Indian Council of Agricultural Research)

G.T. Road By Pass, P.O. Box No. 129, Karnal-132001 (Haryana) India

PREFACE

Goat is an important species of livestock in the country, mainly on account of their short generation interval, higher rate of prolificacy, and the easy marketing of live animals as well as their products. It produces variety of products and by-products like meat, milk, skin and fibre. This species is of economic importance to the people living in arid, semi arid, hilly and heavy rainfall and tribal areas, where goats can sustain themselves on meager forage and extreme climatic conditions where other species of animals may perish. Goats are the main meat animals in the country; their meat is the most preferred and hence costliest of all meats. Almost 95 % of the goat meat produced is consumed locally. However, the per capita availability is still far below the requirement. There is, therefore, considerable potential for developing goat production not only for meat for internal consumption but also for export. The quality leather production does rank high among goat-skin exporting countries. The non-traditional items from goat for export may include certain milk products like cheese and milk powder, for which internal demand is not much.

The current goat population is estimated to around 128 millions (1999-2000) and it may reach 137 millions by 2005. The current mean rate of slaughter of goats is around 41% and the man rate of mortality around 15.5%. The goat population has increased from 47.2 millions in 1951-52 to 115.3 millions in 1991-1992 and 120.6 millions in 1996-1997 with annual growth rate of 3.6 and 3.4%, respectively with reference to the population in 1951-52. Combining the annual rate of population growth of 3.4% with mean slaughter and mortality rates, the goats have shown the potential of 60% annual growth rate. This is the single factor that makes goats as most desired species of animals for meat production. Goats have an advantage over sheep on account of their better prolificacy. 410 million kg of goat meat represented almost 37% of total meat produced in the country, although 1900 million kg of milk represented 3% of the total milk produced. Among other products, skins amounted to 101 million kg, pashmina to 30 metric tones, and manure estimated around 85 00 metric tones.

A study in Tamil Nadu showed that goats provided gainful employment of about 184, 309 and 437 labor man days per annum in small (1-8 goats), medium (9-16 goats) and large (above 16 goats) flocks, respectively. Women and children contributed to this labor force to the extent of 88-91% in all the groups.

In spite of all these advantages from goat rearing, the development efforts have suffered on account of the popular belief that goats cause deforestation and environmental degradation. One of the reasons for such belief is on account of the inherent capacity of goats to survive in the worst of agro-geo-climatic regions. However, the rate at which the goat population has increased would not have been possible if the goats had been responsible for such degradation. Hence, there is imperative need to take up goat development schemes on war footing to exploit the inherent capacities of goat and encouragement should also be given to those interested to exploit goats for intensive meat production, and product technology for export. Here in this bulletin, an effort has been made to present breed characteristics, geographic distribution, the existing management practices, approximate population and genetic variability in the Marwari breed of goat.

The authors take this opportunity to thank Dr A K Patel, Central Arid Zone Research Institute, Jodhpur (Rajasthan), India and his staff for their help at various stages of generating the information. The assistance rendered by Sh Subhash Chander, Immunogenetics Lab, NBAGR, Karnal in collection of field data and preparation of this manuscript is gratefully acknowledged. We are also thankful to the farmers of the breeding tract for their cooperation and assistance.

राष्ट्रीय पशु आनुवंशिक संसाधन ब्यूरो

NATIONAL BUREAU OF ANIMAL GENETIC RESOURCES

(I.C.A.R.)

Makrampur Campus, G.T. Road Bye Pass, Near Basant Vihar,
P.O. Box. No. 129, KARNAL - 132 001 (Haryana)

Dr. S.P.S. Ahlawat
DIRECTOR

Phones : 0184-2267918 (O)
0184-2267247 (O)
0184-2267518 (R)
Fax : 0184-2267654
E-mail : director@nbagr.ernet.in
Gram : GENETICS

FOREWORD

Goats form an integral part of Animal Husbandry and contribute significantly to the Indian economy. Marwari, an important dual-purpose (meat and milk) goat breed, is found in great Thar Desert in Northwestern region of Rajasthan (India). The breed is well adapted to the inhospitable agro-climatic, wider range of vegetation, and management conditions of the hot arid region. The Marwari goats are also superior to other livestock species of the region viz. cattle, sheep, donkey and camel in water use efficiency under water scarcity conditions. The adaptive characteristics make this breed suitable for development and sustainability of meat industry as well as for its own sustainable improvement under the peculiar characteristics of the arid region. Moreover, the breed is suitable for resource poor farmers rearing these animals under fairly simple and extensive production system with a relatively low level of managerial skills. Inspite of their ecological and economic importance, the Marwari goats are inadequately characterized. A systematic survey was, therefore, undertaken by the scientists of NBAGR, Karnal to determine geographic distribution, establish breed characteristics, study the existing management practices, genetic variation, and estimate the approximate population of Marwari breed in its breeding tract. I hope that the bulletin "Marwari Goat- The pride of hot-arid region of India will be useful to the researchers, surveyors and policy planners in taking up the research programmes for further improvement of this breed. I wish to congratulate all the authors for their endeavour in bringing out this bulletin.

(S.P.S. Ahlawat)

CONTENTS

Molecular techniques	3
Statistical analysis	4
Breeding tract of the breed	5
Climatic conditions of the region	5
Body confirmation traits	7
Management of the flock	8
The flock size and breeding management	12
Production performance	13
Reproduction performance	16
Diseases and reproductive problems	17
Genetic variation	18
References	25

Introduction

Marwari, an important dual-purpose (meat and milk) goat breed, is found in great Thar Desert in Northwestern region of Rajasthan (India). The breed derived its name from 'Marwar' region of Rajasthan, which is the natural habitat of the breed. The breed is also known as Barmeri or Black Desert goat of Rajasthan. The breed is well adapted to the inhospitable agro-climatic, wider range of vegetation, and management conditions of the hot arid region. The breed grows faster, breeds more efficiently, tolerate higher salt loads, needs less water and has liking for a wider variety of feeds including many weeds, shrubs etc. than sheep (Rohilla and Patel, 2003). The Marwari goats are also superior to other livestock species of the region viz. cattle, sheep, donkey and camel in water use efficiency under water scarcity conditions (Khan and Ghos, 1981). These goats may lose 1.5% of their body weight/day when water deprived compared to 2, 6 and 8% loss in camel, sheep and cattle, respectively (Shankarnarayan *et al.*, 1985). The adaptive characteristics make this breed suitable for development and sustainability of meat industry as well as for its own sustainable improvement under the peculiar characteristics of the arid region. Moreover, the breed is suitable for resource poor farmers rearing these animals under fairly simple and extensive production system with a relatively low level of managerial skills. Inspite of their ecological and economic importance, the Marwari goats are inadequately characterized. A systematic survey was, therefore, undertaken to determine geographic distribution, establish breed characteristics, study the existing management practices and estimate the approximate population of Marwari breed in its breeding tract.

