STUDIES ON THE CHARACTERISTICS OF MUZZLE DERMATOGLYPHICS IN DAIRY CATTLE AND BUFFALO

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THESIS SUBMITTED TO THE
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IN PARTIAL FULFILMENT OF THE REQUIREMENT
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IN
LIVESTOCK PRODUCTION & MANAGEMENT

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A thesis submitted to the National Dairy Research Institute (Deemed University), Karnal in partial fulfilment of the requirement for the degree of

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s is to certify that the thesis entitled "Studies on the characteri-ics of Muzzle Dermatoglyphics in Dairy cattle and Buffalo" submitted y Mr. Sharad Mishra in partial fulfilment for the Award of the Doctor Philosiphy in the division of Dairy cattle breeding of the National ry Research Institute (*Deemed University*), *Karnal (Haryana), India*, bonafide research work carried out by him under our supervision and adance and no part of the thesis has been submitted for other degree diploma.

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Dedicated to

my grand-father

Pt. Vijay Shankar Mishra

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CHAPTER - 1

INTRODUCTION

1. INTRODUCTION

No two objects in nature are exactly similar in all respects. All continencies, forms and created beings, are not only different from each other in their classes, races and kinds but are also individually distinct. This truth also applies to the dairy animals in general and the complex features of their muzzle in particular.

There are several methods in vogue to identify the dairy animals. But none of them is full proof as there is scope for tempering and misuse. Moreover, their application is limited to organised farms. It is very difficult for the dairyman and farmers to adopt such methods because of certain limitations. Various banks and cattle insurance companies have come forward for the socio-economic upliftment of the poorer section, through District Rural Development Agencies, National Bank for Agricultural and Rural Development and Integrated Rural Development Programmes. The implementation of these programmes have one of constraints, i.e., lack of suitable method of identification of cattle. Therefore, to overcome these limitations, study of the characteristic feature of the muzzle can be used as a permanent method of identification of individuals in a species.

In mammals, skin is covered with hair except limited parts of the body such as palm, sole and lips in human and muzzle in case of bovines. These void regions, however, have linear features with some specific patterns. In human being this characteristic was identified quite earlier. For the first time the hand and finger prints were successfully employed in legal institution for personal identification by the people of scotland (Chatterji, 1967). The thumb impression were also used as seals for the authenticity of documents. The science of these characteristic pattern on the skin is called Dermatoglyphics. Due to variability among individuals and unchanging nature of dermatoglyph the subject has been put into various uses such as personal identification, racial diagnosis, study of genetical syndromes and inheritance in human beings (Chatterji, 1963). However, very less effort has been made to use this subject in the field of animal science. The reason may be due to unawareness of the areas where such pattern exist. Recently, some researcher have reported the existences of pattern in the muzzle and its possible use in animal identification (Millar and West, 1972; Sisson and Grossman, 1975; Dellaman and Brown, 1976). However, these reports were unable to provide basic information about muzzle pattern; characteristics and individual identification criterion. The persistency of various characteristics on the muzzle and the enormous variety in different individuals are two special features required for the purpose of identification. Persistency of the muzzle can be observed principally in the details of different characteristics and in general character of the pattern, not in the measured dimension of any portion of the pattern. In animals the gyration pattern on the muzzle is specific to particular individuals.

The outer surface of the planum nasolabial of ruminants is covered with a special kind of skin. The skin peculiarity consists of its being formed of different characteristics which are raised lines and rounded structures having the mechanical function of helping during grazing. The numerous elevated lines and rounded structures on the muzzle that bear superficial resemblance are ridges and beads.

The practice to descript different body parts in breed characterisation of animals is not very reliable due to changes and wide variation in physical parameters influenced by various factors. Hence the different characteristics of muzzle may help in characterisation and identification of breeds of cattle.

The researchers are still trying to establish some definite association of muzzle dermatoglyph with inheritance, productive and reproductive traits of the animal. There are reports available in literature regarding the significant association between dermatoglyph pattern of the muzzle and milk yield of the cows. If such association could be established then one can easily go for selection of animals by visual examination of muzzle in early stage of life in cattle as well as economise the selection procedure. Dentition and cornual ring countings are generally used for the determination of age in cattle and other species of animals. These methods have their own limitations. The examination of molar teeth in living animals is also not easy. The cornual ring method provides a rough estimation of age in years. Attempts have been made by some workers for determination of age on the basis of muzzle dermatoglyph.

The dermatoglyphics of muzzle thus have tremendous practical importance in the field of animal husbandry. The present investigation, therefore, becomes necessary to investigate the areas about which little information is available with the following specific objectives:

1. To study the different methodologies of muzzle dermatoglyphics.
2. To evolve an easy and quick technique for identification of individual cattle and if possible of buffalo on the basis of muzzle dermatoglyphics.
3. To suggest suitable nomenclature and classification of muzzle dermatoglyphics in cattle.
4. To determine the age of growing animals at which the muzzle dermatoglyph become permanent.
5. To find out relationship (if any) of muzzle print characteristics with certain productive and reproductive traits among dairy cattle.

CHAPTER - 2

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

The word "dermatoglyphics" is consisted of two parts: Dermato (English) means skin and Glyph (Greek) means arch or channel or groove. As like other sciences, it has its own history and mode of development. Though it is well developed in human being, in animals it has not yet attracted much attention of the researchers. Little information is available in literature regarding "Studies on the characteristics of muzzle dermatoglyphics in dairy cattle and buffalo". Therefore, with a view to funnel existing information, the review has been classified as below:

2.1 Techniques.

2.2 Anatomy of the muzzle.

2.3 Structural characteristics on muzzle.

2.4 Animal identification on the basis of muzzle dermatoglyph.

2.5 Classification of characteristics of muzzle.

2.6 Age determination on the basis of muzzle dermatoglyphics.

2.7 Breed difference and intrabreed genetic variability.

2.8 *Inheritance of dermatoglyphics of the muzzle.*

2.9 Relationship with milk yield.

2.10 Milk protein genotypes and dermatoglyphics of cattle muzzle.

2.1 TECHNIQUES

Photography and printing techniques have been reported to study the muzzle. Trofimenko (1988) used zenith camera and photographed the muzzle by keeping 15 cm distance between muzzle and camera. Baranov (1993) analysed muzzle by taking photograph.

The muzzle printing techniques were reported by Pandey (1979) and Mishra and Dave (1989). The technique using eyetex to obtain the muzzle print is called eyetex method (Pandey, 1979) and when a cyclostyle ink is applied on the muzzle to obtain the muzzle print, the procedure is called cyclostyle method (Mishra, 1988). In this procedure some instruments were developed in order to increase clarity of the muzzle impression. This technique is quite similar to the finger printing technique.

2.2 ANATOMY OF THE MUZZLE

The muzzle contains keratinized epithelium which has cells on the surface layer that have lost their nuclei and are filled with keratine, a water resistant protein that forms a protective barrier against the destructive forces of the environment. The epidermis of the muzzle contains stratum cornium. A fifth layer, the stratum lucidum is found only in the planum nasale of the muzzle (Dellaman and Brown, 1976) (Figure 1).

2.3 STRUCTURAL CHARACTERISTICS ON MUZZLE

The distinct elevation and grooves on the muzzle are the characteristic features for the identification (Sisson and Grossman, 1975; Dellaman and Brown, 1976). The oval, rounded or irregular structures over the print were "beads". The structures which were elongated, straight or curved and arranged in specific manner to form a "ridge" which may or may not be branched. The "valley" is a clear space originating centrally at the base of the print and extending upward to a varying extent. The valley is a guide to determine the base of the print (Pandey, 1979). Generally, the examination of muzzle prints were done by dividing it into six sectors, namely, right and left base sectors, right and left middle and right and left top sectors (Pandey, 1979; Mishra and Dave, 1989). Some other characteristic features have raised some controversy among workers

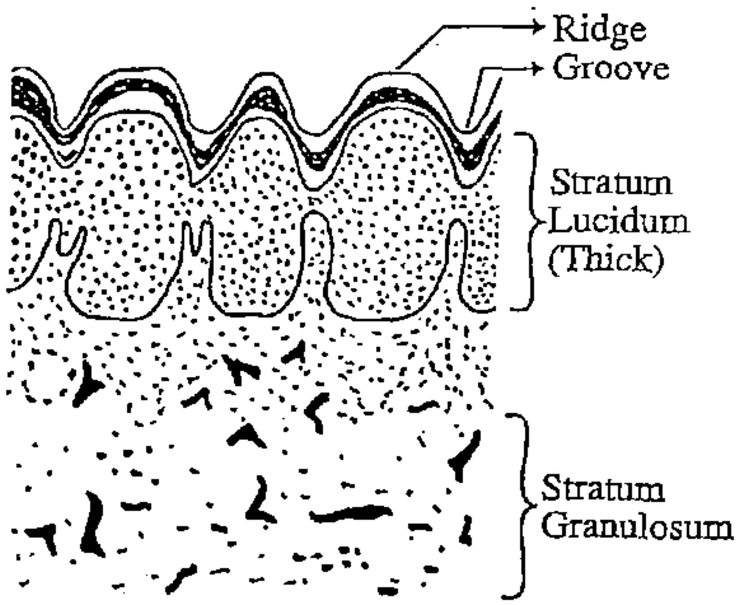
(Pandey, 1979; Mishra, 1988). According to Pandey (1981) some beads were clustered at the base sector (CBS) and others distributed at the base sector (DBS). Whereas, Mishra and Dave (1989) are of the opinion that more than two beads arranged to form a bunched structure of beads were clustered beads which were available in the right and left middle and upper sectors, respectively. Trofimenko (1989) reported different shape of beads and ridges (Figure 2).

2.4 ANIMAL IDENTIFICATION ON THE BASIS OF MUZZLE DERMATOGLYPH

The features on the muzzle form various "patterns" which can be classified into various classes. Whenever an interspace is left between the boundaries of a different system of certain characteristics (beads and ridges), it is fitted by a small system of its own, which will have some specific shape and is called pattern (Chatterji, 1967). The peculiar characteristics on the muzzle were used for animal identification and their age determination (Mishra, 1988).

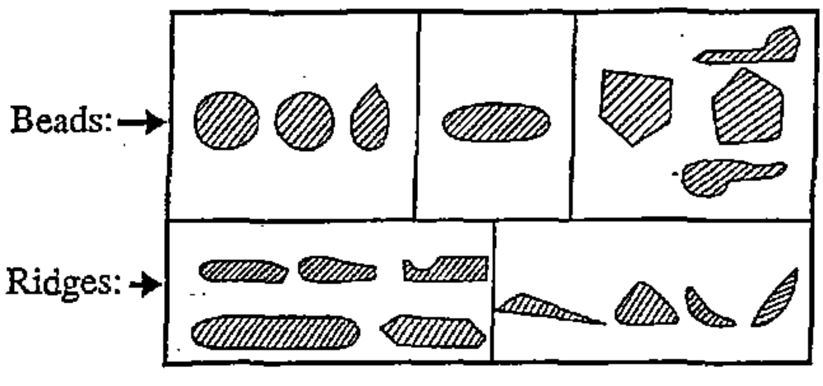
The skin surface of planum nasolabial of ruminants planum rostrale of pigs and planum nasale of dog is subdivided by small grooves into areas (Sisson and Grossman, 1975). They further suggested the surface relief is characteristics feature for individual animals and remain constant with age thus, can be used for identification purpose. The planum nasale of dog and cat is composed of thick keratinized epidermis with distinct elevation and grooves that provide the basis for identification of nose printing similar to finger printing (Dellaman and Brown, 1976).

Pandey (1979) and Trofimenko (1989) observed that the various characteristics features of the muzzle differ from animal to animal and can be utilised to identify the animals. Pandey (1979) further suggested that the dermatoglyph of muzzle in animals over two years of age did not undergo major structural changes with the lapse of time. The ridges in muzzle prints are



(Dellaman and Brown, 1976)

Figure -1: Planum nasale (Muzzle)



(Trofimenko, 1989)

Figure -2: Shape of the characteristics

important characteristics for the purpose of identification of individuals. Pandey (1984) studied proximal end point (PEP) and distal end point (DEP) of two types of ridges belonging to right and left halves of the muzzle prints, respectively. The PEP and DEP of all selected ridges on all the muzzle prints were marked by a dot with a ball pen. The location of both ends of a riddge in relation to the base and perpendicular line was called locus standi of that ridge (Pandey, 1982). The locus standi was determined with the help of a transparent graph paper. In this procedure, "xx" and "yy" axes were drawn on a small transparent graph paper. The "xx" axis was coincided with the base line of muzzle print while "yy" axis was drawn alongwith the perpendicular line in the middle of the base line. The graph paper with two axis marked on it was laid on each muzzle print and locus standi was recorded. The comparative study of the ridges of both sides, revealed that two ends (DEP and PEP) of any two ridges were non-identical with the minimum variation of 5 small squares in 94% cases. However, before the use of this method in identification of muzzle prints, determination of variation due to human and instrumental error was essential (Pandey, 1982). The error may be determined by selecting the same ridge of the muzzle prints obtained from the same source on different occasions and ascertaining the locus standi of their DEP and PEP. The arrangement of beads on ridges also varies from ridge to ridge (Pandey, 1981; Mishra and Dave, 1989). Thus, the locus standi and bead arrangement on ridges of two corresponding ridges belonging to two separate muzzle prints can be dependably used for identification of individuals (Pandey, 1981).

2.5 CLASSIFICATION OF CHARACTERISTICS OF MUZZLE

The classification of characteristics of muzzle for identification of individuals are very important. The analysis of muzzle print and grouping of animals can only be possible after suitable classification of muzzle features. A little effort has been made in this direction by Pandey (1987). He classified the muzzle into two main groups, viz., grooved and non-grooved category. These categories were further sub-divided through their characteristics, i.e, simple and compound ridges followed by prominent and flat ridges. Trofimenko (1989) classified the muzzle into branched, parallel and granular patterns, depending on the arrangement and branching system of the characteristics of the muzzle.

2.6 AGE DETERMINATION ON THE BASIS OF MUZZLE DERMATOGLYPHICS

For the first time, the possible use of muzzle for the age determination of cattle upto 3 years was suggested by Pandey (1982). The distance measured centrally between the two nostrils and also the measurement of the line drawn parallel to the base line along the middle points of the second vertical curve is the "muzzle span", which can be used as the index of age. The muzzle span is measured (in mm) either directly from the muzzle or from a full clear muzzle print of the animals at birth, and 1, 2 and 3 years of age (Table 1). This is denoted by "x". The difference of "x" and "i" was marked as "r". Where, "i" the average muzzle span of the animal at the time of birth. By applying certain constants, the age of an animal can be determined with the help of the following formula (Pandey, 1982):

If, (i) $r < k1$:

age = (r*1.20) months.

(ii) $r = k1$:

age = 12 months.

(iii) $r > k1 < (k1 + k2)$:

age = 12 + (r-k1) * 1.70 months.

(iv) $r = (k1 + k2)$:

age = (12 + 12) months.

(v) $r > (k1 + k2)$ and $< (k1 + k2 + k3)$:

age = (12 + 12 + (r-(k1 + k2) * 1.60 months.

(vi) r = (k1 + k2 + k3):
age = (12 + 12 + 12 months).

Table 1. Muzzle span (MS) (mm) of all the animals recorded age-wise.

Average of animals No. from	Age groups			
	A* i	B* MS	C* MS	D* MS
1 - 5	22.80	33.50	40.00	44.25
6 - 10	23.00	33.00	41.00	44.50
11 - 15	23.00	33.25	40.00	44.50
16 - 20	24.00	32.75	39.80	45.00
21 - 25	23.00	33.00	40.00	44.50
26 - 30	22.50	33.00	40.00	44.25
31 - 35	23.00	33.00	40.25	44.50
36 - 40	23.00	32.50	40.00	44.50
41 - 45	22.50	33.00	40.00	44.00
46 - 50	23.00	33.00	40.50	44.50
51 - 55	23.00	33.25	40.00	44.50
56 - 60	22.50	33.00	40.00	44.50
61 - 65	23.00	33.00	40.00	44.25
66 - 70	23.00	32.25	39.80	44.50
71 - 75	23.00	33.00	40.00	44.50
76 - 80	22.80	33.00	40.00	43.80
81 - 85	23.00	33.00	39.50	44.50
86 - 90	23.00	32.50	40.00	44.50
91 - 95	23.00	33.00	40.00	44.00
96 - 100	22.80	33.00	40.00	44.50
Average of 100 animals	22.94 or 23.00	32.94 or 33.00	40.40 or 40.00	44.42 or 44.50

(Pandey, 1982)

* A, B, C and D are average muzzle span at birth, 1, 2 and 3 years of age, respectively.

Mishra and Dave (1989) studied the muzzle prints to determine the age of crossbred cattle. They analysed the oval and rounded beads present in a square of 2.5 cm * 2.5 cm dimension across the muzzle print area of each animals separately. The imaginary square was further subdivided into 4 equal sectors designated as A1 and A2 in the upper and B1 and B2 in the lower parts. The animals were assigned to age groups with 6 months class interval each. The total number of beads in each sector varies in each age groups of animals, indicating presence of varying number of beads in different age group of animals. It is interesting to note that in all sectors the number of beads decrease with advancing age. The reduction is most remarkable upto 18 months of age (Table 2). *The overall average of bead numbers suggested that after the* age of 24 months, the number of beads did not decline. The analysis of variance indicated that there were significant differences in the number of beads between groups of animal in all the sectors.

Table 2. Average number of beads in different sectors of the muzzle prints of the crossbred animals.

Age group (months)	N	Sectors A1	A2	B1	B2	Average number of beads
1. 06 - 12	10	58.50	53.00	54.80	55.20	55.37
2. 12 - 18	11	39.73	36.28	35.28	36.46	36.93
3. 18 - 24	14	30.65	30.22	32.15	32.74	31.43
4. 24 - 30	14	23.08	24.29	24.57	27.00	24.71
5. 30 - 36	16	22.63	24.07	23.75	24.00	23.61
6. 36 - 42	06	20.17	21.67	21.17	21.50	22.12
Total	71					32.20

(Mishra and Dave, 1989)

The difference of age in the above two studies could be attributed to the rate of growth in animals. The findings of Pandey (1982) were based on non-descript animals (from Bihar), while Mishra and Dave (1989) used crossbred (Gir*Holstein Friesian*Jersey) animals. These two types of animals have apparent differences in their growth rates and could be a reason of difference in age.

Mishra and Dave (1993) further analysed the beaded ridge and clustered beads in order to determine the age of crossbred cattle. They indicated that the number of beaded ridges upto 24 months of age in cattle could be used to determine the age (Table 3). However, they did not find any definite association of clustered beads with the age of animal. Rather, a possible use of clustered beads for the identification of animal was suggested.

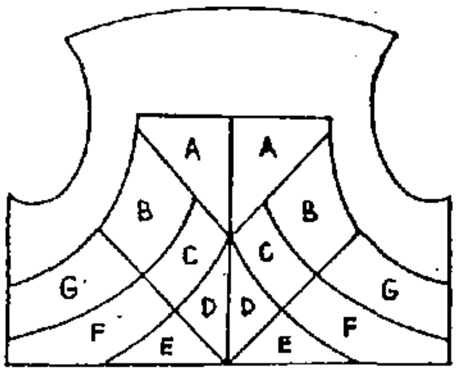
Table 3. Average number of beaded ridge in the muzzle prints.

Age group (months)	N	Sectors A1	A2	B1	B2	Average number of beads
1. 06 - 12	10	3.60	4.00	5.60	6.30	4.87
2. 12 - 18	11	3.54	3.00	4.36	4.72	3.90
3. 18 - 24	14	2.57	2.14	3.78	3.78	3.06
4. 24 - 30	14	2.50	3.07	3.42	3.78	3.19
5. 30 - 36	16	2.81	2.75	3.43	3.18	3.04
6. 36 - 42	06	2.16	2.16	2.50	2.66	2.37
Total	71					3.40

(Mishra and Dave, 1993)

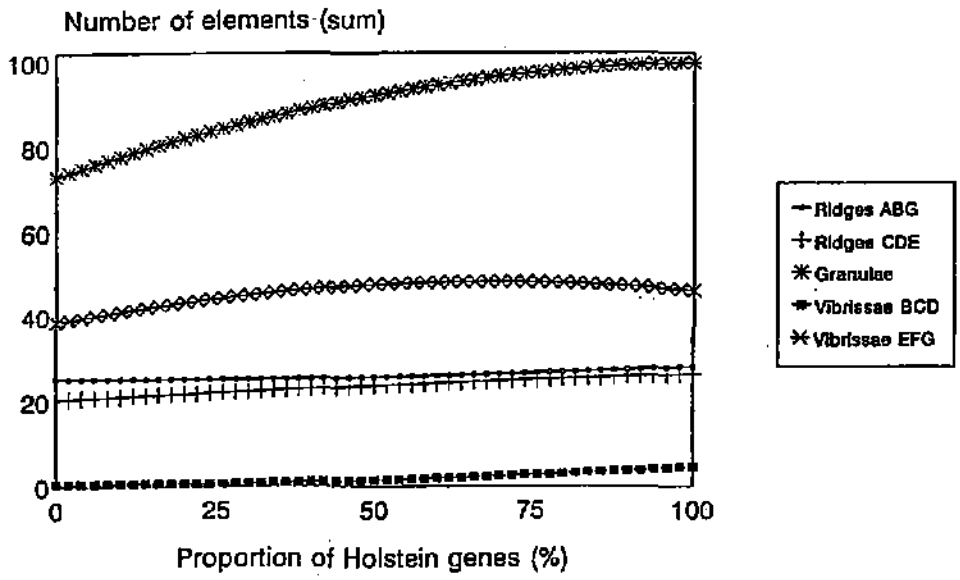
2.7 BREED DIFFERENCE AND INTRABREED GENETIC VARIABILITY

The muzzle characteristics belonging to different region of muzzle differ significantly between breeds (Baranov *et al.*, 1993). The number of ridges, granula and vibrissae of various specified regions of the muzzle of different breed were observed in relation to study breed difference among them. The surface of the muzzle was divided into seven segments (Figure 3) in which 5 different traits were measured - number of ridges in segments A, B and C; number of ridges in segments C, D and E, respectively, and granulae in all segments, number of vibrissae are counted in regions BCD and EFG since in segment A no vibrissae occur. All these characteristics differ significantly between breeds (Table 4). It was observed that the European bison clearly lies outside the range of cattle breeds, due to less structuring. Further, the BCD vibrissae is higher in European bison but surpassed by Friesian cattle. Breed differences remain highly significant when bison is neglected (Baranov *et al.*, 1993). The regression of muzzle structure on percentage of Holstein genes has been estimated. The number of granula and number of vibrissae increased with



(Baranov et.al. 1993)

Figure -3: Sectorial division of the muzzle



R-ABG $y = 25.4 - 0.0173x + 0.00046x*x$; R-CDE $y = 20.5 + 0.0690x - 0.00009x*x$;
Gran. $y = 73.2 + 0.4960x - 0.00230x*x$; V-BCD $y = 0.5 - 0.0047x + 0.00046x*x$;
V-EFG $y = 38.5 + 0.2790x - 0.00203x*x$;

(Baranov et.al. 1993)

Figure -4: Regression curve

proportion of Holstein genes (Figure 4). The linear regression coefficients of number of granula and vibrissae were statistically significant.