Currently, microsatellites are widely used to assess the genetic variability at the DNA level since they are numerous, randomly distributed in the genome, highly polymorphic, and show co-dominant inheritance. In the present study, an attempt has also been made to find out within breed genetic diversity using microsatellite molecular markers. The resulting information from this study may be useful for planning sustainable improvement, conservation and utilization of the breed.

Information on three body biometric characteristics viz. body length from shoulder to pin bone, chest girth and height at wither, and qualitative confirmation attributes and body weights of 284 animals were recorded. These animals included both male and females, though most of them were adult. The information on about 57 stall fed animals was also recorded. The information on feed, management and breeding practices, flock size and its structure, reproductive performance and disease prevalence in the breeding tract was collected through formal interviews (Fig. 1) using a structured questionnaire given to goat owners, who were chosen at random within a structured, stratified framework. In each district, a two stage stratified sampling technique was used. At least two villages within each district, and two goat breeders within each village were chosen at random for the interview. In total, 80 goat breeders across 37 villages over 7 districts were interviewed and the information was recorded. The additional information, if any, was also collected from the veterinary hospital of the village. The total population of Marwari goat was estimated by superimposing the

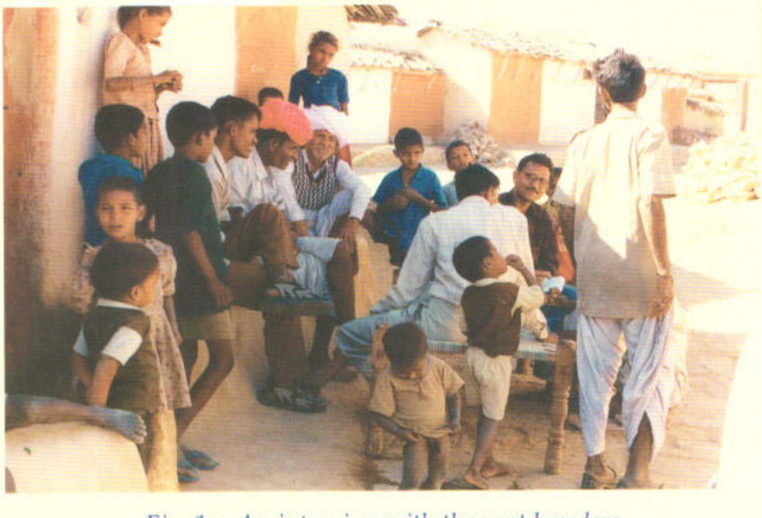

Fig. 1 : An interview with the goat breeders

population obtained through the survey on the Livestock Census data of goat (17[th] Livestock Census, 2003, Govt of India, 2004) in each district.

Molecular techniques

Genomic DNA was isolated from blood samples of 50 unrelated animals of the breed by the method described by Sambrook *et al.* (1989). A battery of 25 microsatellite markers (Table 2) was selected based on the guidelines of ISAG & FAO's DADIS programme to generate data in a panel of 50 animals. Polymerase Chain Reaction (PCR) was carried out on about 50-100 ng genomic DNA in a 25 ml reaction volume. The reaction mixture consisted of 200 mM each of dATP, dCTP, dGTP and dTTP, 50mM KCl, 10mM Tris-HCl (pH 9.0), 0.1% Triton X-100, 2.0 mM $MgCl_2$, 0.75 unit Taq DNA polymerase and 4 ng/ml of each primer using PTC-200 PCR machine (M J Research). The "touchdown" PCR protocol used with initial denaturation of 95 ^{0}C for 1 min, 3 cycles of 95 ^{0}C for 45 sec and 60^{0}C for 1 min, 3 cycles of 95 ^{0}C for 45 sec and 57^{0}C for 1 min, 3 cycles of 95 ^{0}C for 45 sec and 54^{0}C for 1 min, 3 cycles of 95 ^{0}C for 45 sec and 51^{0}C for 1 min, 20 cycles of 95 ^{0}C for 45 sec and 48^{0}C for 1 min. At the end of the reaction, 5.0 ml of stop dye (95% formamide, 0.25% bromophenol blue and 0.25 % xylene cyanol) was added and 6 ml of PCR products were loaded on to a 2 % agarose gel, electrophoresed and visualized over UV light after ethidium bromide staining to detect the amplification.

The PCR products were resolved on 6% denaturing polyacrylamide gels (Sequi GT System, Bio-Rad), 10 bp ladder (Invitrogen life technologies) was used as a size standards for sizing PCR products. To visualize the PCR products gels (Fig 2) were stained using silver staining (Bassam et al., 2001) and dried between sheets of cellophane papers. The genotypes were scored manually. The size of the alleles was calculated online using 'INCHWORM' programme which estimates the length of the molecule, based on the electrophoretic mobility (http://www.molecularworkshop.com/programs/inchworm.html).

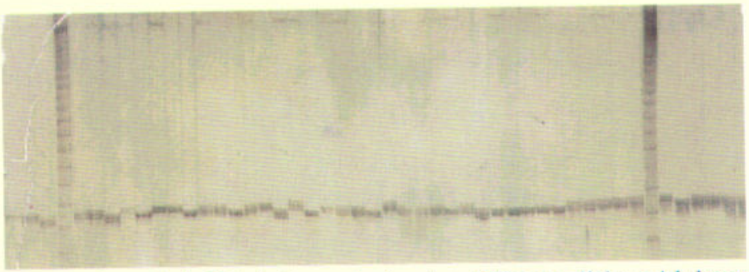

Fig. 2 : A typical Gel photograph showing different alleles with locus ILSTS059 in Marwari Goat. (10 bp marker)

Statistical analysis

For 25 microsatellites loci analyzed, observed and expected heterozygosity estimates were calculated after Levene (1949) and Nei (1973) as implemented in POPGENE software (Yeh et al., 1978). The observed and effective numbers of alleles (Kimura and Crow, 1964) were also calculated using POPGENE software.

The tests for deviation from Hardy-Weinberg equilibrium were derived using the exact tests of POPGENE. Heterogeneity of deviations from Hardy-Weinberg equilibrium among the microsatellite loci was examined by treating the deviations as correlation coefficient and tested accordingly (Barker et al., 2001). As samples were obtained from different localities (districts), deviations from Hardy-Weinberg equilibrium in the population could be due to genetic differences between subpopulations and a consequent Wahlund effect. Given the observed allele frequencies in each subpopulation, the expected hetrozygote deficit due to Wahlund effect can be computed (Li, 1976). Expressing this as a percentage of observed heterozygote deficit then measures the contribution of Wahlund effect to the observed hetrozygote deficit. Heterozygote deficiencies were expressed as $D= [H_0 - H_E] / H_E$ where H_0 is the observed frequency of hetrozygotes and H_E the expected frequency.

Tests for pair wise linkage (genotypic) disequilibrium among the microsatellite loci were done using FSTAT version 2.9.3 an update version 1.2 (Goudet, 1995) for 25 microsatellite loci whose genotypes were determined directly. F-statistics were determined after Weir & Cocheram (1984) as used in F-Stat software with Jackknifing procedure applied over loci in deriving significance levels and Bootstrapping applied over loci in deriving 95% confidence intervals for these statistics. These parameters of population structure are defined as the correlations between pairs of genes (i) within individuals (F) (ii) between individuals in the same population (q), and (iii) within individuals within populations (f), and are analogous to Wright's (1978) F_{IT}, F_{ST} and F_{IS}, respectively.

Finally the bottleneck hypothesis was investigated using BOTTLENECK 1.2.01(Cornuet and Luikart, 1996). The BOTTLENECK tests for the departure from mutation drift equilibrium based on heterozygosity (not hetrozygote), excess or deficiency. This does not require information on historical population sizes or level of genetic variations. It requires only measurement of alleles frequencies from 5-20 polymorphic loci in a sample of approximately 20-30 individuals. The bottleneck compares heterozygosity expected (H_E) at Hardy-Weinberg equilibrium to the heterozygosity expected (H_{eq}) at mutation drift equilibrium in same sample, that has the same size and the same number of alleles. Two models of mutation were used to calculate H_{eq}: the strict one stepwise mutation model (Ohta & Kimura, 1973) and the infinite allele model (Kimura and Crow 1964).

Breeding tract of the breed

The Marwari goats are found within 25° 22'to 28° 01' N latitude and 70° 57'to 73° 40'E longitude. The breed is distributed over 7 districts of Rajasthan viz. Barmer, Bikaner, Jalore, Jaisalmer, Jodhpur, Nagaur and Pali in Great Thar Desert of Rajasthan state of India (Fig. 3). Rabaris, Meenas and Bhils communities of the region reared the Marwari goats for mutton and milk purposes.

Climatic conditions of the region

The Marwari goat breed is found in great Thar Desert in Northwestern region of Rajasthan, which is characterized by very low and

Fig. 3 : The Breeding tract of Marwari breed of goat in Rajasthan marked with black colour.

erratic rain fall and hot climatic conditions. The annual rainfall varied from 18 to 42 cm in different seasons. The temperature reached as low as -0.8° C in winter and as high as 46° C in summer. The humidity in the region varied from 39 to 48%.

Body confirmation traits

Marwari goats were medium sized and uniformly black colored animals with shinny light gray skin (Fig. 4). The muzzle, eyelids and hoofs were also black coloured. The eyes were attractive with medium nose. The horns were small (2″) to long (11″) corkscrew type with grayish black colour in both the sexes. The horns were curved upward or backward (rare). The pendulous ears were small (3″) to long (9″) and speckled, flattened or folded leaf like. The fore head was convex with curly tuft of hair particularly in male (Fig. 5). The thick beard was present in both the sexes. The tassels were also seen in some animals. The tail of the Marwari goat was curved upward. The males were heavier than females and showed higher length, height and girth measurements (Table 1).

Fig. 4 : A Marwari doe browsing in the pasture

Fig. 5 : Marwari buck

Table 1. Biometrical characteristics of Marwari breed of goat

Age/Trait	1 Month	3 Month		6 Month		Adult	
	Kids	Male	Female	Male	Female	Male	Female
No.	19	9	14	11	16	12	203
Weight (Kg)	9.47±0.45	12.89±1.22	13.50±0.80	20.91±0.55	19.94±1.23	39.51±2.24	31.86±0.42
Length (Inch)	17.29±0.39	19.83±1.00	19.71±0.36	23.95±0.24	23.22±0.65	29.54±0.59	27.02±0.15
Height at whither (Inch)	17.96±0.28	21.94±1.67	21.96±0.37	25.64±0.27	25.13±0.60	31.17±0.55	28.05±0.12
Height at hip bone (Inch)	18.17±0.28	21.36±0.56	21.57±0.23	24.50±1.50	24.62±1.05	31.33±0.47	28.76±0.12
Chest girth (Inch)	17.67±0.40	20.89±0.90	21.36±0.44	24.36±0.23	24.53±0.61	30.75±0.66	28.99±0.15
Paunch girth (Inch)	17.93±46	21.38±1.28	22.10±0.62	25.81±0.55	25.81±0.92	32.08±0.90	30.67±0.20

Management of the flock

The flocks are usually stationary (Fig 6) but during scarcity of fodder resources, they migrate to the adjoining states of Haryana, Madya Pradesh, Uttar Pradesh and Gujarat states of the country for grazing. Goats depended mostly on grazing resources (Fig 7) but stall-fed were also found (Fig 8). The daily feed and water intake ranged from 500 to 600 g/day/animal and 1 to 1.5

Fig. 6 : A flock of Marwari goats resting in the open house

Fig. 7 : Khejri (Prosopis cineraria) trees in the pasture

Fig. 8 : Stall-fed goats

litre / day / animal, respectively as observed under field conditions. These goats can be well maintained on degraded pasturelands without any supplementation of feeds. Patel et al. (1999) observed highest body weight (31.0 kg) followed by Jamunapari (24.5 kg), Jakhrana (23.4 kg) and Prabatsar (22.8 kg) breed of goat under degraded pastureland grazing system.