Table 4. Breed effects as deviations from simmental, on muzzle dermatoglyphics (sum of left and right halves).

Breeds	n	Ridges ABC	Ridges CDE	Granula	Vibrissae BCD	Vibrissae EFG
Bavarian Simmental	209	0	0	0	0	0
Bavarian Brown	22	2.4c	-4.9c	-0.6	-1.3	2.3
Murnau-Werdenfelser	6	1.2	-3.4a	1.5	1.9	10.2a
Tyrolean Grey	66	1.3c	-3.9b	10.4c	1.0	10.7c
Yellow Tranconia	8	0.1	-1.6	0.6	-0.8	6.7
German Black & White	46	1.7c	2.1c	12.9c	3.8c	8.3c
Simmental*Red Holstein	59	-0.8	-0.5	4.1	0.6	9.0c
Blonde d'Aduitaine	6	2.7a	-2.3	-3.3	-0.5	2.7
Chianina	10	1.6	-3.6b	-4.9	-1.0	-4.1
Jakutian	15	1.8a	-3.0c	-2.7	-0.8	-4.3
Kalmvkian	18	2.4c	-6.6c	-11.0b	-0.6	-3.2
European bison	25	-4.9c	-7.9c	-26.9c	3.5c	-15.1c

(Baranov et al., 1993)

a 5%, b 10%, c 0.1% significance of difference to Simmentals.

2.8 INHERITANCE OF DERMATOGLYPHICS OF THE MUZZLE

The dermatoglyph of the naso-labial plate of cattle has shown a remarkable inheritance of pattern. If the parents had a particular pattern, it is transmitted to more than 75% of their progeny. A genetic correlation of 0.84 and 0.62 between the muzzle patterns in sire-son and dam-daughter pair respectively is reported (Trofimenko, 1989).

2.9 RELATIONSHIP WITH MILK YIELD

A significant correlation between phenotypic dermatoglyph patterns and variation in milk yield in Russian Black Pied (RBP) cows are observed. The cows with a dense dermatoglyph pattern have higher milk yield (Trofimenko, 1988).

2.10 MILK PROTEIN GENOTYPES AND DERMATOGLYPHICS OF CATTLE MUZZLE

Graml et al. (1993) studied association of the milk protein genotypes with the number of ridges and granulae. The casein genotype account for nearly 20% of the phenotypic variance of muzzle traits which exceeds their influence on casein content of milk (Graml et al., 1985). The additive-genetic effects of the casein genes account for about 80 to 90% of the genotypic variance due to the milk protein genes for number of ridges ABC and for about 60 to 70% for number of granulae. These high values suggests the importance of additive gene effects (Table 5).

Table 5. Proportion of additive genetic variance ascribed to milk protein loci (%)*.

Locus	Ridges ABC	Granulae
α_{s1}-CN	96.7	18.2
β -CN	81.1	75.0
k-CN	82.1	60.0

(Graml et al., 1993)

* Subset of data from Bavarian Brown, Simmental and Tyrolean Grey.

The review of literature indicated the importance of muzzle characteristics for individual identification of cattle. The experimental details with procedure of individual identification through muzzle is however scanty. However, the work reported was based on different techniques to be used to study the muzzle. Unfortunately, none of them were able to define flawlessly the dermatoglyph pattern of the muzzle. The various characteristics distributed on the muzzle were also not fully exploited for the dermatoglyphics studies of the muzzle. On the other hand, most of the findings were handicapped by undue biasness to certain characteristics when total area of the muzzle is not considered. Three major characteristics of the muzzle namely, beads, ridges and vibrissae are reported. These characteristics are independently distributed on the muzzle. The quantitative analysis of these characteristics suggest high variability among individuals. These findings may pave the way when structure and arrangement of such characteristics are studied in detail to develop identification system through it. A reliable result can only be obtained by applying accurate technique. Since no technique can claim 100% accuracy in the results, the technique for the dermatographics study for muzzle prints should be selected by considering the cost, applicability and perfection or accuracy of the technique.

CHAPTER - 3

MATERIALS AND METHODS

3. MATERIALS AND METHODS

The muzzle prints of Tharparkar, Sahiwal, Karan Swiss, Karan Fries cattle and Murrah buffalo were collected from the Cattle Yard of the National Dairy Research Institute, Karnal, India and the muzzle prints of German Black & White and German Red & White cattle were collected from the Karkendam Research Farm of the Institute of Animal Breeding and Animal Husbandry, Christian-Albrechts University of Kiel, Germany. The distribution of experimental animals are detailed in Table 6.

Table 6. Distribution of animals.

No.	Breed/species	No. of animals
1.	Tharparkar	41
2.	Sahiwal	74
3.	Karan Swiss	134
4.	Karan Fries	253
5.	German Black & White	50
6.	German Red & White	50
7.	Murrah buffalo	65
	Total	667

3.1 DERMATOGLYPH TECHNIQUES

The techniques generally applied for collecting the muzzle prints are:

a) Eyetex method.

b) Cyclostyle ink procedure.

c) Photography.

3.1.1 EYETEX METHOD

In this method, the surface of the muzzle was first washed with soap and water, and soaked with a piece of clean towel. A thin film domestic kazal (eyetex) was applied uniformly to the clean day surface of the muzzle. A piece of plain paper, of 12.5 cm * 10 cm size, was then brought into the contact of this surface and gently pressed with the palm. The print obtained was then allowed to dry for a few minutes (Pandey, 1979) (Figure 5).

3.1.2 CYCLOSTYLE INK PROCEDURE

This technique is quite similar to finger printing technique, used in obtaining finger prints of human beings. In this method the printing ink was used for obtaining the muzzle prints. The following items, constitutes the printometry box:

i) Ink pad: Having equal homogeneous surface area.

ii) Roller: Metal roller was used for dispersing the ink on the ink pad, to make an equal homogeneous film on the pad.

iii) Printing ink.

iv) Metal pad: Metal pad is like absorbing pad, generally used in offices for blotting paper. On the pad, a plain paper of 15 cm * 12 cm size was fixed to obtain prints.

v) Plain paper: The paper may be either smooth blotting paper or rough normal plain paper of the size of metal pad.

vi) Clean towel.

The muzzle of healthy animal is always moist which can disturb the quality of print. The muzzle was, therefore, washed and soaked with a clean dried cotton towel. In this method, a printing ink, insoluble in the muzzle moisture, was used so that it remain dispersed on the muzzle for few seconds. The ink pad impregnated with printing ink was applied on the clean and dry muzzle. A uniform dispersion of printing ink on the muzzle surface was to be made. The metal pad with attached paper was then applied on the muzzle. The muzzle print which appears on the paper is then allowed to dry for few minutes (Figure 6).

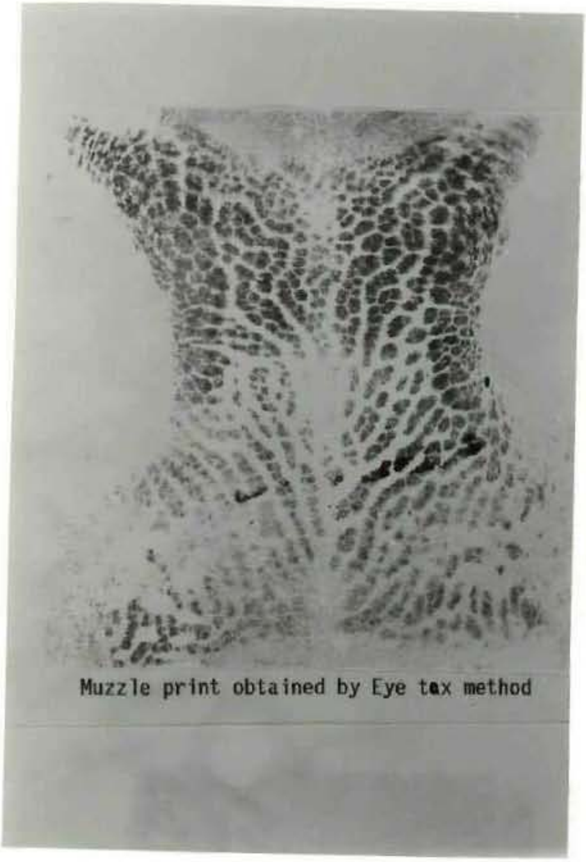
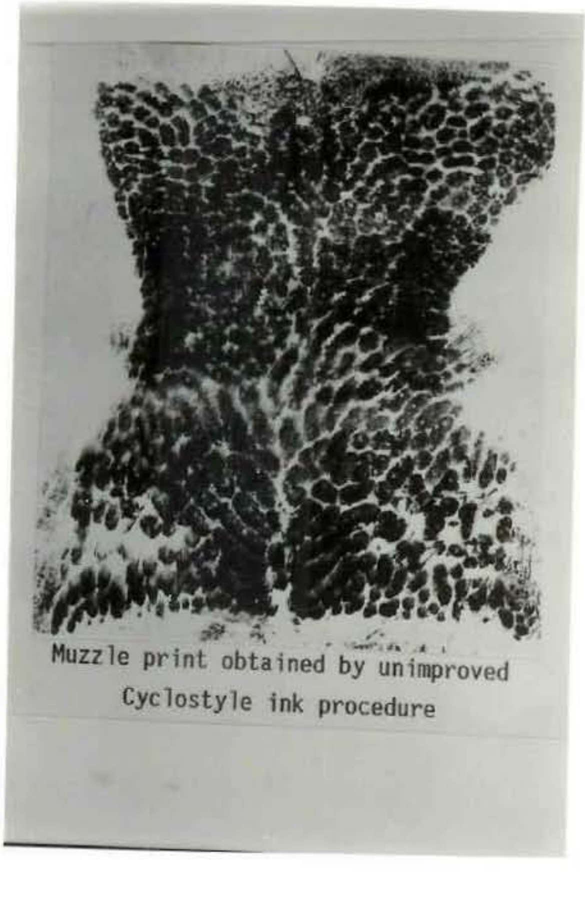


Fig. 5. Muzzle print obtained by eyetex method.

Fig. 6. Muzzle print obtained by unimproved cyclostyle ink procedure



3.1.3 PHOTOGRAPHY

The muzzle of animals were photographed using an ordinary photo camera. The muzzle of an animal was first washed and then photographed covering the whole area of the muzzle (Figure 7).

All these techniques were tried in order to know their applicability and accuracy in obtaining the clear muzzle impression by covering the whole area of the muzzle.

3.2 TRIALS WITH EXISTING TECHNIQUES

A total of 60 animals (20 for each techniques) were used to study three different techniques. The muzzle impression obtained from all the above described techniques were assessed visually for clarity and sharpness of the impression and ease of the technique as well as ability to cover whole area of the muzzle. The problems associated with these techniques, however, were the blurred impression due to profuse sweating. The appearance of hazy and complete black impression were quite often in such techniques. In cyclostyle ink procedure, it was possible to cover the whole muzzle area by driving metal pad but sometimes uniformity of muzzle impression did not exist due to pressure differential while driving the metal pad.

In all techniques, the sharpness of the muzzle impression was greatly affected by profuse sweating from the muzzle. The muzzle prints obtained from the cyclostyle ink procedure were better than the other techniques, due to use of blotting paper, which absorbs the sweat during printing. In cyclostyle ink procedure, the problem of blurred and complete black impression was reduced a lot by applying homogeneous thin film of ink through ink pad.

In photography the muzzle characteristics were sharp only on the focused area of the muzzle. Other area of the muzzle, however, did not appear sharply due to curved surface of the muzzle.

The cyclostyle ink procedure was thus selected for present investigation with certain modification in order to increase clarity of the muzzle impression and the accuracy of the procedure.

3.3 MODIFIED CYCLOSTYLE INK PROCEDURE

The cyclostyle ink procedure was not very handy. Further, the printing ink was not examined for the consistency. The blotting paper used though effective in soaking the sweat was not condusive to improved sharpness of the characteristics also, metal pad used for taking muzzle print did not contain paper attachment device because of which the printing paper got disturbed very often thereby giving blurred impression of the muzzle. No arrangement was made to control the pressure differential so as to avoid missing areas on the muzzle prints. In order to overcome these limitations the existing cyclostyle ink procedure was modified which has been described as under:

3.3.1 QUALITY PRINTERS INK

The black printing ink of smooth texture and free from lumps was used for taking the prints. The ink used was of consistency suitable for rolling into a thin film and quickly drying when transferred to paper.

3.3.2 ROLLER

A roller, generally used by printers for taking prints, was found suitable for muzzle printing work. Soft roller of 15 to 18 cm long (preferably not less than 10 cm) was used. The handle of the roller should have supporting peg to suspend the rubber roller in air when not in use (Figure 8).

3.3.3 SLAB

A piece of few inches thick aluminium plate, with a smooth edges and scratchless surface was used to provide most satisfactory surface for preparing homogeneous thin film of ink (Figure 8).

Figure 7. Photograph of the muzzle.

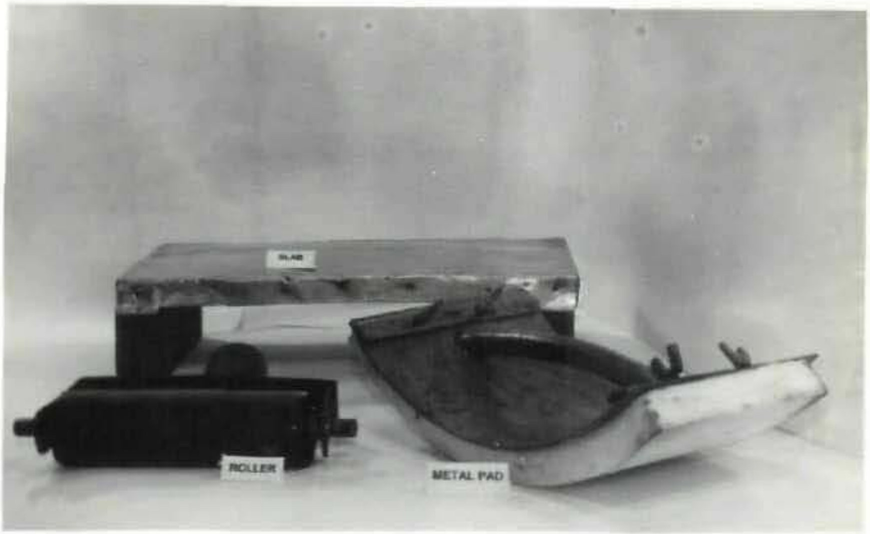


Figure 8. Instruments used for modified cyclostyle ink procedure.

3.3.4 METAL PAD

The metal pad was improved by giving an appropriate curve, i.e., 18 cm radius. The appropriate curve (18 cm) to the metal pad provides smooth driving on the muzzle while covering whole area of the muzzle. The concept of giving curve was quite similar to the finger printing technique wherein finger is rolled completely to obtain full clear finger print. A metal pad of 30 cm long, 15 cm wide with 18 cm curve enabled to obtain more than one muzzle print at a time.

In order to obtain an uniform muzzle impression, a hard and good quality foam, of the same size of the metal pad, was adhered on the metal pad which eliminates the problem of pressure differential. To fix the paper on the metal pad, it was further improved by providing printing paper attachment devices on both the ends of the metal pad (Figure 8).

3.3.5 PRINTING PAPER

Normally a plain paper was used to obtain muzzle print. But in the present study, a quality bond paper of the size 45 cm long and 15 cm wide was used.

3.3.6 ANTI-PERSPIRANT

It was observed that the quality of muzzle impression improved to great extent by using anti-perspirant. Since, profuse sweating of the muzzle resulted in great difficulty to distribute ink uniformly on the muzzle. Thus, it was not possible to get a good quality muzzle impression without checking sweating.

The sweating was controlled by applying laboratory alcohol or market anti-perspirant. Both reagents were used and it was possible to check sweating for few seconds. The anti-perspirants were used immediately after cleaning and washing the muzzle.

3.4 PROTOCOL

A thin homogeneous film of ink was prepared on the cleaned and smooth surface of the slab with the help of cleaned roller. The metal pad was kept ready by fixing printing paper on it. The muzzle was then washed and soaked with clean dried cotton towel. Anti-perspirant was then spread to check sweating. Few minutes later, the muzzle was again soaked with clean towel to remove rest of sweats and excessive anti-perspirant adhered on the muzzle. The slab impregnated with printing ink was applied on the muzzle by holding firmly the head of an animal. Uniform distribution of printing ink on the muzzle surface was made. The metal pad with paper attached was then driven from base to top of the muzzle covering the whole area of the muzzle. The muzzle print appeared on the paper was removed from the metal pad and allowed to dry for few minutes. The muzzle print obtained in this way was the complete muzzle print (Figures 9 to 16).

3.5 PRECAUTIONS

1. The slab and the roller were kept free from dirt and dust.
2. The slab and the roller were cleaned daily and the leftover ink of the previous day was removed using laboratory alcohol.
3. Care was taken to avoid excessive use of ink.
4. The roller was driven each time on the slab to prepare new film for every muzzle print.
5. Only a small quantity of ink was used to prepare a homogeneous thin film/layer of ink.
6. The muzzle was thoroughly cleaned before taking impression.
7. The nostrils were plugged by cotton while applying anti-perspirant in order to avoid inhalation.
8. The ink film was controlled very satisfactorily by cross rolling.

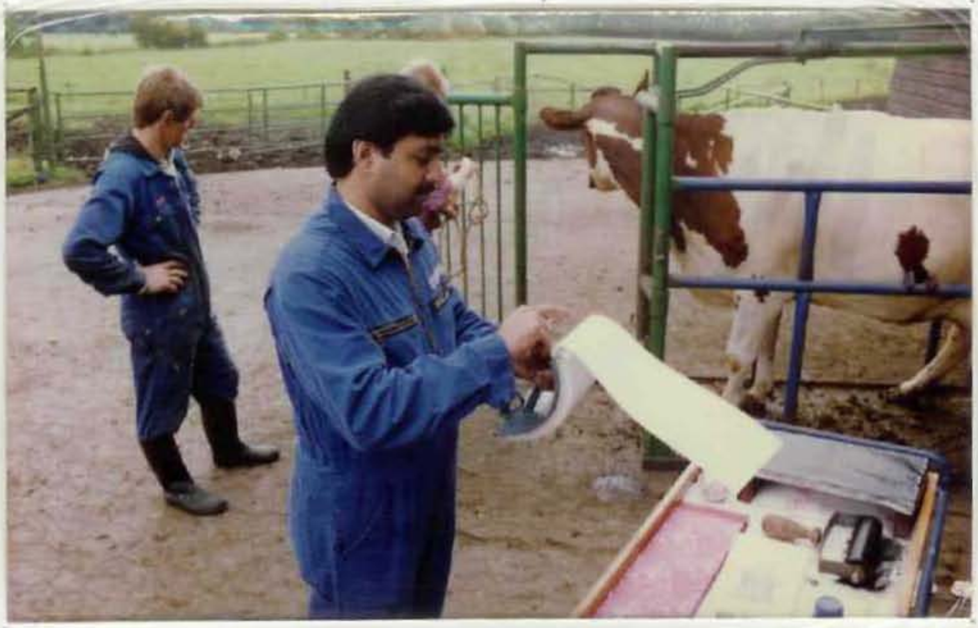


Figure 9. Mounting of printing paper on the ink pad.

Figure 10. Spreading printing ink on the slab homogenously.

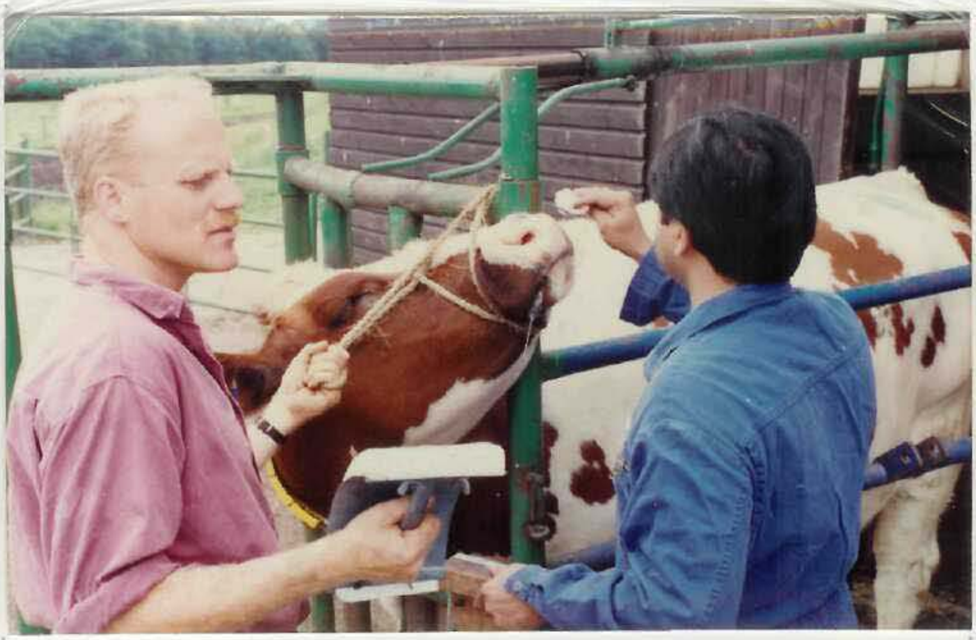


Figure 11. Cleaning and wiping of muzzle.

Figure 13. Final cleaning of muzzle.

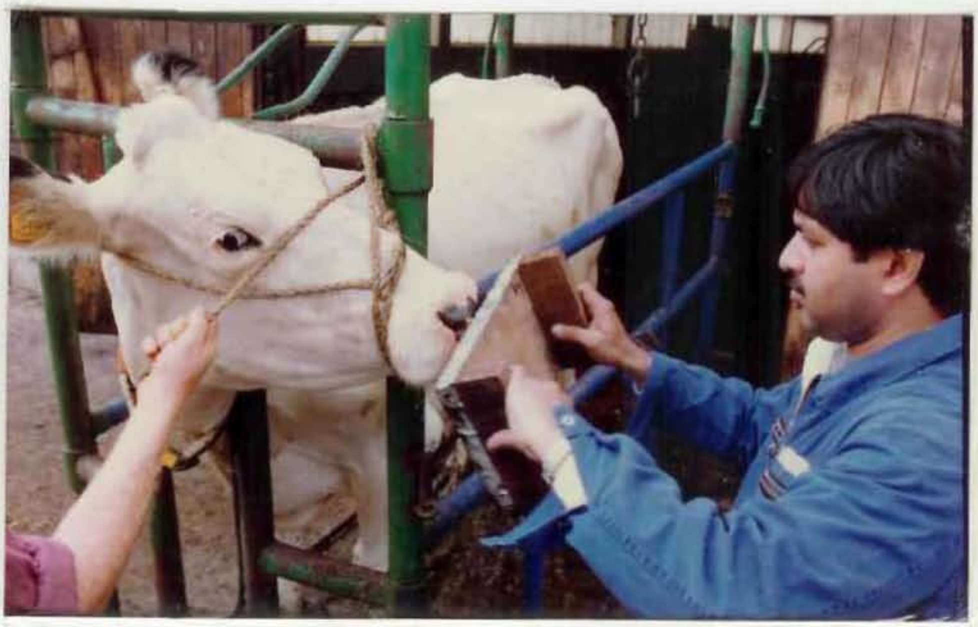


Figure 14. Applying of ink uniformly on the muzzle.

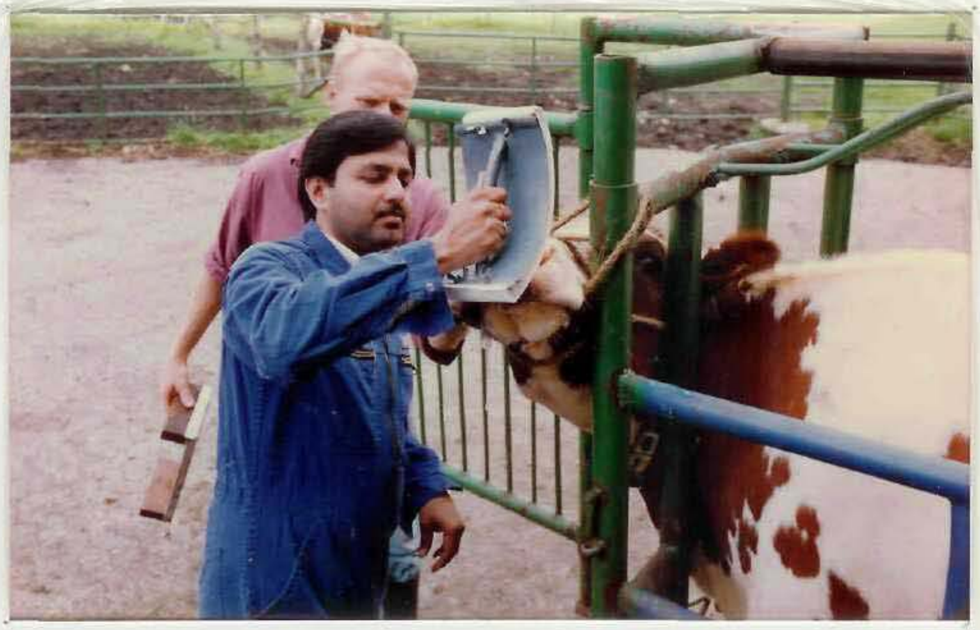


Figure 15. Driving metal pad on the muzzle.

Figure 16. Muzzle print finally obtained.

3.6 MUZZLE PRINT ANALYSIS

The problem to differentiate the muzzle characteristics from sweat pores enforced to eliminate the buffalo muzzle print in subsequent study. In cattle, the muzzle print of each individual has been analysed separately. The first and foremost task of the study was to quantify the each muzzle print so that it can be used for further analysis. The muzzle print of each animal was divided into three standard sectors. This division was made by dividing the total area of the muzzle into 2:1:2 ratio to base, middle and upper sector, respectively. The area of the muzzle was the length * width of the muzzle. Where length was the distance between the base (bottom) line and the peak curve of the upper (top) line. The distance between the nostrils was considered as the width of the muzzle. The width of the muzzle remained constant from top to bottom of the muzzle. The sectorial division was thus the function of the length of the muzzle. From the centre, the entire length of the muzzle was divided allocating 40% area to base, 20% area to middle and 40% area to upper sector. The sectorial division of each muzzle print remained constant throughout the analysis. The diagrammatic representation of sectorial division of muzzle print is shown in Figure 17.

3.6.1 RECORDING AND MEASUREMENT OF DIFFERENT CHARACTERISTICS

The number of beads and ridges available on each sector of the muzzle prints were counted and recorded separately. It was observed that a few ridges originate oftenly either from the central valley or same point located at the centre of the base line of the muzzle. Each ridge had different place of origin and arrangement but all such ridges has common point of origin. These ridges were called pattern ridges. The muzzle was divided into right and left halves when pattern ridges were arranged around central valley. Division of muzzle print into right and left halves was not possible when the pattern ridges were located around "same point" at the centre of the base line of the muzzle. Each

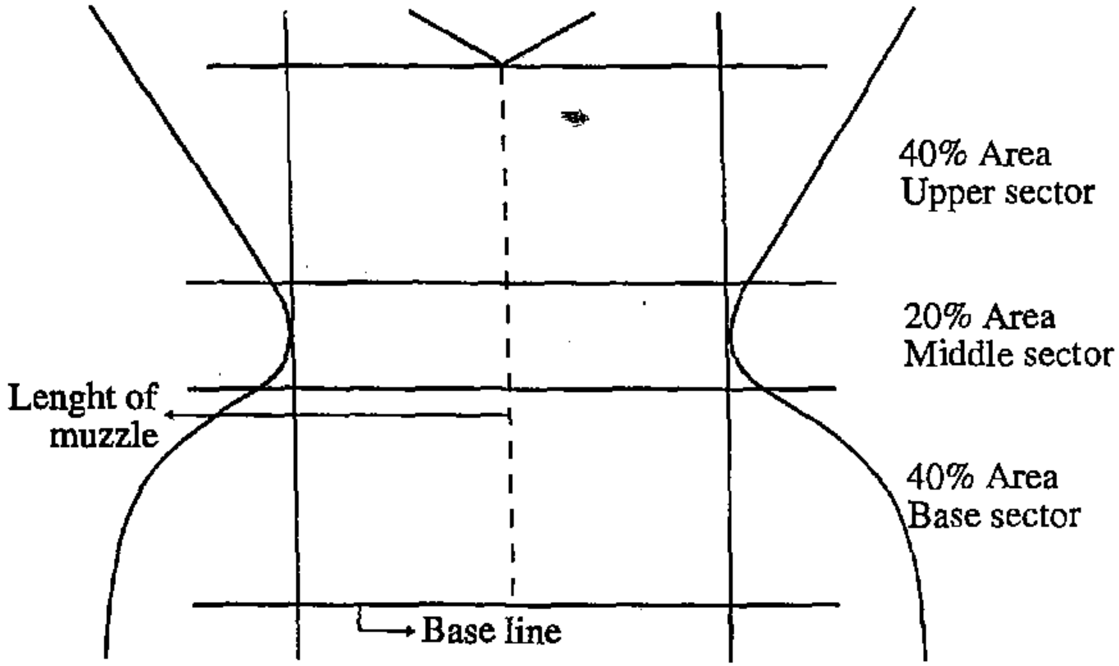


Figure 17. Sectorial Division of Muzzle Prints.

pattern ridge had their own point of origin, shape, length and characteristics features. The point of origin of each pattern ridge differed from each other by the degree of angle when they begin to course. Thus, the number of pattern ridges of each muzzle prints were recorded and subsequently measured for the shape, length, characteristic features and angle of its origin.

3.6.2 ANGLE MEASUREMENT OF PATTERN RIDGES

The number of pattern ridges were traced on the muzzle print and recorded separately for each muzzle print. The pattern ridges were recorded separately for right and left halves, when they arranged around central valley. Whereas, if pattern ridges originate from the "same point" the recording starts from right to left in anti-clockwise direction. First of all, a base line was drawn on the separate paper. The origin and the point of deviation from their normal course were marked on the same paper. Consequently, all traced pattern ridges of the muzzle print were marked and the two marked points of each ridge were joined by an imaginary line. Thus, the angle of pattern ridge was the angle between the imaginary line and a line drawn parallel to the base line (Figure 18).

3.6.2.1 Rules Adopted to Measure and Record the Pattern Ridges

Rule 1: The pattern ridge originating distinctly from the centre or "same point" were counted and measured for the angle. The pattern ridge angle was not measured when some other characteristics present at the point of origin (Figure 19).

Rule 2: The counting and angle measurement of the pattern ridges when positioned at the top of the central valley depends on its course towards right or left hand side (Figure 19).

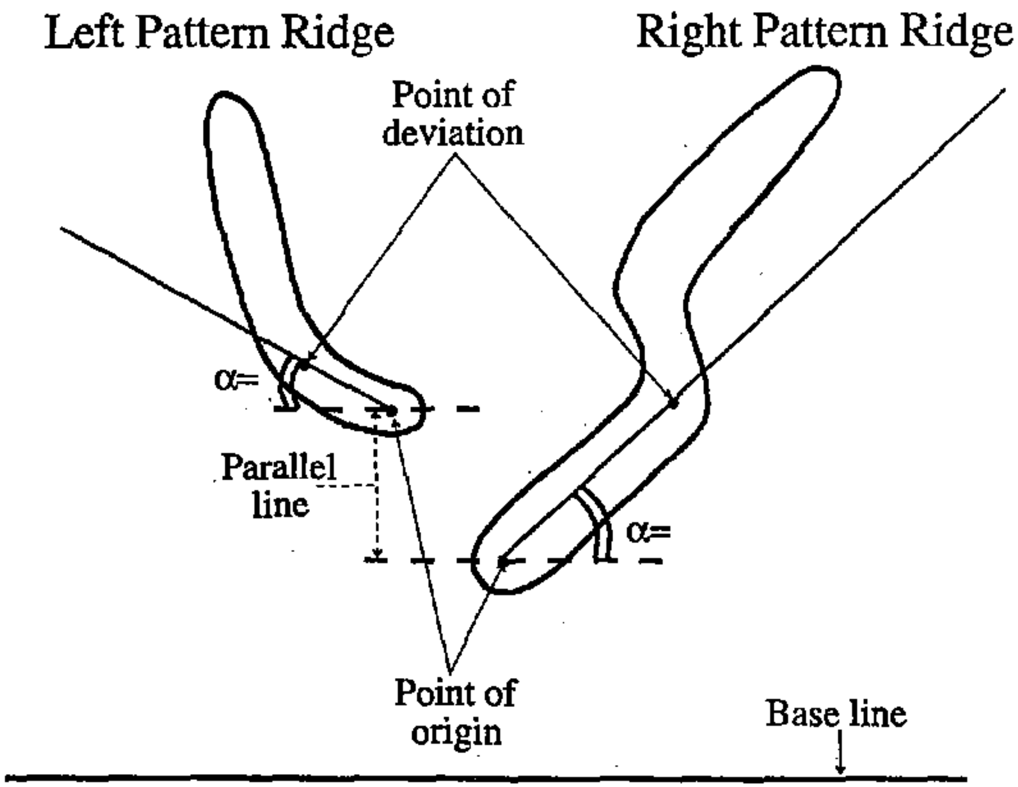


Figure 18. Measurement of Angles formed by Pattern Ridges.

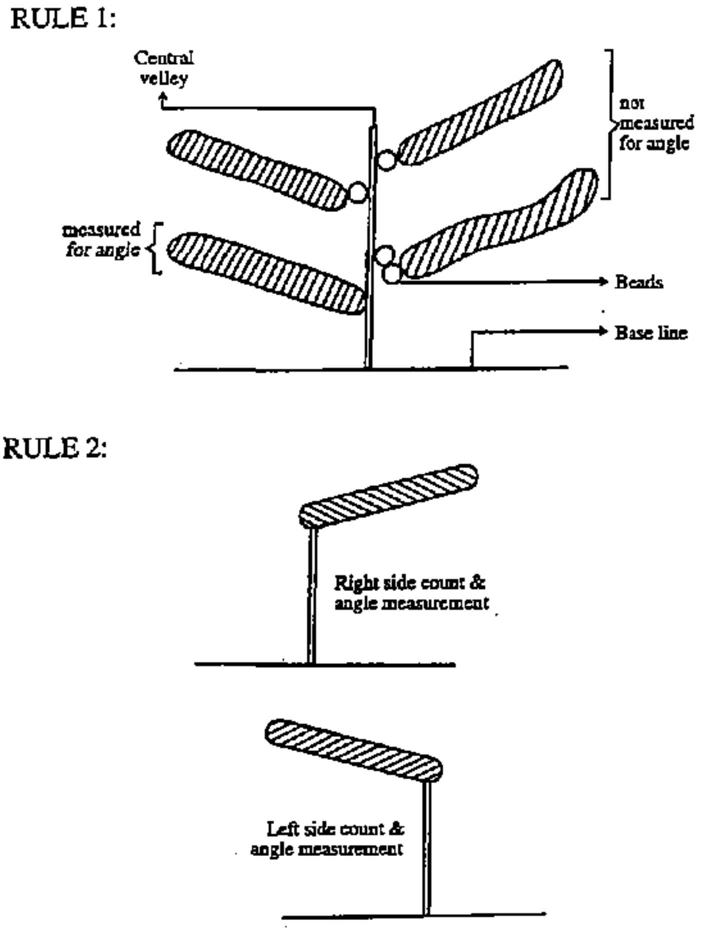


Figure 19. Rules Adopted to Measure and Record the Pattern Ridge.

The ridges apart from the pattern ridges were called distributed ridges. These distributed ridges of base and middle sectors were also counted for total ridge counting of the muzzle.

3.7 EQUATION USED FOR COUNTING THE CHARACTERISTICS

Total beads count of the muzzle (BTO):

BTO = BB + BM + BU

Where,

BB = Number of beads at base sector,

BM = Number of beads at middle sector, and

BU = Number of beads at upper sector.

Total ridge count (RCT):

RCT = RTB + RM

Where,

RTB = Total number of ridge at the base sector, and

RM = Total number of ridge at middle sector.

Total ridge at base sector (RTB):

RTB = RR + RL

Where,

RR = Total number of ridge on right side of the muzzle, and

RL = Total number of ridges on the left side of the muzzle.

Ridge right side (RR):

RR = PRR + DRR

Where,

PRR = Total pattern ridges on the right side of the muzzle, and

DRR = Total distributed ridges on right side.

Ridge left side (RL):

RL = PRL + DRL

Where,

PRL = Total pattern ridges on the left side of the muzzle, and

DRL = Total distributed ridges on the left side.

Ridge in the middle sector (RM):

RM = PRM + DRM

Where,

PRM = Total number of extended pattern ridges in the middle sector, and

DRM = Total number of distributed ridges in the middle sector.

3.8 OBSERVATIONS ON PATTERN RIDGES

The pattern ridges were also observed for the shape, length, type and characteristic features.

3.8.1 SHAPE

Two different shapes were observed in the pattern ridges. The pattern ridge having solid or hollow body with circular equal ends and straight parallel sides were called cylindrical shaped pattern ridges. Whereas, the pattern ridges bulbing at their one end were called club shaped pattern ridges (Figure 20). Both shapes were duly recorded for each pattern ridge.

3.8.2 LENGTH

The pattern ridges also differed from each other in length. Some were long and others were small. Since, it was difficult to measure the length of any curved structure directly by using measuring scale, they were measured visually and classified as follows:

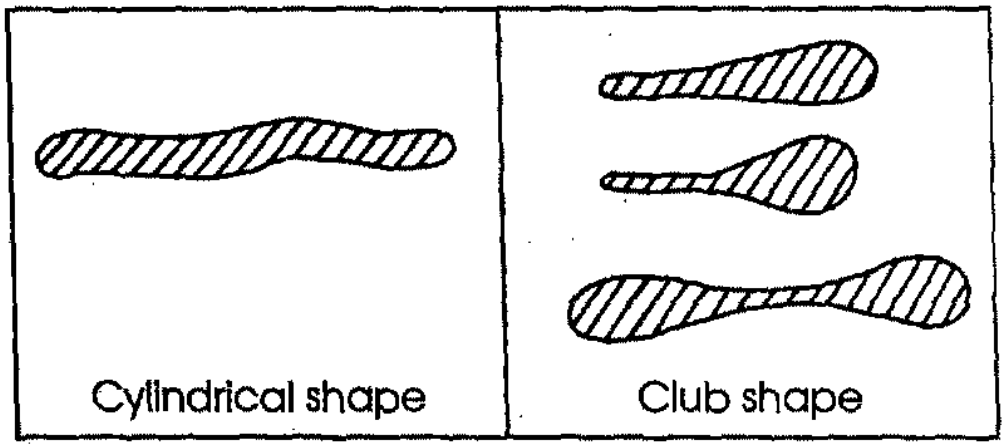
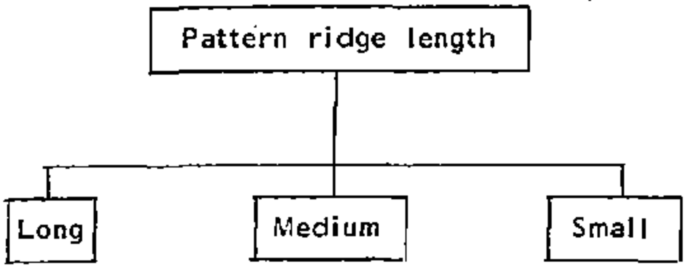


Figure 20. Shape of Pattern Ridges.



The number of respective pattern ridges of each muzzle prints were recorded accordingly.

3.8.3 TYPE

Following four different types were observed in the pattern ridges.

3.8.3.1 Complete Pattern Ridge

The complete pattern ridges were the ridges without any breach in their course from one end to other end (Figure 21).

3.8.3.2 Complete Intercepted Pattern Ridge

A complete pattern ridge with intercepts were called complete intercepted pattern ridges (Figure 21). It was observed that each sweat pores on these ridges were surrounded by intercepts.

3.8.3.3 Fragmented Pattern Ridges

The complete pattern ridges were sometimes fragmented due to presence of vibrissae. Such pattern ridges were called fragmented pattern ridges (Figure 21). The vibrissae (Baranov et al., 1993) were oftenly observed between the fragments of the pattern ridge.

3.8.3.4 Fragmented Intercepted Pattern Ridges

When intercepts were presented in the fragmented pattern ridges then such ridges were called fragmented intercepted pattern ridges (Figure 21).

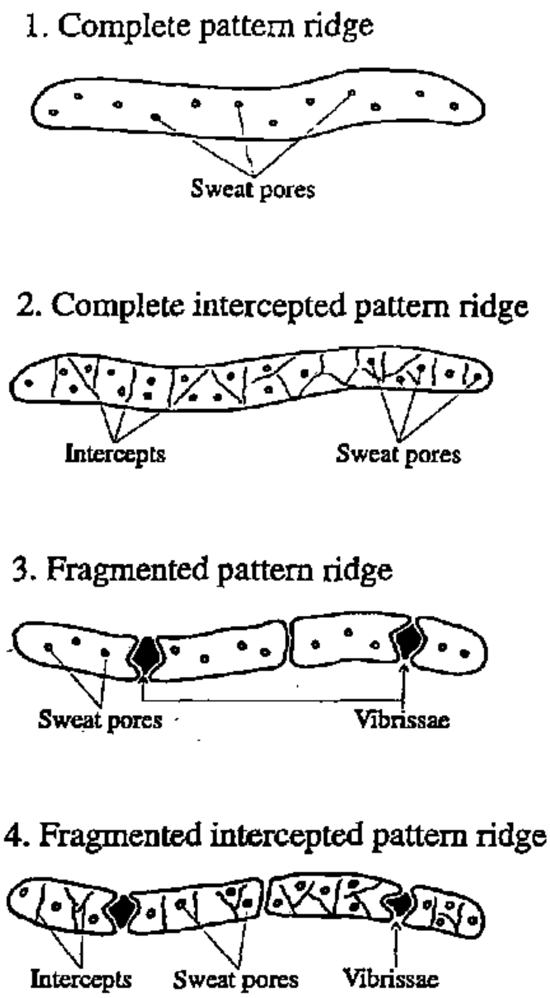


Figure 21. Types of Pattern Ridges.