These desert goats have shown maximum economy in water use in comparison to other types of goats examined (Annual Report, Central Arid Zone Research Institute, Jodhpur, 1998). Desert-dwelling goats are the hardiest of all domestic livestock species studied so far. Khan and Ghosh (1981) reported that when Marwari goats and Marwari sheep of the Rajasthan desert were deprived of water for four days in summer, the goats lost 1.5 per cent of their body weight per day as compared to 6 per cent loss per day in sheep. Reports from Australia and elsewhere indicated that, when water-deprived, cattle might lose, on an average, 8 per cent of their body weight per day, while temperate zone sheep breeds lose about 3-4 per cent of their body weight per day. Only the camel would appear to be somewhat nearer to the desert goat in respect of water use efficiency, losing only 2 per cent of the body weight per day when deprived of water . These reports indicate that goat is quite superior to cattle and sheep in water utilization when subjected to water scarcity conditions. This attribute, together with its flexible feeding habit and its high degree of reproductive success, would make the goat an appropriate animal for use under marginal ecological environments. This is quite evident from the ever increasing trend of the goat population of Western Rajasthan even during drought spells. In study conducted by Khan and Ghosh (1985) on the effect of water stress conditions stretching over 13 days on body water turn over rates (or the metabolic water input rates) in Marwari breed of goat and sheep and in the desert adapted donkey, the goat's remarkable efficiency in maintaining circulatory volume in comparison to that in other two species, has been clearly indicated. In all three treatment groups of experimental animals in this study viz. normally hydrated, partially water restricted and rehydrated, the body water turn over rates were consistently lowest in the goat. The effect of dehydration was very low in this goat breed as the body weight losses were very slow and gradual in comparison to other desert livestock species (Khan and Ghosh, 1985). The studies indicated that dehydration in these animals induces urea recycling almost immediately. These goats gave priority to maintenance of circulatory fluid volume over that of cell and gut water, which they used as an emergency water reservoir (Abichandani and Khan, 1984). The absorption of water from gut to the body may be high in this goat- a characteristic that has considerable eco-physiological implication.

The major fodder resources (Fig 9, 10, 11) in the breeding tract were Pala (*Zizyphus jujuba*), Khejri (*Prosopis cineraria*), Siris (*Albizzia sp.*), Ardu (*Ailanthus excelsa*), Shisham (*Dalbergia sissoo*), Ber (*Zizyphus rotundifolia)*, Neem (*Azadirachta indica*), Babool (*Acacia arabica*), Keeker (*Acacia nilotica*), Su babul (*Leucaena leucocephala*), Dhaman grass (*Grewia sp.*). They also showed a liking for the straws of edible lentils like guar, moth, moong, urad, etc. and those of cereals like Bajra, Jawar etc. These goats showed a marked preference for the leaves of Khejri tree, *Prosopis cineraria*, which contained as much as 15% tannin. The dry matter digestibility of this feed in goats was 49% (Bohra, 1980). These goats also showed special liking for the flowers of the Rohida (Tecomella undulata) tree and for the pods of *Prosopis juliflora* and *Acacia nilotica* in season.

Fig. 9

Fig. 10

Fig. 11

Natural fodder resources in pastures

The goat ability to switch its diet in order to accommodate food items that may be highly ephemeral yet nutritionally important warrants attention. In the Thar desert where edible vegetation is extremely scarce, the goats rely upon the abundantly available succulent leaves of Akra, Calotropis procera-alatex-bearing busy plant that is usually shunned by almost all other livestock species except the gazella, G dorcas. The goat may, on occasions, develop a special liking for a particular thing. For example, there is on record the case of a feral goat developing an unusual liking for roses, so much so that this animal may cross four feet high boundary walls to gain access to its favourite food whenever it smell the fragrance of roses.The upper mobile lip and the ability to assume a bipedal stance during feeding help the goat to nibble at the choicest food.

The stall-fed are also supplemented with concentrate (Guar, Moth, Barley, Gur, Bajra, Wheat, Gram, Lasi etc) @200-250 g per day per animal. The goats were kept in open houses during night. The houses are Katcha with half walled and temporary roof and there is no proper drainage for the urine to drain out and are part of the residence or separate.

The flock size and breeding management

The flock size varies from 5 to 100 (Fig 12). The larger flocks (>100) are also available in the region. The kids to adult ratio varies from 25:75 to

Fig. 12 : A mixed flock of goats en route to the pasture

40:60. The adults constitute the females except one buck in few flocks. The buck is generally selected on the basis of its own body weight and its dam's milk yield. However, such practice found preference with hardly 10% farmers in the breeding tract. Usually one buck is maintained for the flock size of 20 to 100 or even more. There is the practice to use common buck for the entire village and the buck is called 'Amar'.

Production performance

Body weights : The body weights of adult male and female as well as of kids of one to 6 months of age are presented in Table 1. The average body weight of male and female goat is 39.51 and 31.86 kg, respectively. The six months male and female kids weigh 20.91 and 19.94 kg on an average.

Milk yield and its quality : The milk yield (Fig 13) varies from 0.5 to 1kg when kept on pasture grazing and from 2 to 3 kg under stall fed conditions. The lactation length varied from 106 to 197 days (Patel *et al*., 1999). The milk compostion of Marwari goats for fat, total solids, solids not fat, total proteins, lactose and chloride ranged from 4.10 to 4.15, 13.0 to 17.1, 8.9 to 10.3, 3.3 to 3.4, 4.0 to 4.9 and 0.23 to 0.24%, respectively (Mittal, 1984). The goats are

Fig. 13 : Milking of Marwari goat in operation

better converter of feed ingredients than cows. This efficiency in the goat has been found more pronounced (185 kg milk per 100 kg digestible organic matter) than in cow (162 kg milk) and in ewes (135 kg milk). Unlike the cow, goat is almost 100 per cent efficient in converting feed carotene into vitamin A and hence the absolutely white colour of goat milk.

An important characteristic of goat milk is the small size of its suspended fat globules (dia 2 microns), making easier for the fat to be assimilated (Gamble et al , 1939) while cow milk requires about two hours for digestion, goat milk requires only 30 minutes. This is obviously of importance for infants and babies. Goat milk is alkaline while cow milk is acidic in nature, and the former contains not only 7 to 10 times the amount of iron and almost double the quantity of potassium found in the milk of the cow , but three extra minerals, salts and slightly more protein and vitamins as well. Knowles and Watkin (1938) stated that there are large number of well-authenticated cases of beneficial effects following the use of goat milk. The comparative freedom of goat from tuberculosis must always be a point in favour of consumption of its milk. There is , however , a strong prejudice in many quarters against goat milk due to its peculiar and somewhat offensive flavour. This can, however, be easily overcome if the lactating goats are kept away from the buck. It is the buck which emits the objectionable goaty odour, especially during the breeding season.

Carcass yield and its quality : The carcass quality of Marwari goats is very good with excellent colour, tenderness, juiciness and texture. The weight of slaughter, hot carcass weight, dressing percentage and meat: bone ratio of Marwari goat have been reported as 24.7±1.0 kg, 11.8±0.6 kg, 49.2±0.6 to 59.7±0.9 and 13.8±0.3 to 18.7±0.5, respectively (Misra, 1991, Mittal, 1988).