3.8.4 PATTERN RIDGE CHARACTERISTICS

The pattern ridge begin to course in various way from the point of origin in different directions. Such coursing of pattern ridge lead to develop their own characteristic features. The straight, curve and other characteristic features of the pattern ridges were duly recorded.

3.9 STATISTICAL ANALYSES

The total beads and the beads at base, middle and upper sector of the muzzle were statistically analysed using means procedure (SAS, 1992). Their means and standard deviation were determined for each breed of the cattle. Same statistical analysis was applied also on the number of right and left ridges, ridges at base and middle sector, right and left pattern ridges, total pattern ridges, pattern ridge characteristics and its shape, length and type for each breed of the cattle. All above mentioned characteristics were considered to examine variability among individuals.

3.9.1 GENUSES AND THEIR CROSSBREDS, BREEDS AND CATEGORY DIFFERENCES

The observation of each characteristics present in each sectors were examined to study the difference between Bos Indicus, Bos Taurus and crossbred cattle. Breed and category differences were also studied for each characteristics sector-wise. Preliminary analysis showed a significant difference between three groups of the genus. Further, it was also observed that the characteristics differ significantly between breeds and between category. Chi-square test was applied to study the difference between grooved and non-grooved category. The number of observations in special category were less than 1% hence excluded in the statistical analysis. The GLM procedure (SAS, 1992) was applied to study the differences between genuses, breeds and category consequently by using following model:

$$Y_{ijkl} = u + S_i + R_{ij} + C_k + CR_{ijk} + E_{ijkl} \qquad .....1$$

Where,

Y_{ijkl} = Individual observation on the muzzle of k^{th} category of j^{th} breed of i^{th} genus,

u = Population mean,

S_i = Observation on i^{th} genus (i = 1,2,3),

R_{ij} = Observation on the j^{th} breed of i^{th} genus,

C_k = Observation on k^{th} category,

CR_{ijk} = Interaction effect between k^{th} category and j^{th} breed of i^{th} genus, and

E_{ijkl} = Sample error.

Least square means obtained from General Linear Model procedure (SAS, 1992) were compared to study the significant differences. In this procedure, all possible probability values of least-square means of each characteristics of every breeds were compared applying Bonferoni-Holm experiment wise error rate procedure. The Bonferoni-Holm (Alois Essl, 1987) experiment wise error rate was used because of the unequal number of observation for each breed. The t-test probabilities of i^{th} and j^{th} mean of each muzzle characteristics of every breed were compared to declare two means to be significantly different.

3.9.2 CORRELATION STUDIES

3.9.2.1 <u>Association Between Muzzle Characteristics and Between Productive and Reproductive Traits</u>

The association between characteristics of each sectors were calculated using Pearson correlation procedure. The association between characteristics were estimated to observe the type and level of relationship to recognise the distribution of characteristics on the muzzle. Similar procedure was applied to analyse association of muzzle characteristics with first 305 days lactation yield, age at first calving, age at first service and calving interval.

3.9.2.2 Association Between Muzzle Print Characteristics and First 305 Days Lactation Yield

The first lactation yield and various muzzle print characteristics were analysed for the fixed effects of each trait to obtain the first 305 days lactation yield and muzzle print characteristics independent from their fixed effects by using following models:

I. First 305 days lactation yield:

$$Y_{ijklm} = u + S_i + R_{ij} + YSson_{ik} + Afc_{il} + E_{ijklm} \quad .....II$$

Where,

Y_{ijklm} = Observations on first lactation yield,

u = Population mean,

S_i = Fixed effect of i^{th} genus (i = 1,2,3),

R_{ij} = Fixed effect of j^{th} breed (j = 1,2,3,4,5,6) of i^{th} genus,

$YSson_{ik}$ = Fixed effect of k^{th} year season of i^{th} genus,

Afc_{il} = Linear and quadratic regression on age at first calving, and

E_{ijklm} = Random residual effect associated with first lactation yield.

II. Muzzle print characteristics:

$$Y_{ijk} = u + S_i + R_{ij} + E_{ijk} \quad .....III$$

Where,

Y_{ijk} = Observation on muzzle print characteristics,

u = Population mean,

S_i = Fixed effect of the i^{th} genus (i = 1,2,3),

R_{ij} = Fixed effect of the j^{th} breed (j = 1,2,3,4,5,6) of i^{th} genus, and

E_{ijk} = Random residual effect associated with muzzle print characteristics.

Correlation of the residuals of first lactation records and muzzle print characteristics were calculated to obtain correlations which are independent from their nuisance effects.

3.9.2.3 Canonical Correlation

This test was applied to study the dependencies between two sets of variable (Morrison, 1967). Where one set correspond to various traits of the muzzle and another was the first 305 days lactation yield. This test was applicable when there were many correlated traits within the set of variable. Independent linear functions were generated for the two sets of variable. In first attempt the two variable from two respective sets of variables were choosen so as to have as large a correlation as possible. Then the second variable were choosen to have as large a correlation as possible subject to being independent of the first variable, and so on. The canonical correlation was studied using cancorr procedure (SAS, 1992). This procedure studied twice by using two different sets of variable available from muzzle print. One set contains the observations of beads at base, middle and upper sectors as well as total number of beads in the muzzle. The observations on ridges right, left, total ridges in base and middle sectors, total number of ridges in muzzle and right and left pattern ridges were also included. All these variables forms one set of variable and second, to study canonical correlation, was the first 305 days lactation yield independent from their nuisance effect. Model-II was applied to obtain first 305 days lactation yield independent of their nuisance effect. The second set contains informations of pattern ridges, viz., numbers of straight, curved, tented, undulated, bifurcated, long, medium, small, club, cylindrical, complete, complete intercepted, fragmented, fragmented intercepted pattern ridges. All these information combined to form one set of variable and corrected 305 days lactation yield was used as second set to perform canonical correlation.

3.9.3 DISCRIMINANT ANALYSIS TO DIAGNOSE AND CLASSIFY THE GENUSES AND BREEDS OF ANIMALS USING MUZZLE CHARACTERISTICS

The morphometric characteristics of the muzzle were used to compare the Bos Indicus, Bos Taurus and crossbred animals. All breeds and genuses were discriminated using discriminant analysis procedure (SAS, 1992) where it computes various linear discriminant function for classifying observations into two or more groups on the basis of one or more quantitative variables. The linear discriminant function, also known as classification criterion, was determined by a measure of generalised squared distance (Mahalanobis distance). The Mahalanobis distance was based on full covariance matrix. Twenty-four measurements from each individual muzzle were included for classification purpose. The measurements were total number of beads at base, middle and upper sectors, total number of ridges in middle sector and the muzzle, total number of pattern ridges in the muzzle, number of straight, curved, tented, undulated, bifurcated, long, medium, small, complete, complete intercepted, fragmented, fragmented intercepted, club, cylindrical, and percentage of straight, long, small, and cylindrical pattern ridges. The discriminant analysis was carried out separately for genus and breed.

3.9.4 TO DETERMINE AGE WHEN DERMATOGLYPH BECOME PERMANENT

The muzzle characteristics increased in size with advancing age. The phenomenon of increase in the size of characteristics was studied to observe the age when changes in the size of characteristics were negligible. Since pattern existed on the surface relief on an individual remain constant with age (Sisson and Grossman, 1976). Hence, a single characteristics was chosen to study this objective. Total number of 469 animals from Tharparkar, Sahiwal, Karan Swiss, Karan Fries breed, ageing 0 to 144 months age were selected and classified into 12 different classes. The animals ageing 0 to 24 months of age were classified into 4 classes by giving 6 months class interval to each. Animals ageing more than 24 months but less than 96 months were classified with a 12 months class interval. Whereas, 24 months class interval given to the animals ageing more than 96 months to 144 months. The muzzle prints of each animal analysed separately. A square of 1.5 cm * 1.5 cm dimension was drawn in the centre of the middle sector of each muzzle print. The size was kept standard to follow up the progress of morphological changes on the animal muzzle with advancing age in a given area. The total number of beads present in the square was counted. Following model was used to study the age differences:

$$Y_{ijk} = u + R_i + A_j + E_{ijk} \qquad .....IV$$

Where,

Y_{ijk} = Observation on the beads,

u = Population mean,

R_i = Fixed effect of i^{th} breed (i = 1,2,3,4),

A_j = Fixed effect of j^{th} class of age (j = 1,2,3,....,12), and

E_{ijk} = Sample error.

General Least Square Means procedure (SAS, 1992) was applied to study the general significance of the model effects. Least square means were compared by applying Bonferoni-Holm (Alois Essl, 1987) mean comparison test to study the difference between each age class.

CHAPTER - 4

RESULTS AND DISCUSSION

4. RESULTS AND DISCUSSION

The modified cyclostyled ink procedure followed in present study revealed its perfect application on cattle muzzle, whereas, differences were observed when similar technique was applied on the buffalo muzzle. The differences were not directly associated with procedure of improved printing ink technique rather, a great difference between the muzzle of cattle and buffalo was observed. The muzzle prints obtained from cattle were better than the buffalo muzzle prints when accuracy and clarity of the print is concerned. The inefficiency to obtain clear buffalo muzzle print was related to the voluntary nature of the buffaloes muzzle. The buffaloes muzzle were soft and more elastic in nature than the cattle muzzle. Thus, the buffaloes were able to expand and shrink their muzzle very often while taking muzzle print. The nature of the buffaloes muzzle hindered greatly to obtain quality muzzle prints. The buffaloes became very furious when muzzle prints were taken and thus the problem of profuse sweating exaggerated which could not be controlled even after using anti-perspirants. These problems, however, were not observed in cattle. The prints obtained from buffalo muzzle were not the quality print (Figure 22), moreover, the characteristics appeared has not given the real impression due to raised sweat pores in the muzzle of buffaloes which was depressed in cattle, as observed. The reason associated with poor quality muzzle print of buffaloes were the softness and more elastic nature of the muzzle, which in turn disturbed the pressure differential between muzzle and metal pad when metal pad was driven on the muzzle. The disturbed pressure differential was thus resulted in poor quality muzzle prints.

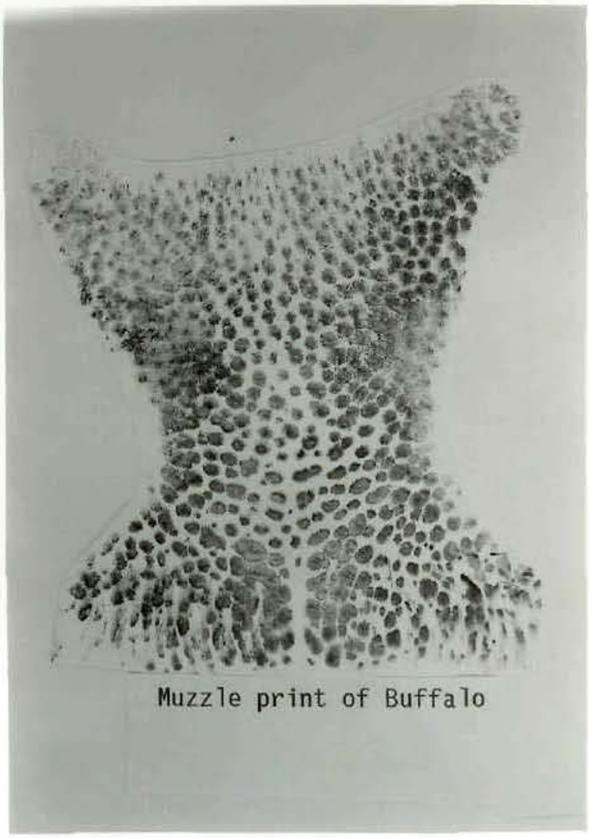


Figure 22. Muzzle print of buffalo.

4.1 CLASSIFICATION OF MUZZLE PRINT

During muzzle print analysis, it was often observed that some animals do contain groove at the centre of the muzzle and others do not. The muzzles based on presence and absence of groove were classified into grooved and non-grooved categories, respectively (Figures 24 and 30). This finding is quite similar to the results reported by Pandey (1979), wherein he observed presence and absence of groove in the muzzle print of animals and classified the muzzle into two main categories. Apart from the two main categories, a very unlike pattern which was neither similar to grooved nor to non-grooved category was also observed. Such muzzle prints were extremely different from others and were kept into third category called special category. The muzzle prints of special category were completely different by uncommon distribution of the characteristics and arrangement of the ridges. Further, the shape and type of pattern ridges of the grooved and non-grooved categories were entirely different. The distribution of animals based on the categorical classification revealed maximum occurrence of animals into grooved category than non-grooved and special categories. Out of 602 experimental animals, 351 animals (58.3%) were directly classified into grooved category, 247 (41.0%) and 4 (0.69%) animals were classified into non-grooved and special categories, respectively (Table 7). Thus, the categorical distribution of the animals indicated presence of very few animals in special category. Hence, the animals of this category were not included in the analysis. Highly significant ($P < 0.01$) difference was observed between grooved and non-grooved categories.

4.1.1 PRIMARY CLASSIFICATION OF MUZZLE PRINTS

The grooved, non-grooved and special categories were further divided on the basis of the distribution of beads and arrangements of pattern ridges into further sub-classes described under the heading "Pattern of the Muzzle".

Table 7. Distribution of animals based on categorical classification of muzzle print.

Breeds	Grooved category	Non-grooved category	Special category	Total
Tharparkar (TH.)	35	6	-	41
Sahiwal (SW.)	71	3	-	74
Karan Swiss (KS.)	72	59	3	134
Karan Fries (KF.)	135	117	1	253
Red & White (RW.)	21	29	-	50
Black & White (BW.)	17	33	-	50
Total	351	247	4	602

Table 8. Distribution of animals of different breeds into the patterns of three category.

Category	Pattern *	Breeds						Total
		TH.	SW.	KS.	KF.	RW.	BW.	
Grooved	1	31	59	60	125	20	17	312
	2	-	-	1	1	-	-	2
	3	2	3	2	4	1	-	12
	4	1	2	4	4	-	-	11
	5	1	7	4	1	-	-	13
	6	-	-	1	-	-	-	1
Non-grooved	1	-	3	23	59	15	22	122
	2	5	-	25	42	8	3	83
	3	-	-	2	3	2	1	8
	4	1	-	4	9	4	6	24
	5	-	-	5	4	-	1	10
Special	1	-	-	1	1	-	-	2
	2	-	-	1	-	-	-	1
	3	-	-	1	-	-	-	1
Total	14	41	74	134	253	50	50	602

* Refer to Table 9 for explanation of the patterns.

The sub-class of each category represent the pattern of the muzzle of an individual. The distribution of animals of different breeds under different patterns are presented in Table 8.

4.1.2 PATTERN OF THE MUZZLE

Beads distribution and pattern ridge arrangements on the muzzle plays an important role in developing pattern on the muzzle. Most of the pattern on the muzzle were formed due to arrangement of the pattern ridges and around 90% of the muzzles were directly classified on the basis of pattern ridge arrangement only. Whereas, the pattern based on distributed ridge and beads as well as pattern formed only by beads were available in 5.81% and 3.82%, respectively, on the muzzle of animals. The animals with no specific arrangement of the characteristics on the muzzle were less than 1 percent (Table 9). Thus, in 90% cases, the pattern ridge arrangement was strictly responsible for the development of the pattern on the muzzle. The grooved, non-grooved and special categories were further classified into 6, 5 and 3 patterns, respectively. Where 4 out of 6 pattern classes of grooved category were perfectly based on pattern ridge arrangement. In non-grooved category, only 3 patterns were completely based on pattern ridge arrangement. The patterns of special category were only due to unlike arrangement of the ridges. Some animals which do not have common or specific arrangement of the pattern ridges on the muzzle due to absence of it, were classified on the basis of ridge and bead distribution. In complete absence of the pattern and distributed ridges, the muzzle was classified into a pattern solely based on the distribution of beads into three respective regions of the muzzle. The flow diagram of the muzzle classification has been presented in Figure 23. Two types of pattern ridges were observed. These were the simple and compound pattern ridges. The compound pattern ridges were more wider and highly intercepted than the simple ones. This was similar to the

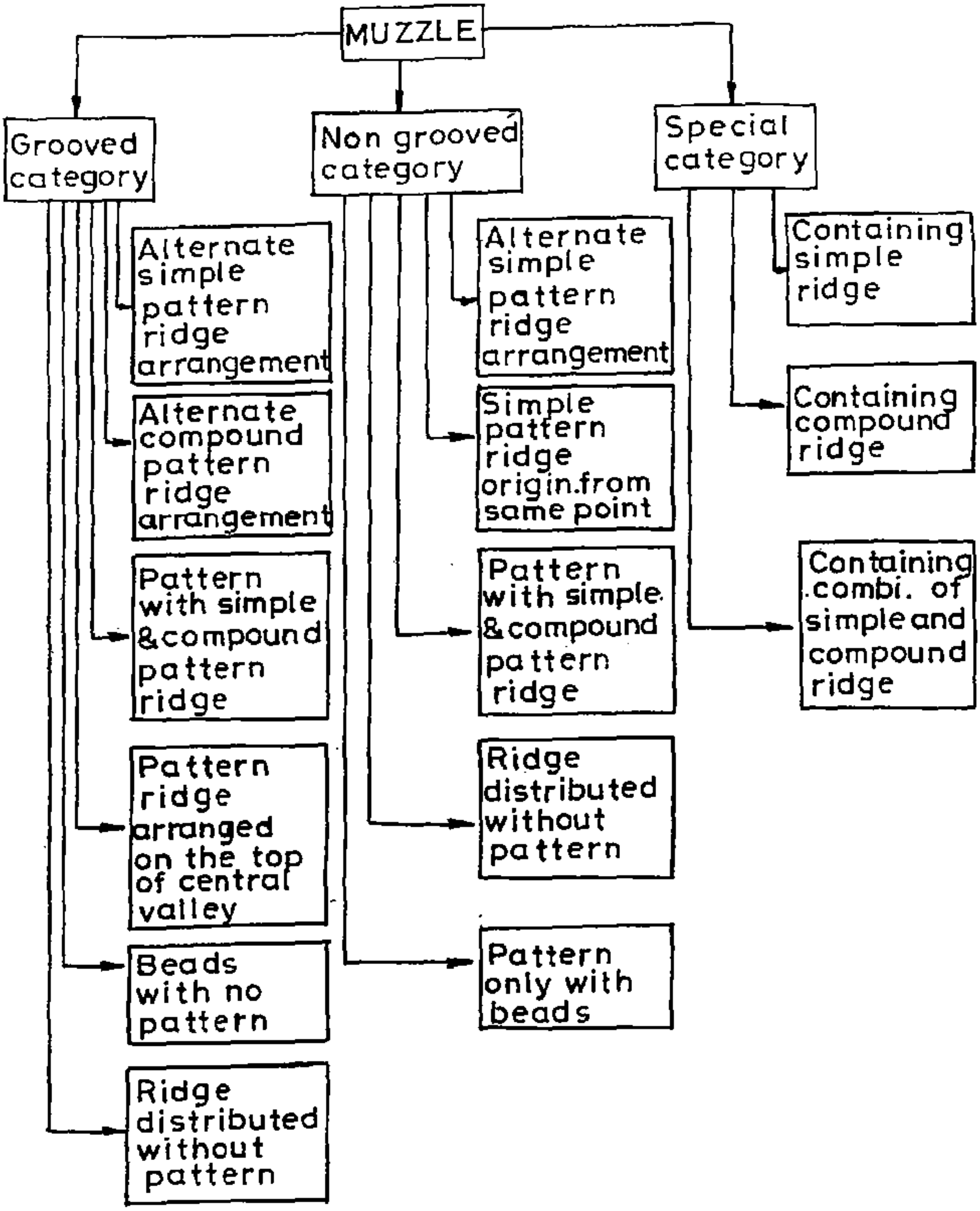


Figure 23. Primary classification of the muzzle

findings of Pandey (1987) where the muzzle was classified on the basis of simple and compound ridges. The patterns of each category is discussed separately under following sub-heads:

4.1.2.1 Patterns of Grooved Category

4.1.2.1.1 Alternate simple pattern ridge arrangement

In this pattern, only simple pattern ridges were observed. All simple pattern ridges were located exactly adjacent around central valley and arranged alternatively into right and left halves of the muzzle (Figure 24). The simple pattern ridge arrangement of this pattern was subjected to the length of the appeared central valley. The pattern may or may not be extended to the middle sector and it depends on the magnitude of the central valley. All the breeds have shown the presence of this pattern (Table 8). Around 52% animals were classified into this pattern which is very high when compared with other patterns (Table 9).

4.1.2.1.2 Alternate compound pattern ridge arrangement

The arrangement of the pattern ridge was very similar to the alternate simple pattern ridge arrangement. This pattern was based completely on the presence of compound pattern ridges. Simple pattern ridges were completely absent in this pattern (Figure 25). Only 0.33 percent animals (1 out of 602 animals each of Karan Swiss and Karan Fries breeds) showed presence of this pattern which is very infrequent in the population (Table 9).

4.1.2.1.3 Pattern with simple and compound pattern ridge arrangement

This pattern consisted of combination of simple and compound pattern ridge. The simple and compound pattern ridges were located explicitly adjacent to the central valley (Figure 26). This pattern was not observed in Black & White cattle, whereas, only 2, 3, 2, 4 and 1 animal of Tharparkar, Sahiwal,

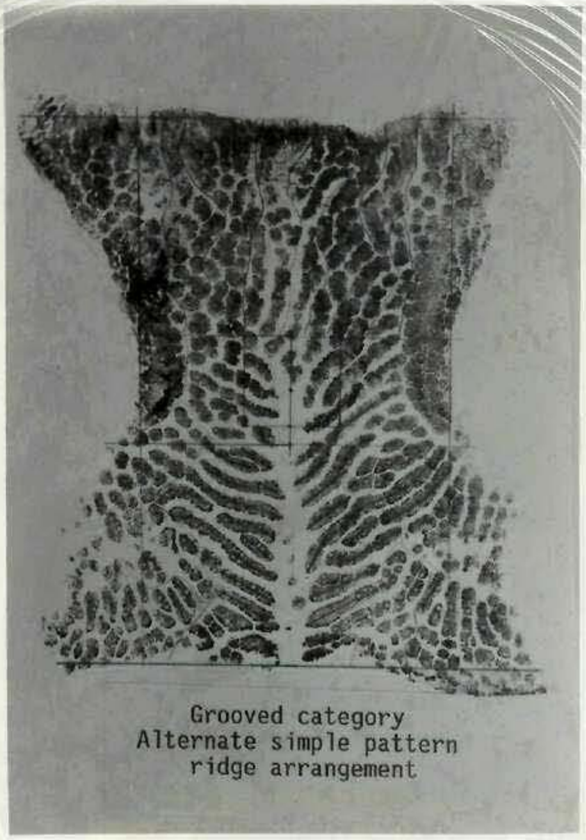


Fig. 24. Alternate simple pattern ridge arrangement of grooved category.

Fig. 25. Alternate compound pattern ridge arrangement of grooved category.

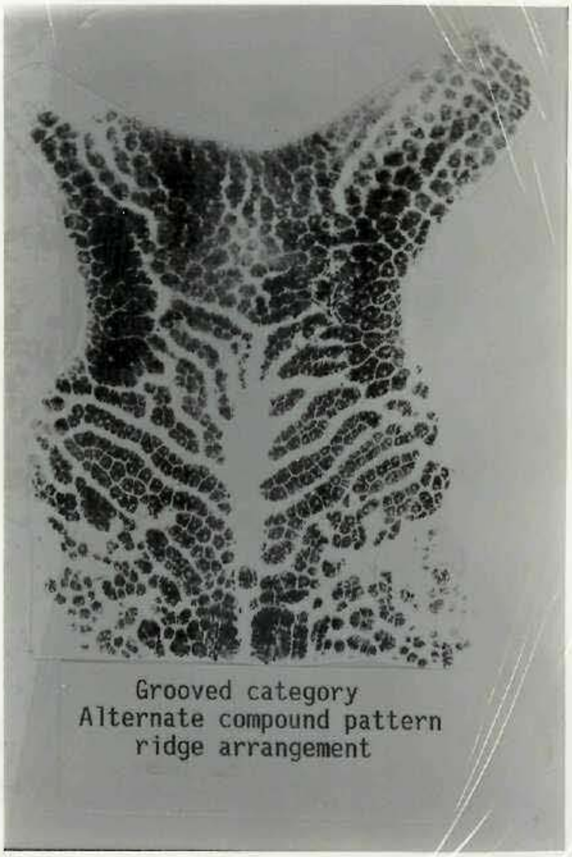


Table 9. Percentage of animals (n = 602) in each pattern.

Sl.	Pattern	Percentage
A.	**Grooved Category:**	
1.	Alternate simple pattern ridge arrangement	51.83
2.	Alternate compound pattern ridge arrangement	00.33
3.	Pattern with simple & compound pattern ridge arrangement	01.99
4.	Ridge distributed without pattern	01.83
5.	Beads with no pattern	02.16
6.	Pattern ridge arranged on the top of central valley	00.17
B.	**Non-grooved Category:**	
1.	Alternate simple pattern ridge arrangement	20.26
2.	Simple pattern ridge origin from same point	13.79
3.	Pattern with simple & compound pattern ridge arrangement	01.33
4.	Ridge distributed without pattern	03.98
5.	Pattern only with beads	01.66
C.	**Special Category:**	
1.	Containing simple ridge	00.33
2.	Containing compound ridge	00.17
3.	Containing simple & compound ridge	00.17

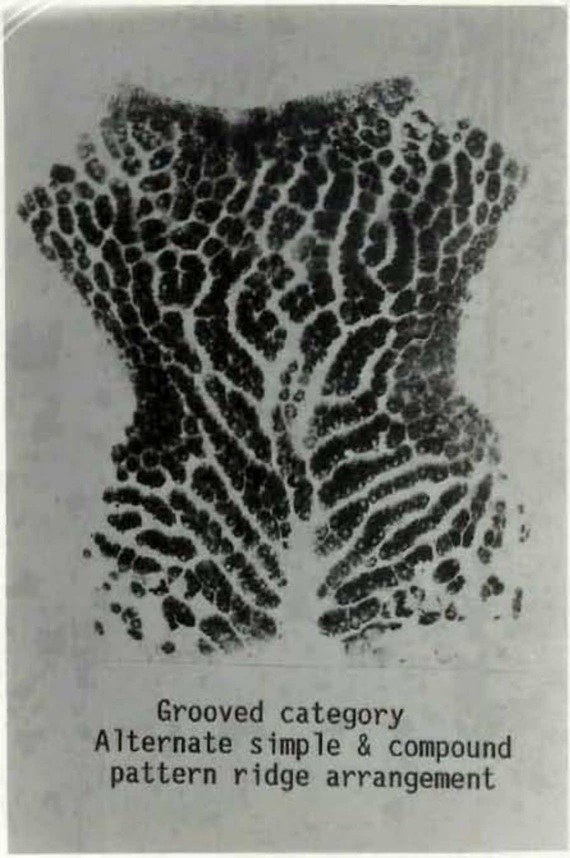
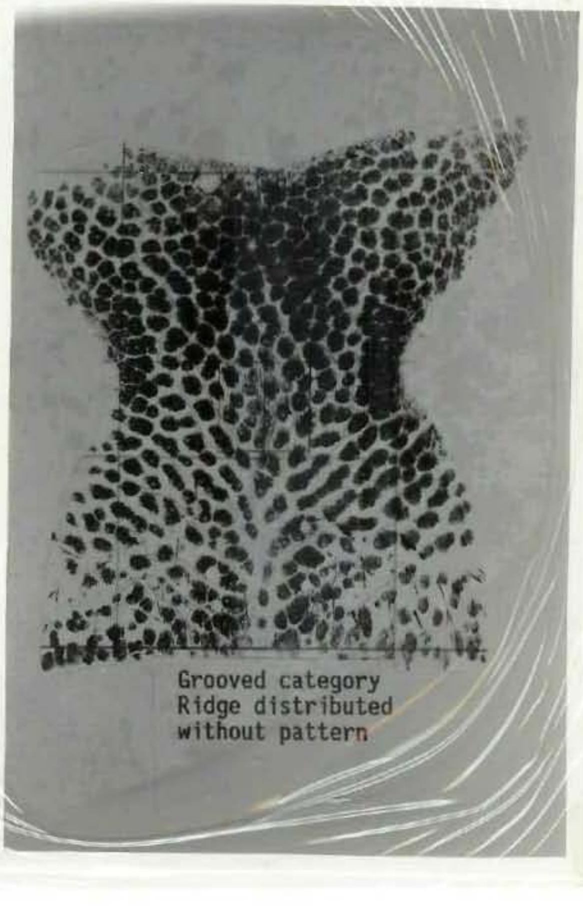


Fig. 26. Pattern with simple and compound pattern ridge arrangement of grooved category.

Fig. 27. Ridge distributed without pattern of grooved category.



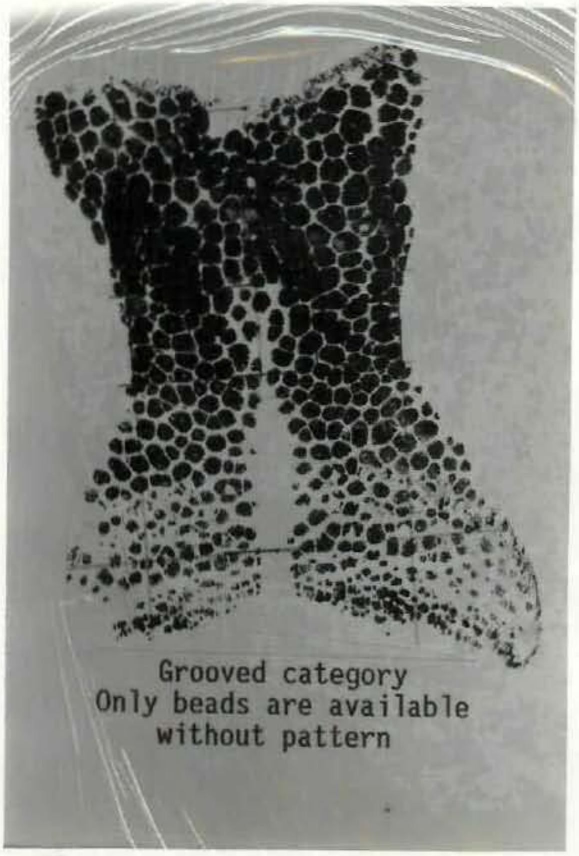
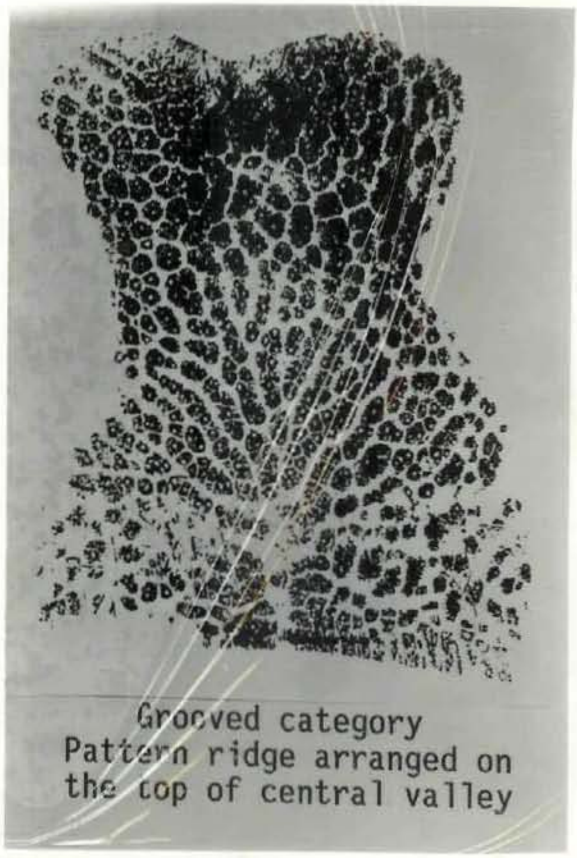


Fig. 28. Beads with no pattern of grooved category.

Fig. 29. Pattern ridge arrangement from the top of central valley (grooved category).



Karan Swiss, Karan Fries and Red & White breeds, respectively, have shown the appearance of such pattern (Table 8). Overall percentage of each pattern in the population was 1.99 (Table 9).

4.1.2.1.4 Ridge distributed without pattern

Due to complete absence of pattern ridges, no specific arrangement was observed. The ridges have no explicit origin and are distributed on the surface relief of the muzzle. These ridges are called "distribute ridges" (Figure 27). The non-existence of specific pattern is itself a pattern of its own type. Hence, the pattern of this type was considered as "Ridge distributed without pattern". This pattern was not observed in Red & White and Black & White cattle, whereas, in Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds only 1, 2, 4 and 4 animals, respectively, exhibited this pattern (Table 8). Overall 1.83 percent animals have shown the presence of this pattern (Table 9).

4.1.2.1.5 Beads with no pattern

Complete absence of pattern ridge and distributed ridges were observed in this type of pattern. Only beads were available and distributed on the muzzle. This pattern was not seen in Red & White and Black & White cattle, whereas, 1, 7, 4 and 1 animals belonging to Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds, respectively, contained this pattern (Table 8). Only 2.16 percent animals have shown this pattern (Table 9). The central valley was present and divide the muzzle into right and left halves (Figure 28). This pattern was also reported by Trofimenko (1989), where he classified such pattern as "Granular Pattern".

4.1.2.1.6 Pattern ridge arrangement from the top of central valley

The beads, distributed ridges and pattern ridges were present in the pattern, but the peculiar arrangement of pattern ridge was entirely different from rest of the pattern. Central valley was present where origin and location of pattern ridges were from either sides and top of the central valley. Only 1 animal was observed to contain such pattern in Karan Swiss breed (Table 8). Most of the pattern ridges were arranged on the top or end point of the central valley and few pattern ridges have shown their origin from either side of the central valley (Figure 29).

4.1.2.2 Patterns of Non-grooved Category

The central valley was completely absent in this category. Thus, it is a distinguishing feature of the non-grooved category. The pattern ridges originate very often from the centre of the muzzle. Therefore, centre of the muzzle was considered as a point of origin of the pattern ridges in this category. The muzzle is divided into right and left halves due to arrangement and course of the pattern ridge to its respective direction. In case of patterns formed by distributed ridges as well as those formed by beads alone the muzzle is not divided into right and left halves. The patterns of non-grooved category are discussed under following headings:

4.1.2.2.1 Alternate simple pattern ridge arrangement

The simple pattern ridges of different characteristic features, shapes and types were arranged alternatively. The arrangement of pattern ridges in this category was quite close to alternate simple pattern ridge arrangements of grooved category. The major difference between these patterns of grooved and non-grooved categories was the absence of central valley in non-grooved category. This pattern is observed in all breeds except Tharparkar (Table 8). Around 20 percent animals exhibited this pattern, which is less than half of the percentage of animals belonging to the alternate simple pattern ridge arrangement of grooved category (Table 9). The simple pattern ridges must be examined for their location and point of origin at the central area of the muzzle print to decide whether this pattern actually belongs to an alternate simple pattern ridge arrangement of non-grooved category. If such is not the case, the muzzle can never be classified into this pattern. The pattern ridges of this pattern originate from centre and course towards lateral aspects of the muzzle. Such coursing of the pattern ridges caused the division of muzzle into right and left equal halves (Figure 30).

4.1.2.2.2 Simple pattern ridge originating from same point

This is the most peculiar pattern among all patterns of grooved and non-grooved category. The arrangement of pattern ridges was not alternate, rather, they were located at the same point and distributed at the centre of the muzzle. Only simple pattern ridges were found in this pattern. No demarcation into right and left halves could be made, due to origin of pattern ridges from the same point (Figure 31). The pattern appeared in all the breeds except Sahiwal (Table 8) and, around 14 percent animals directly classified into this pattern (Table 9).

4.1.2.2.3 Pattern with simple and compound pattern ridge arrangement

This pattern was similar to one of the patterns of grooved category. The similarities were due to the arrangement and presence of both types, i.e., simple and compound pattern ridges (Figure 32). Absence of central valley was the differential characteristic to distinguish it from same pattern of grooved category. Other features were similar in the two patterns. The pattern appeared in less number of animals of Karan Swiss, Karan Fries, Red & White and Black & White cattle, whereas, it was not observed in Tharparkar and Sahiwal cattle (Table 8). Only 1.33 percent animals were found to contain this pattern.

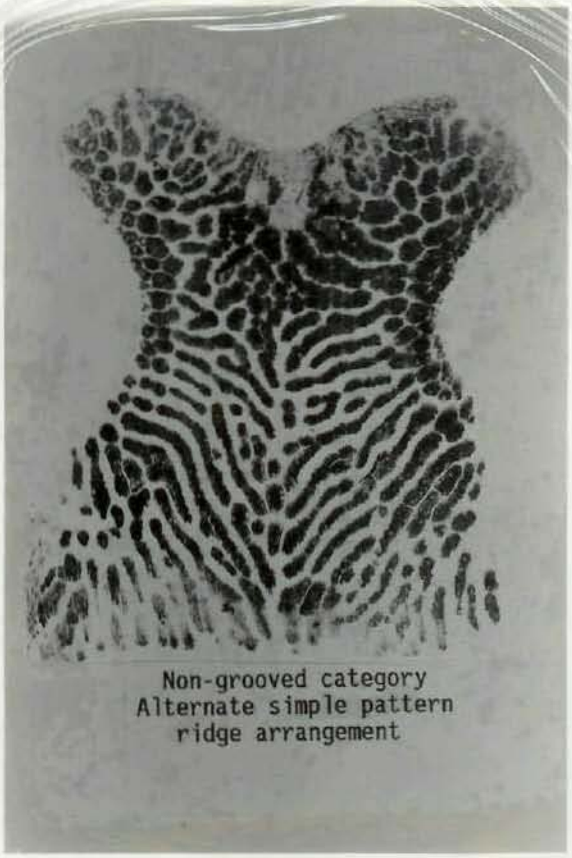


Fig. 30. Alternate simple pattern ridge arrangement of non-grooved category.

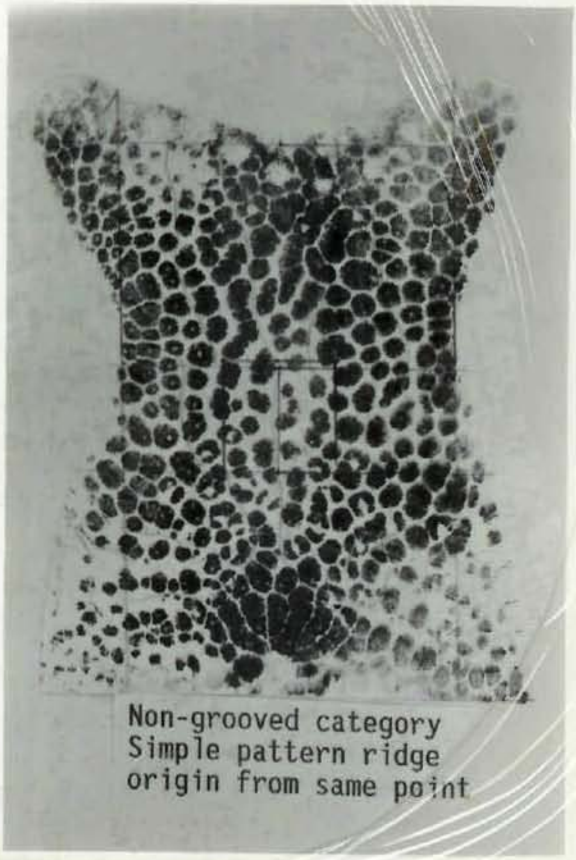


Fig. 31. Simple pattern ridge originating from same point (non-grooved category).

4.1.2.2.4 Ridge distributed without pattern

The pattern ridges were completely absent in this category. This pattern was similar in all respect to the pattern "ridge distributed without pattern" of grooved category except with the absence of central valley (Figure 33). All breeds exhibited the presence of this pattern except Sahiwal (Table 8). The animals contributing in the presence of this pattern were 3.98 percent. This was double than the percentage observed in same pattern of grooved category (Table 9).

4.1.2.2.5 Pattern only with beads

Only beads were available in this pattern. Complete absence of pattern ridges, distributed ridges and central valley were the distinguishing features of this pattern (Figure 34). The pattern was not found in Tharparkar, Sahiwal and Red & White cattle, whereas, Karan Swiss, Karan Fries and Black & White breeds have shown the presence of such pattern in 5, 4 and 1 animals, respectively (Table 8). Overall only 1.66 percent animals were found containing this pattern (Table 9).

4.1.2.3 Patterns of Special Category

Less than 1 percent animals showed the patterns of special category. The special category had three main patterns, i.e., muzzle containing simple ridge, containing compound ridge and the combination of simple and compound ridges. All the patterns were found in Karan Swiss breed, though the number of animals was one in each pattern. Only one animal was observed containing pattern formed by simple ridge in Karan Fries breed. The patterns of this category were not found in other breeds (Table 8). Only 0.33, 0.17 and 0.17 percent animal exhibited simple ridge, compound ridge and the combination of simple and compound ridge patterns, respectively (Table 9). This indicated presence of such patterns only in crossbred population.

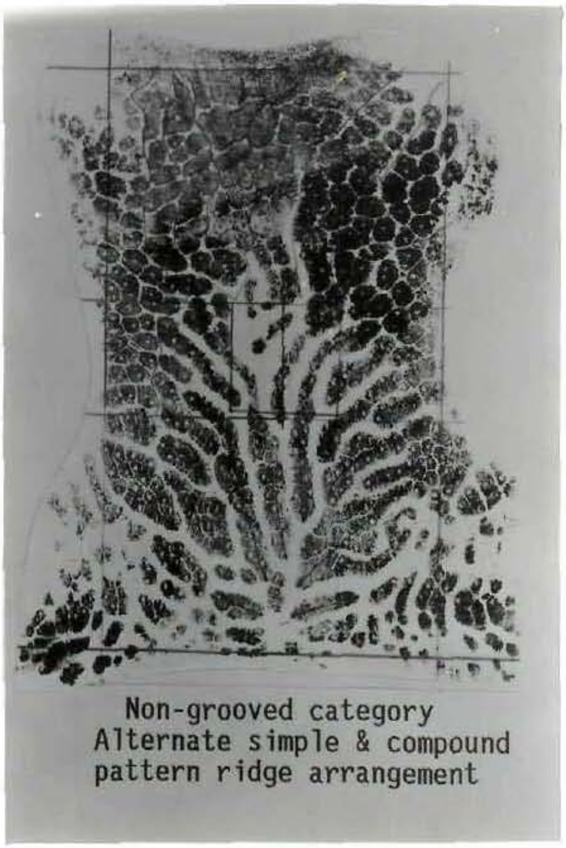


Fig. 32. Pattern with simple and compound pattern ridge arrangement of non-grooved category.