Fibre yield and its quality : The Marwari goats are prized for long locks of hair (Fig 14). The average hair production per year is 90.32, 158.24, 330.72, 404.00 and 470 g in male and 85.71, 150.42, 180.25, 220.41 and 230.32 g in female goats at 3, 6, 12, 24 and 36 months of age (Mital, 1988). The respective values for fibre diameter are 60.22, 62.15, 63.70, 71.42 and 98.66 μ for males and 58.75, 60.13, 60.22, 61.85 and 77.80 μ for females. The length of the hair

Fig. 14 : A Marwari doe with long locus of hair

varies from 2 to 9 cm in males and 2 to 7 cm in females depending upon the age. The effect of age is significant on the weight, length and diameter of the hair. The average values for weight, length and diameter of hair are significantly higher in males than in females.

Goat manure: Goat manure (Fig 15) is several times richer in nitrogen and phosphorus than the manure of cows or buffaloes. Goat urine is equally rich in both nitrogen and potash. It has been estimated that one hectare of

Fig. 15 : Heaps of Goat feaces used as manure

land receives a sufficient dressing of manure if 4800 goats are kept there for a single night (ICAR, 1981). It may be surprising but it is true that the annual receipt from the sale of goat manure exceeds that from the sale of milk.

Others: Besides the above, the horns and hoofs of goats are in demand for preparing horn and hoof meals, decorative articles, fertilizer and gelatine and the intestines of the goats are used to make surgical sutures and musical instruments.

Reproduction performance

The doe and buck show the sexual maturity at 9 to 12 and 6 to 10 months of age, respectively. The goat is a non-seasonal breeder though showing three major heats (Summer, spring and Winter) per year. The summer (May-June) is the main breeding season, and spring (February-March) and winter (Oct-Nov) are minor breeding seasons.

The animal kids twice in 16 months period. Generally there is one kidding per year and the doe conceive 8-10 times in its life span. The gestation period and kidding interval range from 145 to 158 days and 250 to 254 days, respectively. The females generally show heat symptoms 6 to 8 weeks after parturition and continue doing so at an interval of 18 to 21 days till the next conception takes place. The heat period in does generally lasts for 24 to 36 hours. In general, 10 per cent twinning was observed in Marwari goat, however, twinning and kidding percentage and multiple births improved with supplementary feeding under stall fed conditions. The farmers observed up to 50% twining under stall fed conditions. Mathur *et al.* (1999) reported 58% twinning with supplementary feeding in these goats. This showed the genetic potential of the breed for twinning trait. The kidding percentage observed under field conditions was 80-90%. The breeders observed 5% abortions, 1-2% still births and 5-10% post gestational mortality of the kids.

Semen characteristics and sexual behaviour in males: The mean values for ejaculate volume, per cent motile sperms, sperm density ($x10^8$) , total number of sperms ($x10^8$) , per cent live sperms and per cent abnormal sperms have been observed as 0.65, 73.75, 20.44, 12.88, 75.73, and 7.71, respectively. Season has no effect on these characteristics. The average values for hydrogen-ion concentration, methylene blue reduction time (min), fructose (mg/100 ml) and DNA (mg/100 billion sperms) in semen are 6.85, 2.10, 712.78, 571.32, 757.27 and 2.15, respectively. These values do not differ with seasons (Mittal, 1988).

The average values for age and weight at maturity in male kids are 12 months and 17.10 kg, respectively. The number of ejaculations (3.20 in 30 min), the time taken for first mount (1.30 min) and first ejaculation (2.23 min) do not vary significantly between seasons of the year and thus proved that the Marwari bucks are non-seasonal in their reproductive behavior (Mital, 1988). The mean values for ejaculate volume, per cent motile sperms, sperm density (X 10^8), per cent live sperms and per cent abnormal sperms are 0.65, 73.75, 20.44, 12.88,75.73 and 7.71, respectively. Season has no effect on these characteristics.

Diseases and reproductive problems

Infertility, prolapse, abortion, and stillbirths are reported to be the main reproductive problems in the region mainly due to mineral deficiencies. Pica and general weakness is observed due to mineral deficiency in the animals. Foot and mouth disease, mastitis, jaundice, diarrhoea, bloating, goat pox and respiratory problems are also observed.

Population status

The total population of Marwari breed in its breeding tract was 19,77,622 based on sampling estimates. The population varies from 20% (Jodhpur district) to 50% (Pali district) of the total goat population across the districts under study. Therefore, the population status is normal based on numerical strength of the breed. The results indicated that there is a good scope for the improvement of the breed both by selective breeding selite bucks and improvement in management practices particularly the feeding practices.

Genetic variation

The Marwari goat karyotype has 30 pairs of chromosomes (2N=60), out of which 29 pairs are acrocentric autosomes. Various measures of genetic variation based on micro satellite studies are presented in the tables 2 and 3. The F-statistics estimates are presented in table 4.

The number of alleles observed across the microsatellite loci studied varies from 2 (ILST065) to 9 (ILST033) with an overall mean of 5.80 ±0.08 (Table 2). The observed number of alleles across the loci is more than the effective number of alleles (1.1 to 5.4) as per expectations. The Shannon information index (Table 2) shows that all the loci except one (ILSTS065) are highly informative indicating the high polymorphism across the loci with an overall mean of 1.2945. The average observed hertozygosity is lesser than the expected (Table 3). The average expected gene diversity (Nei, 1973) within the population range from 0.1195 (ILSTS065) to 0.8150 (Oar HH 64) with an overall mean of 0.6228±0.0410. Twenty of the total 25 loci studied show significant deviations from Hardy Weinberg Equilibrium. All the loci except one show significant heterozygote deficiency in the Marwari goat population. Tests for heterogeneity of deviations from Hardy Weinberg Equilibrium for all the loci studied show heterogeneity among loci (X^2 =1179, df 24, P< 0.01). Wahlund effects accounts for 1.55 to 14% of the observed hetrozygote deficiency at 4 loci only.

Significant linkage disequilibrium is detected in the overall microsatellite data for 19 out of 300 loci pairs. The overall means for the F-statistics were significantly different from zero. The relatedness among the individuals in the given sample is also significantly different from zero. The over all Rst, an estimator of genetic differentiation among these samples is 0.046. Rst and q Fst are of the same magnitude (0.046 and 0.051, respectively).