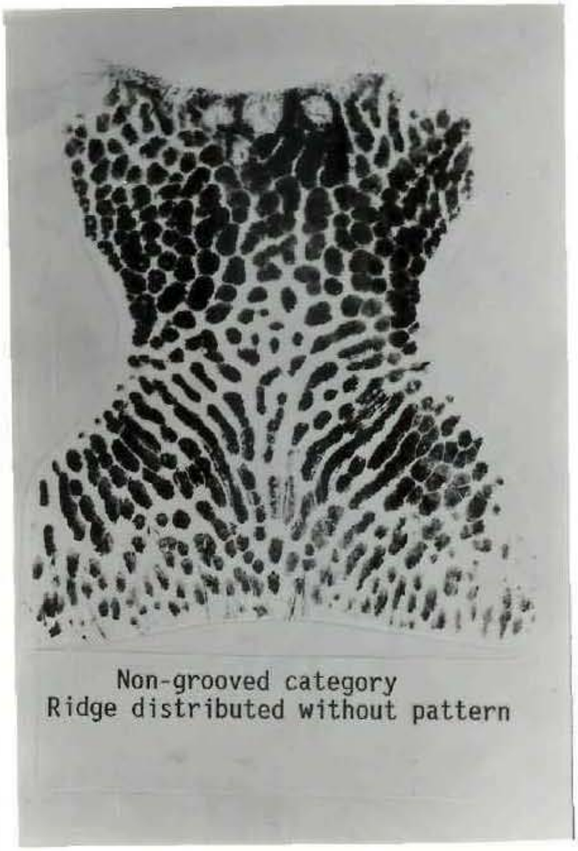


Fig. 33. Ridge distributed without pattern of non-grooved category.

The peculiarity of the patterns of special category was distinct and irregular arrangement of ridges on the muzzle (Figures 35, 36 and 37). The ridges had no specified arrangement as it occurred in case of various patterns of grooved and non-grooved categories. The special category was divided into three patterns on the basis of types of ridges present on the muzzle. Only simple ridges were present in "simple ridge pattern" of special category. Whereas, the patterns "compound ridge" and "combination of simple and compound ridge" contained only compound ridges and combination of simple and compound ridges, respectively.

The diagrammatic representation of all patterns under three categories are presented in Appendix-I.

4.2 THE PATTERN RIDGE CHARACTERISTICS

Around 90 percent animals were classified only on the basis of pattern ridges and remaining 10 percent animals based on the distributed ridges and beads (Table 10). Therefore, pattern ridges were very important for the classification of muzzle. Different varieties of the pattern ridges were observed while classifying muzzle print. Not only pattern ridges, but distributed ridges have also exhibited the diversity. But in this study, only pattern ridges were studied due to their major impact on classification system. The pattern ridges were observed for the following:

Table 10. Percentage of pattern based on muzzle characteristics.

Characteristics	Percentage
Pattern based on pattern ridges	89.70
Pattern based on distributed ridges	05.81
Pattern based on beads	03.82
Others	00.67

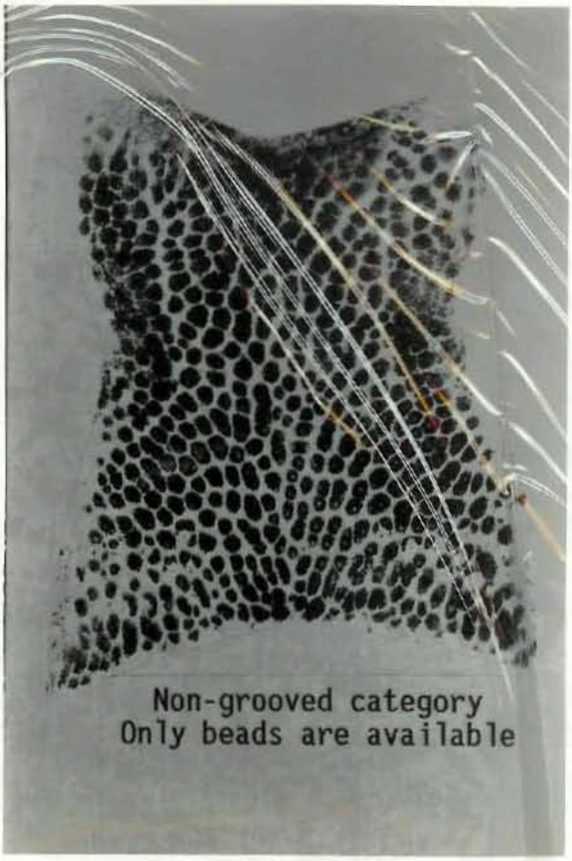
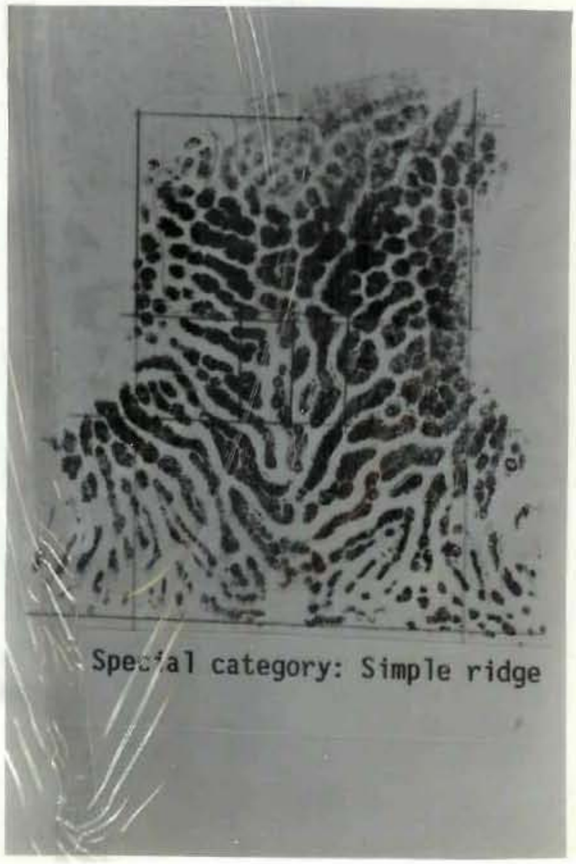


Fig. 34. Pattern only with beads (non-grooved category).

Fig. 35. Special category containing simple ridge.



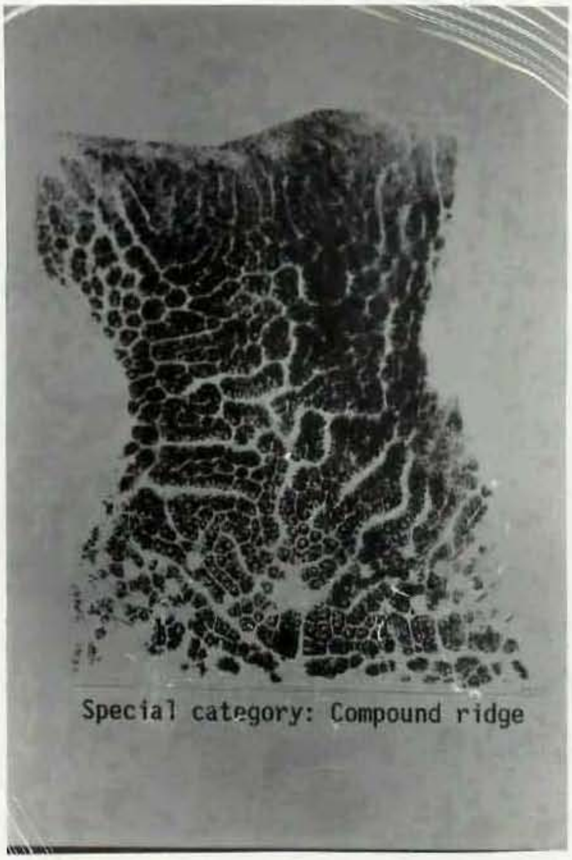


Fig. 36. Special category containing compound ridge.

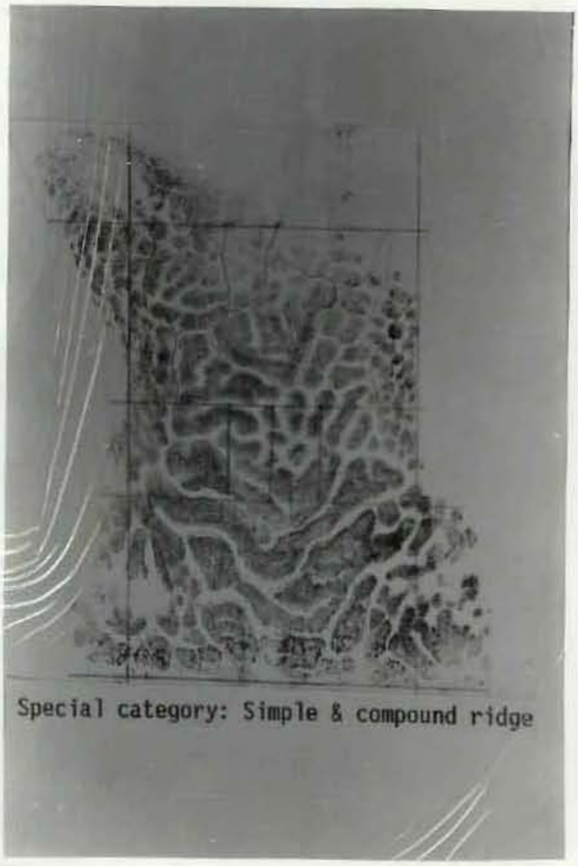


Fig. 37. Special category containing simple and compound ridge.

4.2.1 CHARACTERISTICS FEATURES

The pattern ridges arranged around the site of origin on the muzzle present different features based on trend of the course. The pattern ridges develop their own individual structure while coursing from one end to other in different ways and direction. Such structure formed by the pattern ridge may or may not be similar to other pattern ridges, but, few pattern ridge may resemble others. This analogy has made it possible to classify the pattern ridges into 6 different classes called "major class" (Figure 38). The idea behind studying pattern ridges was to explore the possibility of individual identification because, the primary classification of muzzle merely indicated the existence of various patterns on the muzzle. Further, these patterns were not able to fulfil the requirement of individual identification. Different structures of the pattern ridges of major class have lead to the development of the minor classification which indicated multiplicity in the pattern ridges of major class. This multiplicity arouse great variability in all pattern ridges of same muzzle. The polymorphic nature of the muzzle and pattern ridge characteristics will be able to give a fillip to the correct individual identification of different categories of animals and could create new vistas in animal science research.

4.2.2 MAJOR CLASSIFICATION OF PATTERN RIDGES

The diversity on pattern ridges were grouped into six major classes namely, curved, bifurcated, straight, tented, undulated and miscellaneous class. The pattern ridges belonging to curved, bifurcated and tented major class resulted in development of heterogeneity among them. Therefore, they were further classified into minor classes. Each minor class represent the minor details of the pattern ridges. Miscellaneous class was opened to accommodate those pattern ridges which had no concordance with any of the other specified minor and major classes. The minor classes of each major class are discussed separately under following headings:

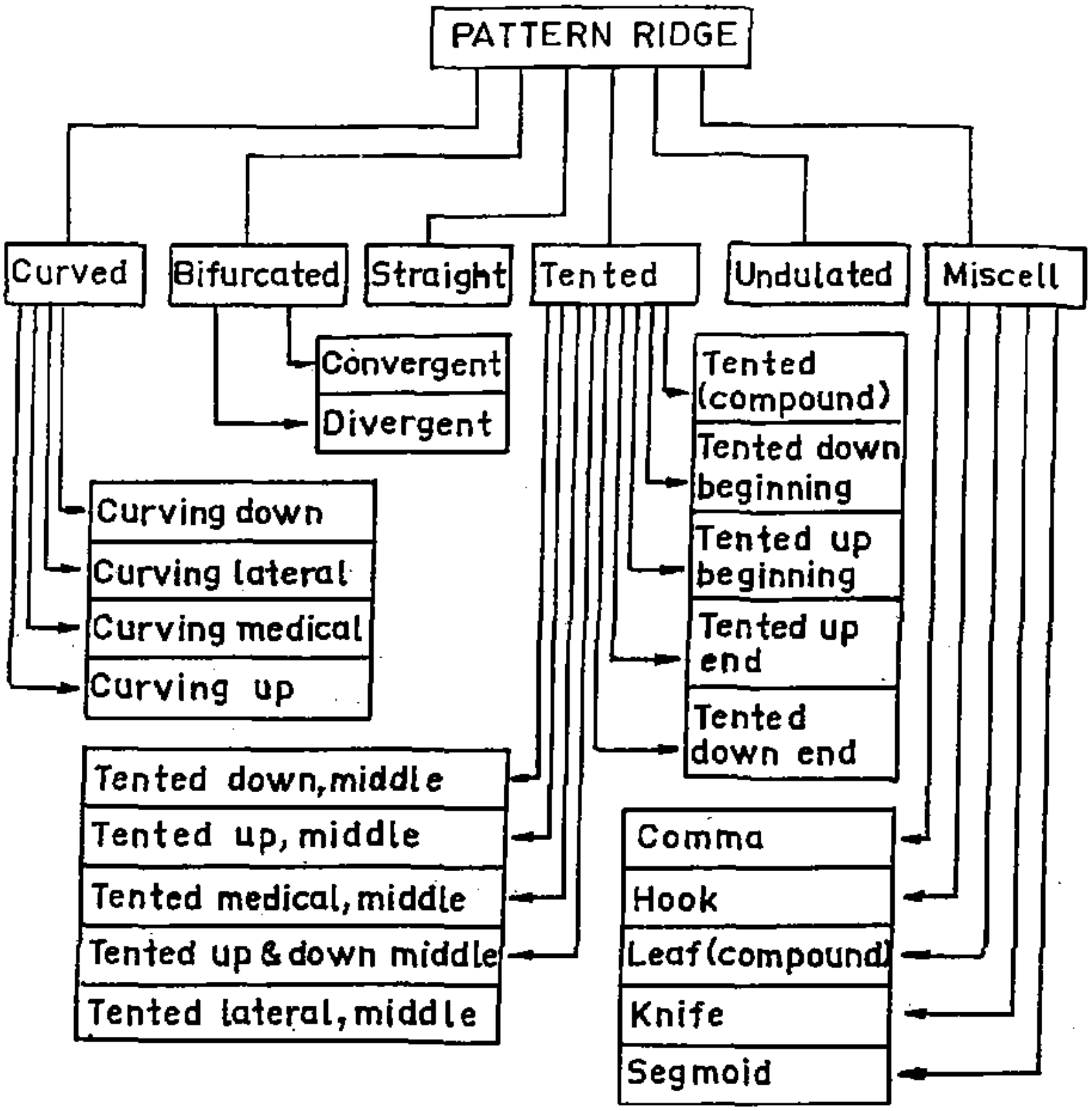


Figure 38. Classification of pattern ridge characteristics

4.2.2.1 Curved Pattern Ridge

The body of the curved pattern ridges were always bent. Each curved pattern ridge originates at certain specified angle of its own and extend to various lengths. The mean, standard deviation and coefficient of variation of curved pattern ridges are presented in Table 11. The average of 1.77 curved pattern ridges per muzzle is higher than the other pattern ridges except straight pattern ridge. The variability of this pattern ridge was very high. The minor classification was based on the position or direction of the curve on pattern ridges. Since 4 different directions were observed, thus, 4 minor classes were also made. The minor classes were curving down, curving medial, curving lateral and curving up. Curving down and curving up pattern ridges were due to the downward and upward position of the curve. Whereas, in case of curving medial and curving lateral pattern ridges the curve was located towards medial and lateral aspect of the muzzle (Figure 39).

4.2.2.2 Bifurcated Pattern Ridge

Bifurcation is dividing or forking of single pattern ridge into two or more branches. Thus, bifurcated pattern ridges were divided into two minor classes, i.e., convergent and divergent (Figure 39). The convergent type of bifurcated pattern ridges were formed by joining two branches of the pattern ridge, whereas, divergent type was the bifurcation of single pattern ridge after originating from the point of origin. The average of the bifurcated pattern ridge was less than one per muzzle leading to high variability. Only 4 bifurcated pattern ridges were observed as a maximum value on the muzzle. In convergent type, only one branch of the bifurcated pattern ridge was observed and measured for angle as a single unit of bifurcated pattern ridge.

4.2.2.3 Straight Pattern Ridge

The pattern ridge coursing in a straight way were considered as "straight pattern ridge" (Figure 39). Further classification of this pattern ridge

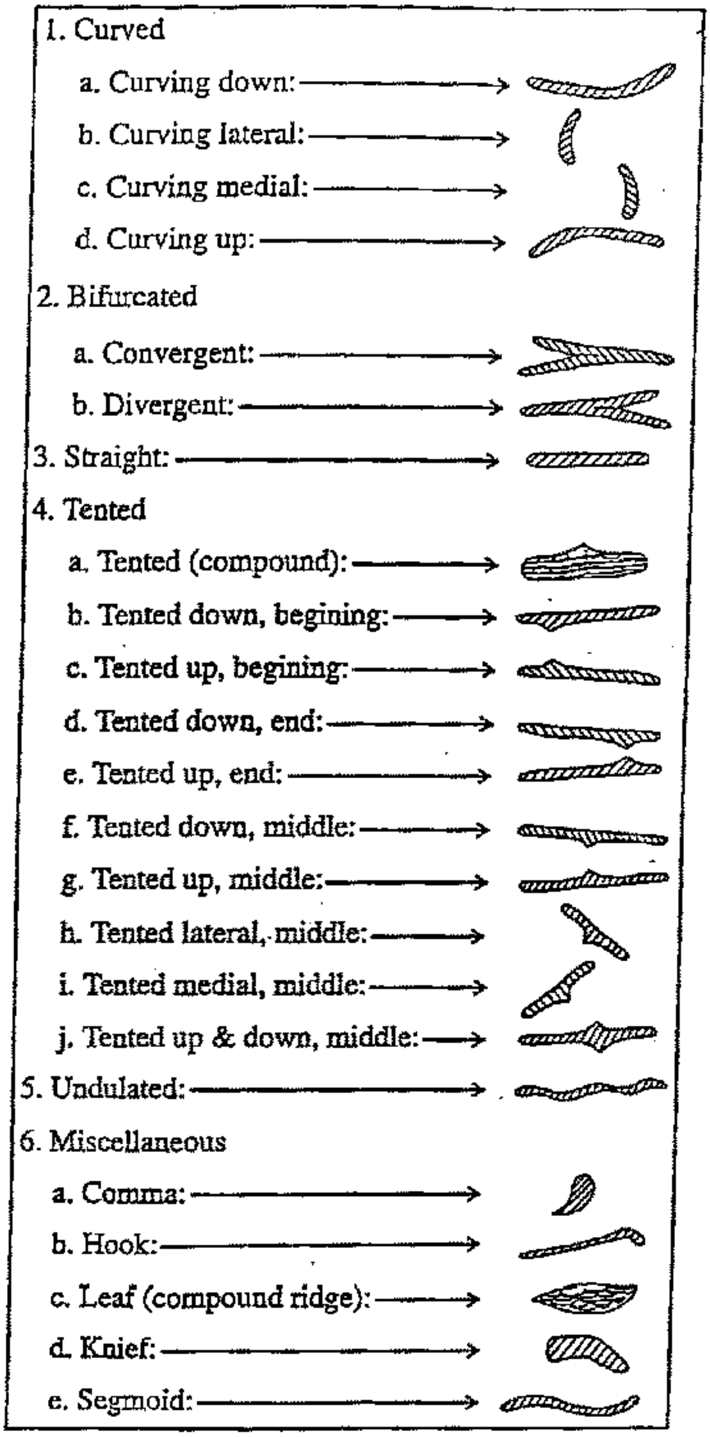


Figure 39. Diagrammatic representation of pattern ridge characteristics.

Table 11. Means, standard deviation and coefficient of variation of pattern ridges of major class, its length, shape and type (n = 539).

Pattern ridge characteristics	$\bar{x}$	sd	cv
Major Class:			
Curved	1.77	1.42	80.17
Bifurcated	0.16	0.47	296.17
Straight	2.65	1.82	68.66
Tented	0.33	0.64	192.17
Undulated	0.81	1.06	130.16
Miscellaneous:			
Comma	0.07	0.30	438.08
Hook	0.28	0.57	198.09
Leaf	0.009	0.09	1034.40
Knife	0.01	0.10	943.38
Segmoid	0.38	0.66	173.73
Length:			
Long	2.83	2.13	75.40
Medium	2.24	1.71	76.18
Small	1.55	1.50	96.78
Shape:			
Club	1.24	1.22	98.40
Cylindrical	5.39	2.76	51.33
Type:			
Complete	0.75	2.04	271.72
Complete intercepted	5.01	2.94	58.76
Fragmented	0.14	0.59	406.97
Fragmented intercepted	0.77	1.51	161.99

was not possible. The mean value was comparatively higher than the other pattern ridge. On an average, 2.65 pattern ridges of the type were observed per muzzle.

4.2.2.4 Tented Pattern Ridge

Presence of thrust at the border of pattern ridge was the characteristic feature of tented pattern ridge, though it is not always necessary that the thrust will be pointed one. The thrust to form tent may be pointed or rounded in nature. Presence of thrust was not only limited to particular area of the pattern ridge, but always tended to vary. This variation has enabled classification of the tented pattern ridges into various minor classes. The minor classification was solely based on the position of thrust on the border of the pattern ridge. These thrusts were observed on three different positions at the body of the pattern ridge. These were beginning, middle and end part of the body. Consequently, two different location were also observed on three respective positions. The location of the thrust was towards either upward or downward direction. The combination of the position and direction had resulted in 10 minor classes, namely, tented (compound), tented downward at the beginning, tented upward at the beginning, tented upward at the end, tented downward at the end, tented upward at the middle, tented downward at the middle, tented lateral at the middle, tented medial at the middle and tented upward and tented downward at the middle. The 1st class was observed only in heavily intercepted compound pattern ridges (Figure 39).

The mean value of 0.33 of tented pattern ridges suggested its less occurrence than the straight and curved pattern ridges, but, more than bifurcated pattern ridge. The variability of this pattern ridge was very high (Table 11).

4.2.2.5 Undulated Pattern Ridge

This pattern ridge coursed in the form of a wave to which ultimately developed undulation (Figure 39). It had no further sub-division into minor classes. Presence of undulation is the characteristic feature of it. This pattern ridge comes to IIIrd position, after straight and curved ones in its occurrence. An average of 0.81 undulated pattern ridge was observed on the muzzle (Table 11).

4.2.2.6 Miscellaneous Class

Different varieties of pattern ridge were observed during the course analysis, which did not resemble other pattern ridges of major class. Thus, miscellaneous class was opened to group such pattern ridges into one class. Comma, hook, leaf, knife and segmoid pattern ridges are the examples (Figure 39). The appearance of these pattern ridges were similar to the names allocated. The leaf pattern ridges were found only in compound ridges. The mean values ranged between 0.0093 to 0.3840 for all the pattern ridges of this class, which was less than other pattern ridge and suggested their occasional presence on the muzzle (Table 11).

4.2.3 LENGTH OF THE PATTERN RIDGES

The diversity in the characteristic feature of pattern ridges can be attributed to its course, which was either long or small. As it was not possible to measure the length of pattern ridge by the use of measurement scale, a criteria was made to classify the length of pattern ridges based on visual observation. The pattern ridges were considered as "long pattern ridge" when they touch or cross the border of the base sector. But, if they cover more than or equal to half the area of the base sector then they were classified as "medium pattern ridge" and less than half coursed pattern ridges were classified as "small pattern ridge". The mean values for long, medium and small pattern ridge were 2.83, 2.24 and 1.55, respectively (Table 11). This indicated greater occurrence of long pattern ridge than medium and small ones.

4.2.4 SHAPE

Two shapes were observed on the pattern ridge. These were club and cylindrical shape. The comma pattern ridges always occurred in club shape. The occurrence of club shape was less frequent than the cylindrical shape. The mean values were 1.24 and 5.39 for club and cylindrical shape pattern ridge, respectively (Table 11).

4.2.5 TYPE OF PATTERN RIDGES

Presence of intercepts and breach in the continuity represented the type of pattern ridge. Four different type of pattern ridges were observed. These were complete, complete intercepted, fragmented and fragmented intercepted pattern ridges. The mean values were 0.75, 5.01, 0.14 and 0.77 for complete, complete intercepted, fragmented and fragmented intercepted pattern ridge, respectively (Table 11). This indicated greater occurrence of complete intercepted type of pattern ridge on the muzzle than others. The occurrence of fragmented pattern ridges was very less.

4.3 SECONDARY CLASSIFICATION

The secondary classification was developed to seek out the possibility of individual identification of animals. The pattern ridges, distributed ridges and beads subsequently, in the base, middle and upper sectors were used as pedestal for secondary classification. In this classification, an effort was made to develop a system to code individual muzzle by using information of characteristics. As 89.70 percent animals were classified only on the basis of pattern ridges, the pattern ridges and beads were selected to develop coding system for 89.70 percent animals, whereas, the distributed ridge and pattern formed by beads were the criteria to classify only 5.81 and 3.82 percent animals, respectively (Table 10) and, therefore, distributed ridges combined with beads were used to classify 5.81 percent animals and only beads were used as a source of information to differentiate 3.82 percent animals from each other. Thus, in 89.70 percent cases the pattern ridges arranged to form pattern were numbered according to their position around site of origin. The numbers were used to code such pattern ridges. The right and left pattern ridges were numbered separately when right and left halves does exist, otherwise numbering started from right to left direction, i.e., in case of "simple pattern ridge origin from same point" pattern. The numbering started from bottom to top direction (in ascending order) in case of all other patterns based on pattern ridge arrangement. Therefore, the pattern ridge situated at the beginning of the bottom was assigned number 1 and if it belonged to either right or left side, then the alphabet "R" or "L" was combined to develop a code for that pattern ridge. Where "R" and "L" indicated right and left halves of the muzzle. In case of "simple pattern ridge origin from same point" pattern the alphabet "R" was combined with pattern ridge number. The code thus developed indicated the position and area of the pattern ridge. Since there were three sectors, all sectors were accordingly coded to develop final code of the muzzle.

The basis of secondary classification was the maximum utilisation of highly variable characteristics from all sectors to develop easy and reliable identification system. The coefficients of variation of beads at base and middle sector were 44.80 and 42.66 percent, respectively (Tables 12 and 13). Whereas, the coefficients of variation of beads at upper sector was close to half of the variability of middle and base sectors, i.e., 22.44 percent (Table 14). Overall, the coefficients of variation of beads in the muzzle was 25.81 percent (Table 15) which was less than the variation observed for beads at base and middle

Table 12. Overall mean, standard deviation and coefficient of variation of beads in the base sector of the muzzle.

Breed	Beads in the base sector			
	N	$\bar{x}$	sd	cv
Tharparkar	141	54.09	18.98	35.09
Sahiwal	74	58.68	22.19	37.81
Karan Swiss	132	68.28	30.46	44.60
Karan Fries	253	59.71	23.71	39.71
Red & White	50	36.68	18.30	49.91
Black & White	50	41.36	18.92	45.74
Total	600	57.64	25.82	44.80

Table 13. Overall mean, standard deviation and coefficient of variation of beads in the middle sector of the muzzle.

Breed	Beads in the middle sector			
	N	$\bar{x}$	sd	cv
Tharparkar	41	60.34	12.03	19.94
Sahiwal	74	54.13	13.61	25.15
Karan Swiss	132	57.25	16.94	29.59
Karan Fries	253	43.62	17.91	41.05
Red & White	50	23.64	12.65	53.53
Black & White	50	26.44	13.65	51.63
Total	600	45.96	19.61	42.66

Table 14. Overall mean, standard deviation and coefficient of variation of beads in the upper sector of the muzzle.

Breed	Beads in the upper sector			
	N	$\bar{x}$	sd	cv
Tharparkar	41	126.53	22.01	17.39
Sahiwal	74	119.63	22.23	18.58
Karan Swiss	132	143.01	26.34	18.42
Karan Fries	253	125.43	19.49	15.54
Red & White	50	85.80	18.77	21.87
Black & White	50	91.50	19.74	21.58
Total	600	122.53	27.49	22.44

Table 15. Overall mean, standard deviation and coefficient of variation of total beads in the muzzle.

Breed	Total beads in the muzzle			
	N	$\bar{x}$	sd	cv
Tharparkar	41	240.97	33.78	14.02
Sahiwal	74	232.05	42.61	18.36
Karan Swiss	132	267.87	52.59	19.63
Karan Fries	253	228.00	46.15	20.24
Red & White	50	145.94	42.10	28.84
Black & White	50	158.50	38.54	24.31
Total	600	225.53	58.21	25.81

sector. Such large variations in the muzzle characteristic of three respective sectors suggested necessity of sectorial division of muzzle to develop identification system. The coefficients of variation of ridges at base and middle sector were 45.86 and 77.57 percent (Table 16), respectively. The middle sector achieved highest variability among all. The coefficients of variation of pattern ridges was 58.94 percent (Table 17). This analysis indicated that beads were much variable at base and middle sector and less variable in upper sector. But ridges at base and middle sector and pattern ridges were most variable among all traits. This analysis paved the way to select the traits of high variability. Further, it had given a clue to combine the beads and ridge information, together in such way, that final code for the individuals could be developed. Thus, pattern ridge was selected to develop code for the base sector to classify 89.70 percent animals where patterns were formed by pattern ridges. This was due to greater complexities in the muzzle characteristics of the base sector in 89.70 percent cases. The pattern ridge and number of beads were combined together, to develop code for middle sector. The information of beads at upper sector was used in different way, due to less variability. This was done by classifying the beads into various ranges. By using such information, it thus became possible to develop a coding system for secondary classification. The coding system is discussed separately for each sector.

4.3.1 CODING BASE SECTOR

A small block was prepared to code the base, middle and upper sectors. The block was used for writing information of the characteristics present in base sector. The block was divided into two equal halves by drawing straight line with in it. The straight line was drawn only when central valley was present. Thus, straight line indicated grooved category of muzzle. Straight line was not drawn when central valley was absent, which applied to all the

Table 16. Overall mean, standard deviation and coefficient of variation of total ridges in the base and middle sector of the muzzle.

Breed	Ridges (base sector)				Ridges (middle sector)		
	N	x̄	sd	cv	x̄	sd	cv
Tharparkar	41	13.97	5.09	36.43	2.34	1.68	71.85
Sahiwal	74	8.97	4.60	51.31	3.27	2.51	76.80
Karan Swiss	134	12.11	6.36	52.48	3.24	2.91	89.66
Karan Fries	253	13.56	5.67	41.87	4.83	3.68	76.26
Red & White	50	14.46	5.11	35.37	6.92	3.28	47.42
Black & White	50	15.48	6.32	40.84	6.30	2.85	45.37
Total	602	12.93	5.93	45.86	4.41	3.42	77.57

Table 17. Mean, standard deviation and coefficient of variation of total pattern ridge in the muzzle.

Breed	Total pattern ridge in the muzzle			
	N	x̄	sd	cv
Tharparkar	41	8.02	3.57	44.54
Sahiwal	74	4.55	3.13	68.78
Karan Swiss	134	5.68	3.50	61.65
Karan Fries	253	6.52	3.50	53.70
Red & White	50	5.66	3.40	60.11
Black & White	50	4.36	2.53	58.20
Total	602	5.94	3.50	58.94

patterns of non-grooved category. In two equal halves, the coded pattern ridges of right side were written in numerator position and denominator position was used to write the coded pattern ridges of left side. This was applicable to those patterns of grooved category which were formed by pattern ridges. Whereas, in case of "alternate simple pattern ridge arrangement" of non-grooved category the straight line was not drawn due to absence of central valley, but the pattern ridges were still written into numerator and denominator position without drawing straight line (Figure 40). The right and left arrangement of pattern ridge was observed in 75.91 percent animals, whereas, 13.79 percent animals out of 89.70 percent animals with pattern ridge did not follow this arrangement. Thus, the code of base sector was written in different way for 13.79 percent animals. Due to right and left arrangement of the pattern ridges, it become possible to study the right and left pattern ridge combination in 75.91 percent animals. The distribution of animals into the possible combination would suggest the accuracy of secondary classification.

4.3.2 PATTERN RIDGE COMBINATION

The pattern ridge combination proved an asset to study the various possible right and left pattern ridge combination which exist. This combination was denoted by "R/L". The total number of pattern ridges available into right and left halves were used to develop R/L combination. A table was prepared after observing the minimum and maximum values of right and left pattern ridge, to generate the maximum possible combinations that could occur on the muzzle. It was observed that minimum and maximum values for right and left pattern ridges were 0 to 10 and 0 to 8 (Table 18), respectively. Therefore, R/L combination table contained all possible combination between 0/0 to 8/10 (Table 19).

Table 18. Minimum and maximum value of beads at upper sector and right and left pattern ridge.

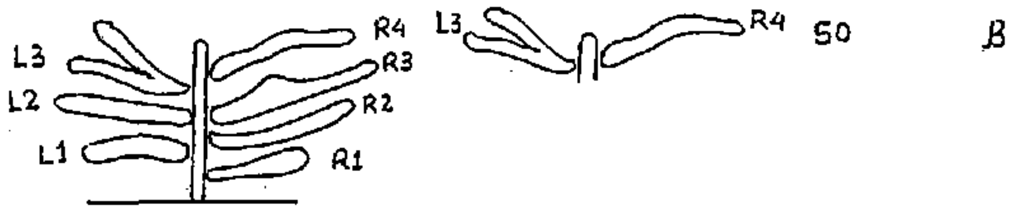
Characteristics	Minimum	Maximum
Beads (upper)	41	212
Right pattern ridge	0	10
Left pattern ridge	0	8

4.3.3 CODING MIDDLE SECTOR

During analysis, it was observed very frequently that some pattern ridges were extended upto middle sector. Such extension was related to their length. Generally, long pattern ridge or pattern ridge located at the top of central valley, were responsible for their presence in the middle sector. Such pattern ridges were called "extended pattern ridge" in middle sector and were subsequently used to develop a code together with number of beads in middle sector. System of coding extended pattern ridges was similar to the base sector. Thus, no further coding was required. Already coded pattern ridges from base sector when extended to middle sector were written to numerator and denominator positions. The straight line was drawn when it belonged to grooved category. Therefore, the straight line here again indicated the category. The pattern ridges originated from right and left side of the base sector and extended to middle sector thus, they were designated right extended pattern ridge and left extended pattern ridge, respectively. In case of "simple pattern ridge origin from same point" pattern of non-grooved category, the term left or right would became a misnomer if used because of absence of any demarcation between left and right halves. Therefore, all the extended pattern ridges in this category were called only "extended pattern ridges".

Model for secondary code.

Base sector		Middle sector		Upper sector
Pattern ridge number	Extended pattern ridge number	Numeric value of beads		Latin alphabet
Right pattern ridges / Left pattern ridges	Right extended pattern ridge / Left extended pattern ridges			



Pattern ridge combination = R/L = 4/3

R1,R2,R3,R4 / L1,L2,L3	R4 / L3	50	B

Figure 40. Model for Secondary Code.

No coding was required for the number of beads in middle sector. The system of coding has been explicitly illustrated in Figure 40.

4.3.4 CODING UPPER SECTOR

The system of coding upper sector was same for all pattern of two respective categories except for the patterns formed by distributed ridges and pattern formed by beads. Due to less individual variation in this sector, the number of beads were classified into different classes. The classification was made by observing its minimum and maximum number of beads in the upper sector which ranged from 41 to 212 beads (Table 18), respectively. This range was divided into 5 different classes by keeping 40 as a class interval. Each class was denoted by using latin alphabets (Table 20).

4.3.5 FINAL SECONDARY CODE

The final secondary code was developed by combining codes of base, middle and upper sectors together (Figure 40). Thus, the developed final code was the identification code of an individual animal. The developed final code was tested against its resemblance to other developed secondary code. Therefore, the base sector code was chosen and frequency distribution of the pattern ridge combination studied to examine their resemblance with each other. The frequency distribution of pattern ridge combination (Table 21) revealed great concordance when secondary code of base sector was compared. The 2/2 combination exhibited highest proportion of animals and the combinations 3/2, 3/3 and 4/4 were also comparatively higher in proportion of animals (Table 21a). Only one animal was observed indicating 10/8 pattern ridge combination. Similar finding was also observed in 13.79 percent cases in which the demarcation between left and right halves was not possible (Table 21b). Such distribution of animals indicated more fragile, weak and irresolute nature of secondary code. Therefore, secondary code was not of much help to uniquely

Table 19. Right and left pattern ridge combination.

Right →, Left ↓

	0	1	2	3	4	5	6	7	8	9	10
0	0/0	0/1	0/2	0/3	0/4	0/5	0/6	0/7	0/8	0/9	0/10
1	1/0	1/1	1/2	1/3	1/4	1/5	1/6	1/7	1/8	1/9	1/10
2	2/0	2/1	2/2	2/3	2/4	2/5	2/6	2/7	2/8	2/9	2/10
3	3/0	3/1	3/2	3/3	3/4	3/5	3/6	3/7	3/8	3/9	3/10
4	4/0	4/1	4/2	4/3	4/4	4/5	4/6	4/7	4/8	4/9	4/10
5	5/0	5/1	5/2	5/3	5/4	5/5	5/6	5/7	5/8	5/9	5/10
6	6/0	6/1	6/2	6/3	6/4	6/5	6/6	6/7	6/8	6/9	6/10
7	7/0	7/1	7/2	7/3	7/4	7/5	7/6	7/7	7/8	7/9	7/10
8	8/0	8/1	8/2	8/3	8/4	8/5	8/6	8/7	8/8	8/9	8/10

Table 20. Classification and coding of beads at upper sector.

S.No.	Range		Code
1.	40 - 80	(Alpha)	α
2.	81 - 120	(Beta)	β
3.	121 - 160	(Gamma)	γ
4.	161 - 200	(Delta)	δ
5.	201 - 240	(Eata)	ϵ

Table 21a. Distribution of animals (75.91%) based on right and left pattern ridge combination.

Left ↓ / Right →	0	1	2	3	4	5	6	7	8	9	10
0	0	3	1	2	3	0	0	0	0	0	0
1	1	12	10	9	4	0	0	0	0	0	0
2	8	21	30	29	15	5	1	0	0	0	0
3	4	10	18	28	21	10	8	1	0	0	0
4	1	2	9	18	27	10	6	3	2	1	0
5	1	2	8	9	15	17	8	2	1	0	0
6	0	1	0	2	5	13	8	3	1	0	0
7	0	0	0	4	2	4	5	2	0	1	0
8	0	0	0	0	2	0	1	2	2	0	1

Table 21b. Distribution of animals (13.79%) for the pattern ridges distributed around same point.

Pattern ridge number	1	2	3	4	5	6	7	8	9	10	11
Frequency	0	3	9	18	25	12	10	2	4	0	1

identify the 89.70 percent animals. To overcome this problem a further classification called "sub-secondary classification" was developed.

4.4 SUB-SECONDARY CLASSIFICATION

The *sub-secondary classification was based on the angle measurement of* the pattern ridges. Where angles were used to further differentiate the pattern ridges of one muzzle from the other. The difference between secondary and sub-secondary classification existed only with the use of pattern ridges. In sub-secondary classification, the pattern ridge angles were coded instead of pattern ridge numbers. Thus, code for base and middle sector were altered, but, code for middle sector (beads) and upper sector remained the same. The sub-secondary classification was developed to give strong and unique system for individual identification through muzzle.

In sub-secondary classification, two types of angular deviation was observed due to the difference in the arrangement of pattern ridges. As mentioned earlier, in 75.91 percent animals the pattern ridges were distributed into right and left halves and 13.79 percent animals showed pattern ridge distribution at the same point. Thus, the angular deviation in 75.91 percent cases varied from 0° to 90°, whereas in 13.79 percent cases the angular deviation ranged between 0° to 180° angle. The wider angular deviation resulted in the pattern ridges originating from same point. Since all pattern ridges in this pattern were distributed from right to left hand side, thus, the angle was taken as 0° to 180° in this case.

While developing sub-secondary code, the angle of the corresponding pattern ridge was used instead of pattern ridge number. To avoid any confusion in the use of angles for reading sub-secondary code in base sector, an alphabetic index was prepared indicating alphabetic code for each degree of angle.

4.4.1 ALPHABETIC INDEX

Alphabetic index was prepared to generate alphabetic code for all possible angular deviations that could exist in pattern ridge. Since, it was obvious that all pattern ridges were distributed within 0° to 180° angle, the alphabetic index also contained codes for all angles lying between 0° to 180° of deviation. The alphabetic index was prepared by combining small and capital letters, where capital letters indicated 1 unit changes in the angle and small letters represented changes after 10 units. Therefore, it was possible to generate an alphabetic code for each deviation which could occur within 0° to 180° angle by combining small and capital letters (Table 22).

Table 22. Alphabetic index for pattern ridge angle.

Angle	0°	1°	2°	3°	4°	5°	6°	7°	8°	9°
00°	a	B	C	D	E	F	G	H	I	J
10°	b	bB	bC	bD	bE	bF	bG	bH	bI	bJ
20°	c	cB	cC	cD	cE	cF	cG	cH	cI	cJ
30°	d	dB	dC	dD	dE	dF	dG	dH	dI	dJ
40°	e	eB	eC	eD	eE	eF	eG	eH	eI	eJ
50°	f	fB	fC	fD	fE	fF	fG	fH	fI	fJ
60°	g	gB	gC	gD	gE	gF	gG	gH	gI	gJ
70°	h	hB	hC	hD	hE	hF	hG	hH	hI	hJ
80°	i	iB	iC	iD	iE	iF	iG	iH	iI	iJ
90°	j	jB	jC	jD	jE	jF	jG	jH	jI	jJ
100°	k	kB	kC	kD	kE	kF	kG	kH	kI	kJ
110°	l	lB	lC	lD	lE	lF	lG	lH	lI	lJ
120°	m	mB	mC	mD	mE	mF	mG	mH	mI	mJ
130°	n	nB	nC	nD	nE	nF	nG	nH	nI	nJ
140°	o	oB	oC	oD	oE	oF	oG	oH	oI	oJ
150°	p	pB	pC	pD	pE	pF	pG	pH	pI	pJ
160°	q	qB	qC	qD	qE	qF	qG	qH	qI	qJ
170°	r	rB	rC	rD	rE	rF	rG	rH	rI	rJ
180°	s									

4.4.2 CODING BASE SECTOR

The procedure to code base sector was similar to secondary classification except using alphabetic code instead of writing pattern ridge number in secondary code. Thus, the alphabetic code of each pattern ridge belonging to right and left side was written in numerator and denominator positions, respectively.