Table 2. Sample size (diploid genome), observed and effective number of alleles, and Shannon's Information index

S. No.	Locus	Sample Size	Observed number of alleles	Effective number of alleles	Information index
1.	ILSTS008	92	8.0000	2.9166	1.4068
2.	ILSTS059	92	4.0000	2.2716	0.9442
3.	ETH225	90	3.0000	1.4372	0.5680
4.	ILSTS044	88	6.0000	1.3624	0.6114
5.	ILSTS002	88	7.0000	3.8489	1.6266
6.	OarFCB304	94	8.0000	5.1733	1.7866
7.	OarFCB48	94	5.0000	3.6183	1.4300
8.	OarHH64	92	8.0000	5.4049	1.8351
9.	OarJMP29	94	6.0000	4.3102	1.5905
10.	RM4	90	4.0000	2.7054	1.1418
11.	ILSTS005	94	3.0000	1.7779	0.7781
12.	ILSTS019	84	6.0000	4.8595	1.6726
13.	OMHC1	92	6.0000	4.9671	1.6748
14.	ILSTS087	92	6.0000	5.1863	1.7135
15.	ILSTS30	92	6.0000	4.3992	1.6295
16.	ILSTS34	94	6.0000	1.4052	0.6922
17.	ILSTS033	92	9.0000	4.2236	1.7513
18.	ILSTS049	94	5.0000	3.9167	1.4632
19.	ILSTS065	94	2.0000	1.1357	0.2374
20.	ILSTS058	70	8.0000	3.6458	1.6334
21.	ILSTS029	92	8.0000	2.0484	1.1779
22.	RM088	92	6.0000	1.6694	0.8633
23.	ILSTS022	82	3.0000	2.7091	1.0399
24.	OARE129	88	7.0000	4.8099	1.6913
25.	ILSTS082	68	5.0000	3.4559	1.4023
	Mean	89	5.8000	3.3303	1.2945
	St. Error	.0796	0.0914		

Effective number of alleles [Kimura and Crow (1964)]
Shannon's Information index [Lewontin (1972)]

Table 3. Sample size (diploid genotype), genetic variation and significant tests of deviation from Hardy-Weinberg equilibrium

S. No.	Locus	Sample Size	Heterozygosity[a] Observed	Expected	Nei's	Heterozygote Deficiency[b]	f-value[c]
1.	ILSTS008	92	0.5652	0.6644	0.6571	-0.1493	-*
2.	ILSTS059	92	0.5870	0.5659	0.5598	0.0372	0.280
3.	ETH225	90	0.2222	0.3076	0.3042	-0.2776	-
4.	ILSTS044	88	0.2500	0.2691	0.2660	-0.0709	0.182
5.	ILSTS002	88	0.6136	0.7487	0.7402	-0.1804	0.193
6.	OarFCB304	94	0.6596	0.8154	0.8067	-0.1910	0.187
7.	OarFCB48	94	0.5957	0.7314	0.7236	-0.1855	
8.	OarHH64	92	0.5000	0.8239	0.8150	-0.3931	0.397
9.	OarJMP29	94	0.7021	0.7763	0.7680	-0.0576	0.205
10.	RM4	90	0.4889	0.6375	0.6304	-0.2331	-
11.	ILSTS005	94	0.4255	0.4422	0.4375	-0.0377	-
12.	ILSTS019	84	0.8810	0.8038	0.7942	0.0960	0.489*
13.	OMHC1	92	0.4130	0.8075	0.7987	-0.4885	0.389
14.	ILSTS087	92	0.5000	0.8161	0.8072	-0.3873	0.585
15.	ILSTS30	92	0.3261	0.7812	0.7727	-0.5833	-
16.	ILSTS34	94	0.2553	0.2915	0.2884	-0.1241	0.500
17.	ILSTS033	92	0.3913	0.7716	0.7632	-0.4928	0.550
18.	ILSTS049	94	0.3404	0.7527	0.7447	-0.5728	-
19.	ILSTS065	94	0.1277	0.1208	0.1195	0.05711	0.538
20.	ILSTS058	70	0.3429	0.7362	0.7257	-0.5342	-
21.	ILSTS029	92	0.5000	0.5174	0.5118	-0.0336	0.197
22.	RM088	92	0.3261	0.4054	0.4010	-0.1956	0.773
23.	ILSTS022	82	0.1463	0.6387	0.6309	-1.2070	-
24.	OARE129	88	0.7045	0.8012	0.7921	-0.0738	0.401*
25.	ILSTS082	68	0.4412	0.7212	0.7106	-0.4248	0.151*
Mean		89	0.4522	0.6299	0.6228	0.284	
St. Error			0.0372	0.0414	0.0410		

[a] *Expected heterozygosity were computed using Levene (1949) and Nei's (1973) expected heterozygosity*
[b] *Heterozygote deficiencies were expressed as D= (Ho –He)/He, refer the text for symbols used*
[c] *f-values (Weir and Cockerham 1984) given for significant tests after Bonferroni corrections*
* *Wahlund effects varied from 1.55 to 14.18%*

Table 4. F-statistics analyses for 25 microstellite loci in Marwari breed of goat

Locus*	$f(F_{IS})$	$\theta(F_{ST})$	$F(F_{IT})$	Relat	Relatc	R_{st}
ILSTS008	-0.035	0.030	-0.004	0.060	0.068	-0.026
ILSTS059	0.225	0.123	0.321	0.187	-0.582	0.181
ETH225	0.077	-0.015	0.063	-0.029	-0.166	-0.017
ILSTS044	0.144	0.063	0.198	0.105	-0.337	0.021
ILSTS002	0.169	0.008	0.175	0.013	-0.407	0.047
OarFCB304	0.205	-0.011	0.197	-0.018	-0.517	0.004
OarFCB48	0.082	0.052	0.130	0.092	-0.179	0.011
OarHH64	0.364	0.051	0.397	0.073	-1.146	0.067
OarJMP29	0.202	0.039	0.233	0.064	-0.505	0.027
RM4	0.024	0.018	0.041	0.034	-0.049	0.005
ILSTS005	-0.097	0.008	-0.089	0.017	0.178	0.016
ILSTS019	0.482	-0.021	0.471	-0.029	-1.860	-0.005
OMHC1	0.357	0.094	0.417	0.133	-1.111	0.270
ILSTS087	0.601	0.000	0.601	0.000	-3.013	-0.032
ILSTS30	0.110	-0.014	0.097	-0.025	-0.246	-0.027
ILSTS34	0.462	0.182	0.560	0.233	-1.715	-0.013
ILSTS033	0.529	0.054	0.554	0.069	-2.245	0.075
ILSTS049	-0.061	0.004	-0.057	0.009	0.115	0.004
ILSTS065	0.493	0.160	0.574	0.203	-1.943	0.042
ILSTS058	0.025	0.012	0.037	0.023	-0.051	0.019
ILSTS029	0.197	-0.007	0.191	-0.012	-0.490	-0.030
RM088	0.743	0.171	0.787	0.191	-5.782	0.295
ILSTS022	0.100	0.085	0.176	0.144	-0.222	0.122
OARE129	0.398	0.010	0.404	0.014	-1.325	-0.034
ILSTS082	0.139	0.009	0.147	0.016	-0.322	0.012
Mean[a]	0.264 (0.046)	0.051 (0.013)	0.302 (0.049)	0.078 (0.019)	-1.325	0.046

• Refer to the text for F symbols

*[a]Standard error in parentheses- estimate from jackknife over loci. * $p < 0.05$*

Relat, an estimator of the average relatedness of individuals within samples when compared to whole (Queller and Goodnight's, 1989)

Relatc estmates the inbreeding corrected relatedness (Pamilo, 1985)

[a]Standard errors – estimate from jackknife over loci and significance from t-test using these estimates, $p < 0.05$

The Sign and Wilcoxon tests could not detect any significant departure from mutation-drift-equilibrium in the population. However, standardized difference test indicated significant departure of the population from the mutation drift equilibrium under two phase and single step mutation models. The deviation is negative under two phase and single step mutation models (T_2 = - 1.67, -6.35, respectively, $P < 0.05$).

The Marwari breed of goat has substantial genetic variation based on its gene diversity and average number of alleles per locus. The average genetic variation (0.4522) observed in this study is lower than the values (0.54 - 0.69) reported for other five Indian breeds of goat viz. Black Bengal, Barbari, Chegu, Jamnapari and Sirohi (Behl et al., 2003; Ganai and Yadav, 2001). The Marwari population, however, shows more polymorphism across studied loci than these Indian breeds. The average genetic variation observed in this population is also lower than the average gene diversity (0.520) among populations of Asian goats (Barker et al., 2001). However, the genetic variation of similar magnitude was reported in Maasai, Maure, Arsai-Bale, and Djallonk goat breeds of Sub-saharan Africa (Chenyambuga et al., 2004).

All f (F_{IS}) estimates across the loci except 3 were significantly positive (significant hetrozygote deficit) based on table wide randomizations ($P< 0.05$). The f estimates ranged from 0.025 to 0.743 with an average of 0.264±0.046. The lower genetic variation observed in this breed compared to other Indian breeds may be due to higher rate of inbreeding. However, higher polymorphic information content across the studied loci may be due to lower frequency of alleles over the loci. Similar high estimates were also reported for Asian goat populations (Barker et al 2001). The f estimates obtained in the study contrast strongly with most of studies in livestock populations where f generally was not significantly different from zero even for rare breeds (Behara et al., 1998; Canon et al., 2000). However, significant hetrozygote deficiencies have been reported in some studies of goats (Luikart et al., 1999; Barker et al., 2001).

The significant hetrozygote deficiency found in Marwari breed of goat could be due to one or more of the following reasons: segregation of non–amplifying (null) alleles, Wahlund effects, scoring biases (heterozygotes scored incorrectly as homozygotes) or inbreeding. Distinguishing among these generally is difficult (Christiansen et al., 1974). However, null alleles are most unlikely to be segregating at all the loci. Similarly possible Wahlund effects (localities with known-subpopulations) do not account for more than 14% of the observed heterozygote deficit, and that too for just few loci in the population. Scoring bias may be possible for a few loci but not for all loci. Overall then there is strong inbreeding in this population is indicated by high value of f estimate (0.264), presumably resulting from the unplanned and indiscriminate mating prevalent in the breeding tract leading to small effective population size / or mating between relatives and consequent genetic drift. The general practice of breeding in the region was to allow a few bucks for the whole village. Therefore, inbreeding may be most reasonable cause of heterozygote deficit. The non-random association of alleles across the loci is also compatible with genotypic disequilibrium observed in the population. Both the samples (taken from different localities) were substantially differentiated from each other as indicated by the term theta and Rst estimates. These estimates are also in accordance with measures of Wahlund effect in the study. F_{IT} estimates revealed significant deviations (hetrozygote deficit) from Hardy-Weinberg equilibrium across most of the loci studied. These estimate showed global heterozygote deficit in the population after applying the Bonferroni corrections to different tests.

The individuals within samples were more closely related as compared to the whole data set of the entire population. However, it was quite interesting to note that the individuals within samples were quite dispersed when accounted for inbreeding among the samples as indicated by negative relatedness (Relatc = - 1.325). This indicated the influx of new germplasm in the population from outside. This is quite obvious in this region where there is a lot of intermixing with other breed(s) particularly with Sirohi breed of Rajasthan preferred by the breeders because of its high milk yield and lustrous coat color.

The negative T_2 statistics under TPM and SMM models indicated significant deficiency of heterozygosity, possibly caused by introduction of unique/rare alleles by immigrants. These T_2 statistics estimates were compatible with the negative relatedness (Relatc).

The population of the Marwari breed in its breeding tract was also assessed based on two stage stratified sampling techniques. The sample estimates from 21 villages across four districts were superimposed on Census data of goats available for each district (Rajasthan Statistical Abstracts, 2000) to work out the total population of the breed. There were around 10,00,000 breedable female population in its entire tract based on sample estimates. In spite of this large size population, the breed was getting diluted mainly due to intermixing and inbreeding in the population. These results strongly contrast with those of Nivsarkar and Bhat (1996), who pointed out that goat breeds with over 30,000 populations with no serious declining trend can be considered as normal. Hence, the procedure for the identification and categorization of endangered breeds of livestock needs refinements. The results of this study clearly pinpointed the need for suitable genetic management so as to retain the founder alleles to the extent possible in the population.

The results of this study indicated that there is substantial genetic variation and polymorphism across studied loci in the Marwari breed of goats and population is neither in Hardy-Weinberg equilibrium nor in mutation drift equilibrium under two phase and single step mutation models. The population appears to be divided into significantly differentiated small subpopulations, which resulted in mating among close relatives leading to high level of inbreeding observed in this study. However, the breed was also receiving new genetic materials through introduction of immigrants. Appropriate breeding strategies should therefore be designed for this breed for conservation conditions and improvement of its unique attributes like adaptability and fitness under harsh climatic conditions of the arid zone.

References

Abichandani, R. K. and Khan, M. S., 1984. Rearing desert sheep and goats on minimal water. Indian Farming 34, 58-59.

Barker, J. S. F., Tan S .G., Moore, S.S., Mukherjee, T. K., Matheson, J. L. and Selvaraj, O. S., 2001. Genetic variation within and relationships among populations of Asian Goats (Capra hircus). J. Anim. Breed. Genet. 118, 213-233.

Bassam, B. J., Coetano- Anolles, G. and Gresshoff, P. M., 1991. Fast and sensitive silver staining of DNA in polyacrylamide gels. Anal Biochem. 196: 80-83.

Behara, A.M. P., Colling, D. T., Cothran, E. G. and Gibson, J.P., 1998. Genetic relationships between horse breeds based on microsatellite data: applications for livestock conservation. Proceedings 6th Wld. Cong. Genet. Appl. Livetock Prod. 28, 119-122.

Behl, R., Sheoran, N., Behl, J., Vijh, R.K. and Tantia, M.S., 2003. Analysis of 22 heterologous microsatellite markers for genetic variability in Indian goats. Anim. Biotechnol. 14, 167-175.

Bohra, H. C., 1980. Nutrient utilization of Prosopis cineraria (Khejri) leaves by desert sheep and goats. Annals of arid zone 19, 73-81.

Canon, J., Checa, M. L., Carleos, C., Vega-Pla, J. L., Vallego, M. and Dunner, S., 2000. The genetic structure of Spanish Celtic horse breeds inferred from microsatellite data. Anim Genet. 31, 39 - 48.

Chenyambuga, S.W., Hanotte, O., Hirbo, J., Watts, P.C., Kemp, S.J., Kifaro, G.C., Gwakisa, P.S., Petersen, P.H. and Rege, J.E.O., 2004. Genetic characterization of indigenous goats of Sub-saharan Africa using microsatellite DNA markers. Asian-Aust. J. Anim. Sci. 17, 445-452.

Christiansen, F. B., Frydenberg, O, Gyldenholm A. O. and Simonsen, V., 1974: Genetics of Zoarces populations VI. Further evidence, based on age group samples of a hetrozygote deficit in the EST III polymorphism. Hereditas 77, 225-236.

Cornuet, J.M. and Luikart, G., 1996. Description and power analysis of two tests for detecting recent population bottlenecks from allele frequency data. Genetics 144, 2001-2014.

Gamble, J.A., Ellis, N.R., and Basley, A.K., 1939. Compostition and properties of goat's milk as compared within cow's milk. U S Department of Agriculture, Teahnical bulletin, No. 67, pp72.

Ganai, N.A., and B.R. Yadav. 2001. Genetic variation within and among three Indian breeds of goat using heterologous microsatellite markers. *Anim. Biotechnol.* **12**:121-136.

Goudet, J., 1995. FSTAT (version1.2): A computer programme to calculate F-statistics. J. Hered. 86, 485-486.

ICAR. 1981. 'Handbook of Animal Husbandry', Indian Council of Agricultural Research, New Delhi, pp 788.

Khan M. S. and Ghosh P. K., 1981. Water use efficiency in the Indian desert goat. In proceedings of International Symposium on 'Nutrition and systems of goat feeding' at INRA-ITOVIC, Tours, France. Vol 1, 249-253.

Khan M. S. and Ghosh P. K. 1985. Body-water relationship during water deprivation in desert animals. Indian Journal of Animal Sciences 55, 169-172.

Kimura, M., and Crow, J.W., 1964. The number of alleles that can be maintained in a finite population. Genetics. 49, 725-738.

Knowles, F. and Watkin., J. E., 1938. The milk of goat under Engish conditions Jornal of Dairy Science 9:153.

Levene, H.,1949. On a matching problem arising in genetics. Ann. Math. Stat. 20, 91-94.

Lewontin, R.C., Krakauer, J., 1972. Distribution of gene frequency as a test of the theory of the selective neutrality of the polymorphism. Genetics 74:174-195.

Li, C.C., 1976. First course in Population Genetics, Boxwood Press, Pacific grove, California.

Luicart, G., Biju-Dual, M. –P., Ertugrul, O., Zagdsuren, Y., Maudet, C. and Taberlet, P., 1999. Power of 22 mocrosatellite markers in fluorescent multiplexes for parentage testing in goats (*Capra hircus*). Anim Genet. 30,, 431-438.

Mathur B. K., Abichandani R. K., and Patel A K.1999. Higher incidents of twinning in Marwari goats by supplementary feeding in hot arid region. Paper presented in IX Animal Nutrition Conference, Hyderabad (India) w.e.f.December 2-4, 1999.

Misra R. K., 1991. Genetic improvement of meat goats in India. Dairy Guide 13,44-47.

Mittal, J. P., 1984. Summer Institute on livestock under arid conditions. Central Arid Zone Research Institute, Jodhpur (Rajasthan), India.

Mittal, J. P., 1988. Breed characterization of Marwari goat of arid western Rajasthan. Indian Journal of Animal Sciences 58, 357-361.

Nei, M., 1973. Analysis of gene diversity in subdivided populations. Proc.Natl.Acad. Sci. USA 70, 3321-3323.

Nei M.1978. Estimation of Average heterozygosity and genetic distance from a small number of individuals. Genetics. 89:583-590.

Nivsarkar, A. E., and Bhat, P. N., 1996. Conservation of animal genetic resources in India. Indian Journal of Animal Breeding and Genetics 18, 1-21.

Pamilo, P., 1985. Effect of inbreeding on genetic relatedness. Hereditas 103, 195-200.

Patel A. K. Mathur, B. K. and Kaushish, S. K., 1999. Comparative productive and reproduction performance of goats in hot arid rangelands. Indian journal of Animal Sciences 69, 139-140.

Queller, D.C., Goodnight, K.F., 1989. Estimating relatedness using genetic markers. Evolution 43, 258-275.

Rohila, P.P. and Patel, A.K., 2003. Marwari goat breed of Rajasthan. Indian J. Anim. Sci. 73, 705-709.

Sambrook, J., Fritsch, E. F. and Maniatis, T., 1989. Molecular Cloning: A Laboratory Manual 2nd ed, Cold spring Harbour, Cold Spring Laboratory Press, NY.

Shankarnarayan, K.A., Bohra, H.C. and Ghosh, P.K., 1985.The Goat: An appropriate animal for arid and semi-arid regions. Economic and Political Weekly XX, 1965-1972.

Weir, B.S. and Cockerham, C.C., 1984. Estimating F-statistics for the analysis of population structure. Evolution 38, 1358-1370.

Yeh, F. C., Boyle, T., Rongcai Y., Ye Z. and Xian, J. M., 1999. POPGENE version 3.1(http://www.ualberta.ca/-fyeh/fyeh.)

Published by : **Director, NBAGR**

For enquiries, please contact :

DIRECTOR, NATIONAL BUREAU OF ANIMAL GENETIC RESORCES

(Indian Council of Agricultural Research)

P.O. Box. No. 129, G.T. Road By-Pass, Near Vasant Vihar, KARNAL - 132001 (Haryana)

Tel. : 0184-2267918 Fax : 0184-2267654 E-mail : director@nbagr.ernet.in