Straight line was drawn between two respective position when muzzle represent grooved category. The alphabetic code was written in a straight line for "pattern ridge origin from same point" pattern of non-grooved category.

4.4.3 CODING MIDDLE AND UPPER SECTOR

The angles for right and left extended pattern ridges were used to develop middle sector code. The procedure was quite similar to code middle sector of secondary classification.

The number of beads present in middle sector and latin alphabets of upper sector were used in similar manner as done in secondary classification (Figure 41).

4.4.4 FINAL CODES FOR SUB-SECONDARY CLASSIFICATION

As it is clear that the patterns formed by pattern ridges were available in 89.70 percent and patterns depending on distributed ridge and beads together were available only in 5.80 percent animals. Whereas, 3.82 and 0.67 percent patterns on the animals were based on distribution of beads and special category, respectively. Thus, the final code for these three systems should also differ in line with their style of coding. The final code for these systems are discussed as under. The procedure to develop final code was same in all cases.

4.4.4.1 Final Code for the Muzzle with Pattern Ridge

The final code for this system was a combination of alphabets, numeric values and latin alphabets representing base, middle and upper sector, respectively. The developed final code was unique and distinguished all 89.70 percent animals from each other (Figure 41).

4.4.4.2 Final Code for Muzzle containing Distributed Ridge and Beads

The pattern formed by distributed ridge and beads were available in both categories. The procedure for the final coding was similar to other code. The coding system for this system differed only by using distributed ridge to code base and middle sector. The number of distributed ridges present in right and left halves were written in numerator and denominator positions, respectively, by drawing straight line between them. In non-grooved category, number of distributed ridges available in base sector were written.

The number of distributed ridge and beads available in middle sector were written in the specified block, separately after drawing vertical line. No latin alphabets were used to specify upper sector. Number of beads present in upper sector were written as such to code upper sector. The final code was developed by combining base, middle and upper sector codes (Figure 41). Using frequency of occurrence of each characteristic for every sector resulted in numeric code. The final code of one muzzle print did not appear to have any concordance with thereof other muzzle prints.

4.4.4.3 Final Code for the Muzzle Pattern formed by Beads only

This pattern was noticed in 3.82 percent animals belonging to grooved as well as non-grooved categories. The final code for this system was developed by using total number of beads present in base, middle and upper sectors to be written in each specified block representing sector. Thus, the final code was developed by combining base, middle and upper sector codes together (Figure 41).

4.4.4.4 Coding System for the Pattern belonging to Special Category

The coding system for the patterns of special category was entirely different from all other systems. On account of unique distribution and

Model for subsecondary code.

Base sector		Middle sector	Upper sector
Alphabetic code for right & left pattern ridge angle	Extended right & left ridge angles	No. of beads	Latin alphabets

Final code for the muzzle with pattern ridge:

Grooved category:

I. Alternate simple pattern ridge arrangement.

II. Alternate compound pattern ridge arrangement.

III. Pattern with simple and compound pattern ridge arrangement.

* * * *	REPRA		
——————	——		
# # # #	LEPRA		

Non-grooved category:

I. Alternate simple pattern ridge arrangement.

II. Pattern with simple and compound pattern ridge arrangement.

* * * *	REPRA		
# # # #	LEPRA		

III: Simple ridge origin from same point.

R>>>>>>>>>>L	EPRA		

——————	=	Central valley.
*	=	Alphabetic code for right pattern ridges angles.
#	=	Alphabetic code for left pattern ridges angles.
REPRA	=	Right extended pattern ridge angle.
LEPRA	=	Left extended pattern ridge angle.
R>>>>>L	=	Alphabetic code for pattern ridges from right to left side.
EPRA	=	Extended pattern ridge angle.

Final code for the muzzle containing distributed ridges and beads:

Grooved category: I. Ridge distributed without pattern.

R D R / L D R	Number of distributed ridge in MS	Number of beads in MS	Number of beads in upper sector

RDR = Right distributed ridge.
LDR = Left distributed ridge.

Non-grooved category: II. Ridge distributed without pattern.

Number of distributed ridge in base sector	Number of distributed ridge in MS	Number of beads in MS	Number of beads in upper sector

Final code for the muzzle pattern formed by beads only:

Number of beads in base sector	Number of beads in middle sector	Number of beads in upper sector

Coding system for the pattern belonging to special category:

I. Pattern containing simple ridge:

SSR	*Serial number of the print*

SSR = Simple ridge pattern of special category.

II. Pattern containing compound ridge:

SCR	Serial number of the print

SCR = Special category, compound ridge.

III. Pattern containing simple & compound ridge:

SS&CR	Serial number of the print

SS&CR = Special category, simple & compound ridge.

Figure 41. Models for subsecondary code under three systems and patterns of special category.

arrangement of characteristics, the muzzle print of an animal itself represented its own identity. Since, less than 1 percent belonged to this category, the coding system was developed by combining abbreviation of the pattern and print number. For example, if 2 muzzle prints were found containing "simple ridge pattern" then the code for the two prints would be SSR1 and SSR2, respectively. The abbreviation SSR indicate simple ridge pattern of special category. The abbreviation for the pattern "containing compound ridge" and "containing the combination of simple and compound ridges" were "SCR" and "SS&CR", respectively (Figure 41).

In total, 14 muzzle patterns were observed in this study. The patterns of special category were very rare in the population. The reason of its less occurrence in the population is still not known. It is now possible to group the cattle according to the known muzzle patterns. Moreover, these patterns were complementary in studying the distribution and arrangement of beads, ridges and pattern ridges on the muzzle. By virtue of which a system of secondary classification, though fragile and weak, was developed. The secondary classification system has paved the way to generate models of established muzzle pattern and which in turn resulted in developing a strong and unique coding system for individual identification in sub-secondary system. In the present study, the code developed by sub-secondary classification system has uniquely identified each animal. However, this system has to be studied on large scale under field condition. Where the chances of getting two similar codes from different individuals, if occurred, then it is necessary to compare characteristic features of the coded pattern ridges to solve the dispute. Therefore, the identified pattern ridge characteristics are also equally important and their records/information must be stored while giving final identification code to the owner of the cattle.

The established system of coding may have an important application in those areas, where chances of forgery, mischief and false identification of animals are very common.

4.5 DIFFERENCE BETWEEN BOS TAURUS, BOS INDICUS AND THEIR CROSSBRED CATTLE

The muzzle characteristics of three respective sectors and pattern ridge characteristics were studied to examine the difference between Bos Indicus (zebu), Bos Taurus cattle and their crossbred. Model-I was applied and the effects used in the model and a summary of their significance for various traits are given in Tables 23 and 24. The number of observations used in Model-I were 596 for the beads present in base, middle, upper sectors as well as in the muzzle (BTO). Whereas, 598 observations were used for rest of the characteristics presented in Table 23. Similar model was applied to examine the difference between the two genuses and their crossbreds by pattern ridge characteristics. The observations on pattern ridge characteristics were taken on 539 animals. The study to distinguish the genuses and crossbred cattle has been described for muzzle characteristics and pattern ridge characteristics separately.

4.5.1 BASED ON MUZZLE CHARACTERISTICS

The two genuses and their crossbreds were found significantly different ($P < 0.01$) in muzzle characteristics, namely, beads in the base, middle and upper sectors, and in the muzzle as well as in the ridges of the base, middle sectors and in the muzzle. The difference between genuses as well as crossbred were also observed ($P < 0.01$) in right and left ridges. The differences were not significant when right, left and total pattern ridges were compared (Table 23). To obtain the magnitude of the difference between zebu, taurus and crossbred cattle, the least square means of each muzzle characteristics were estimated and tested by applying Bonferoni-Holm test (experiment wise error rate). The least

Table 23. Effects of muzzle print characteristics and their level of significance.

Muzzle characteristics	Genus	Breed	Effects Category	Category Within breed
Beads base (BB)	***[1]	**	---	---
Beads middle (BM)	***	***	*	---
Beads upper (BU)	***	***	---	---
Beads total (BTO)	***	***	---	---
Right ridge (RR)	**	---	***	*
Left ridge (LR)	**	**	***	**
Ridge base (RTB)	***	*	---	---
Ridge middle (RM)	***	***	---	---
Ridge muzzle (RCT)	***	*	---	---
Right pattern ridge (PRR)	---	*	***	*
Left pattern ridge (PRL)	---	---	***	**
Total pattern ridge (PRTO)	---	**	***	---

1: * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and --- = NS

Table 24. Effects of pattern ridge characteristics and their level of significance.

Pattern ridge characteristics	Genus	Breed	Effects Category	Category within breed
Straight pattern ridge	***[1]	---	---	---
Curved pattern ridge	---	---	---	---
Tented pattern ridge	---	---	---	---
Undulated pattern ridge	***	---	**	**
Bifurcated pattern ridge	---	---	---	---
Long pattern ridge	---	---	**	---
Medium pattern ridge	*	---	**	---
Small pattern ridge	***	**	---	---
Club pattern ridge	***	---	---	---
Cylindrical pattern ridge	**	*	***	---
Complete pattern ridge	---	---	---	---
Complete intercepted	**	---	**	---
Fragmented pattern ridge	---	---	---	---
Fragmented intercepted	***	***	---	---

1: * = P < 0.05, ** = P < 0.01, *** = P < 0.001 and --- = NS square means of the muzzle characteristics beads in the base sector were 57.3, 64.2 and 37.9 for zebu, crossbred and taurus cattle, respectively (Table 25). When the probability levels of the least square means were compared the taurus cattle differed from zebu and crossbred cattle significantly, due to less number of beads present in the base sector. Whereas, the difference between zebu and crossbred cattle was not significant. But the crossbred surpassed the zebu and taurus cattle, due to maximum presence of beads in the base sector (Table 25).

The beads present in middle sector revealed significant ($P < 0.05$) difference between zebu, crossbred and taurus cattle. The least square means of middle sector beads of zebu, crossbred and taurus cattle were 60.4, 50.7 and 24.3, respectively (Table 25). The zebu cattle differed significantly ($P < 0.05$) from crossbred and taurus cattle due to maximum occurrence of beads in the middle sector. Taurus cattle contained comparatively less beads, therefore, differed significantly ($P < 0.05$) from crossbred and zebu cattle. The crossbred lied in between the zebu and taurus cattle. Presence of more beads in the middle sector than the base sector was observed particularly in zebu cattle. But, it was always lower than the base sector of crossbred and taurus cattle.

Least square means of the beads of upper sector were also compared to study the genuses and crossbred cattle. The least square means revealed presence of 127.2, 134.1 and 88.5 beads in zebu, crossbred and taurus cattle, respectively. High and low least square means were observed in crossbred and taurus cattle, respectively. Therefore, the taurus cattle differed significantly ($P < 0.05$) from zebu and crossbreds. However, no significant differences were observed between zebu and crossbred. This indicated the pre-dominance of zebu inheritance in crossbred population. In general, it was observed that 40 percent area of the upper sector contained maximum beads than the base and middle. On the other hand, a decreasing trend of beads from upper to middle sector was

Table 25. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of Bos Indicus, Crossbred and Bos Taurus cattle.

Muzzle characteristics	Genus					
	Bos Indicus		Crossbred		Bos Taurus	
	LSQM	SE	LSQM	SE	LSQM	SE
BB	57.3[a][1]	4.4	64.2[a]	1.3	37.9[b]	2.5
BM	60.4[a]	2.9	50.7[b]	0.8	24.3[c]	1.6
BU	127.2[a]	3.9	134.1[a]	1.1	88.5[b]	2.2
BTO	244.8[a]	8.3	248.2[a]	2.4	150.4[b]	4.7
RR	4.3[a]	0.6	4.9[a]	0.1	6.3[b]	0.3
RL	4.1[a]	0.6	5.0[a]	0.1	6.2[b]	0.3
RTB	11.4[a]	1.0	12.7[a]	0.3	15.0[b]	0.5
RM	2.7[a]	0.5	3.9[b]	0.1	6.7[c]	0.3
RGT	13.8[a]	1.2	15.1[a]	0.3	20.0[b]	0.7
PRR	2.2[a]	0.3	2.5[a]	0.1	2.4[a]	0.1
PRL	2.2[a]	0.3	2.5[a]	0.1	2.4[a]	0.1
PRTO	5.8[a]	0.5	6.1[a]	0.1	5.3[a]	0.3

1: a, b, c = Lsq means with different letter differ significantly ($P < 0.05$) within row.

observed in crossbred and taurus cattle. This was different in zebus, where it started from base to upper sector. Such differences between specified sectors within each genus and between genuses could be attributed to simultaneous presence and absence of other muzzle characteristics.

The beads in the muzzle were not different between zebu and crossbred, rather, a significant ($P<0.05$) difference was observed when taurus was compared with zebu and crossbred cattle. Least square means were 244.8, 248.2 and 150.4 beads for zebu, crossbred and taurus cattle, respectively (Table 25). The difference was related to least difference between least square means of zebu and crossbred cattle.

The least square means of 4.3, 4.9 and 6.3 were observed for the right ridges (RR) of zebu, crossbred and taurus cattle, respectively (Table 25). The difference between zebu and crossbred was not significant. Whereas, the taurus cattle differed significantly ($P<0.05$) in view of the fact that they contained maximum ridges in right side. Similar trend of difference was observed in case of left ridges (RL). The least square means for left side ridges were 4.1, 5.0 and 6.2 for zebu, crossbred and taurus cattle, respectively. Thus, it was clear that the taurus cattle contained maximum ridges in two respective halves. Though it was not statistically examined, but the observed difference between right and left ridge of each genus and crossbred cattle be well enough to indicate asymmetry in the muzzle.

The ridges in the base sector (RTB) followed similar pattern of statistical difference where high least square means were observed in taurus cattle (15.0) and comparatively lower least square means were observed in zebu (11.4) and crossbred (12.7) cattle.

The two genuses and crossbred cattle differed significantly ($P<0.05$) between each other when least square means of the middle sector ridges (RM) were compared. The least square means of middle sector ridges were 2.7, 3.9 and 6.7 for zebu, crossbred and taurus cattle, respectively. Taurus cattle contained three times more ridges than the zebu, whereas, crossbred contained only half as many ridges as observed in taurus cattle. Therefore, the ridges in the middle sector explicitly indicated significant ($P<0.05$) differences between the two genuses and crossbred cattle than ridges in the base sector. Overall the ridges in the muzzle (RGT) were indifferent between zebu and crossbred. Taurus cattle showed maximum occurrence of the ridges and thus, differed significantly ($P<0.05$) from zebu and crossbred population. The zebu (13.8) contained less ridges than crossbred (15.1) and taurus (20.0) cattle.

The right and left pattern ridges of zebus, crossbred and taurus cattle were showing difference insignificantly. Non significant ($P<0.05$) differences were observed in case of total pattern ridges (PRTO) of crossbred, zebu and taurus cattle, with crossbreds (6.1) containing more pattern ridges than the zebu (5.8) and taurus (5.3) muzzle.

4.5.2 BASED ON PATTERN RIDGE CHARACTERISTICS

The pattern ridge characteristics were studied to examine the difference between the two genuses and crossbred. Model-I was applied and significant effect of genus at various level of probabilities found (Table 24). The pattern ridge characteristics mainly, curved, tented, bifurcated, long pattern ridge, complete and fragmented pattern ridge suggested non-significant difference between zebu, crossbred and taurus cattle (Table 24). The taurus cattle differed significantly ($P<0.05$) from zebu and crossbred cattle by straight and undulated pattern ridge. The medium length, cylindrical shape and complete intercepted type pattern ridges of crossbred cattle were different from zebu and taurus cattle due to the presence of more such characteristics in their muzzle (Table 26).

Table 26. Least square means (LSQM) and standard error (SE) of the pattern ridge characteristics of *Bos Indicus*, Crossbred and *Bos Taurus* cattle (n=539).

Pattern ridge characteristics	Genus					
	Bos Indicus		Crossbred		Bos Taurus	
	LSQM	SE	LSQM	SE	LSQM	SE
Major Class:						
Straight	2.7[a][1]	0.3	2.7[a]	0.1	1.7[b]	0.2
Curved	2.1[a]	0.2	1.7[a]	0.1	1.6[a]	0.1
Tented	0.4[a]	0.1	0.3[a]	0.0	0.2[a]	0.6
Undulated	0.5[a]	0.2	0.7[a]	0.0	1.3[b]	0.1
Bifurcated	0.1[a]	0.1	0.1[a]	0.0	0.1[a]	0.0
Length:						
Long	2.3[a]	0.4	2.9[a]	0.1	3.0[a]	0.2
Medium	1.8[a]	0.3	2.3[b]	0.1	1.7[a]	0.6
Small	2.3[a]	0.2	1.6[b]	0.1	1.1[c]	0.1
Shape:						
Club	2.1[a]	0.2	1.2[b]	0.1	1.1[b]	0.1
Cylindrical	4.2[a]	0.5	5.6[b]	0.1	4.7[a]	0.3
Type:						
Complete	0.6[a]	0.3	0.8[a]	0.1	0.7[a]	0.2
Complete intercepted	4.0[a]	0.5	5.2[b]	0.1	4.1[a]	0.3
Fragmented	0.1[a]	0.1	0.1[a]	0.0	0.1[a]	0.1
Fragmented intercepted	1.7[a]	0.2	0.6[b]	0.1	0.8[b]	0.1

1: a, b, c = Lsq means with different letter differ significantly ($P < 0.05$) within row.

The club shaped pattern ridges were maximum in zebu as compared to the crossbred and taurus muzzle. Therefore, zebu differed significantly from crossbred and taurus cattle. The zebu, crossbred and taurus cattle were distinct from each other when small pattern ridges were compared. The zebu contained maximum amount of small pattern ridges (Table 26). The least square means of the major class of the pattern ridges indicated prevalence of straight pattern ridge than the other pattern ridges in each genus and crossbred. The curved pattern ridge ranked second position in each genus and crossbred. But, the tented and bifurcated pattern ridges indicated their occasional presence in the muzzle.

In case of length, the general trend was the prevalence of long pattern ridge than the medium and small pattern ridges in the muzzle. In zebu, the small pattern ridges were more than the medium one. In crossbred and taurus cattle, the medium pattern ridges were always higher than the small pattern ridges. The cylindrical pattern ridges were higher than the club shaped pattern ridges in each genus and crossbred cattle. Inspite of being higher in zebu and taurus cattle, the least square means revealed its maximum occurrence in crossbred cattle. The complete intercepted pattern ridges were more than other types in general, but exhibited its greater presence in crossbred in particular (Table 26). The complete and fragmented pattern ridges did not appear very frequently in the muzzle. In most of the cases, the pattern ridges may either be complete intercepted or fragmented intercepted types in the muzzle.

4.6 BREED DIFFERENCE

Breed is one of the important factors affecting the muzzle and it affected almost all muzzle characteristics at various levels of probabilities (Table 23). The breed effects were significant (P 0.05) for the pattern ridge characteristics like small length, cylindrical shape and fragmented intercepted type pattern ridge (Table 24). The muzzle characteristics and pattern ridge characteristics were compared for the breed effect. The Bonferoni-Holm test (experiment wise error rate) was applied to compare the least square means.

4.6.1 BASED ON MUZZLE CHARACTERISTICS

Breed Karan Swiss, Red & White and Black & White cattle differed significantly ($P<0.05$) when beads of the base sector were examined. The breed Karan Swiss contained 68.6 beads in the base sector, whereas, 35.9 and 40.0 beads were observed in the base sector of Red & White and Black & White cattle (Table 27). The Karan Swiss cattle differed significantly ($P<0.05$) from Red & White and Black & White cattle due to more structuring in the base sector. Non-significant differences between Red & White and Black & White cattle indicated less occurrence of beads in the base sector when compared with other breeds. A significant ($P<0.05$) difference was also observed between Tharparkar and Black & White and between Karan Fries and Karan Swiss breeds. The base sector of Tharparkar breed contained 58.9 beads which was more than Red & White and Black & White cattle. Non-significant difference was observed between Tharparkar and Sahiwal cattle which indicated resemblance of base sector and size of beads. Resemblance similar to that observed in the base sector of Tharparkar and Sahiwal breeds was also indicated in Karan Swiss. Thus, analysis of base sector revealed maximum occurrence of beads in the base sector of Karan Swiss and its minimum occurrence in Red & White and Black & White cattle. The maximum occurrence could be attributed to the smaller size of beads present in Karan Swiss breed.

Similar findings were also observed for the beads of the middle sector. Wherein, the averages of 23.1 and 25.7 beads were noticed in the middle sector of Red & White and Black & White cattle. But, the middle sector of

Table 27. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of breeds.

Muzzle characteristics	Breeds TH.[1] LSQM	 SW. LSQM	 KS. LSQM	 KF. LSQM	 RW. LSQM	 BW. LSQM
BB	58.9[a] (5.3)[2]	55.6[a] (7.1)	68.6[a] (2.1)	59.8[b] (1.5)	35.9[c] (3.4)	40.0[c] (3.6)
BM	60.5[a] (3.5)	60.4[a] (4.6)	57.4[a] (1.4)	44.0[b] (1.0)	23.1[c] (2.3)	25.7[c] (2.3)
BU	127.4[a] (4.8)	127.0[ab] (6.4)	142.6[b] (2.0)	125.6[a] (1.4)	85.0[c] (3.1)	92.1[c] (3.2)
BTO	246.8[ab] (10.0)	242.9[ab] (13.4)	267.9[a] (4.0)	228.7[b] (2.9)	143.8[c] (6.5)	157.2[c] (6.8)
RR	3.8[a] (0.7)	5.0[ab] (1.1)	4.6[a] (0.3)	5.3[ab] (0.2)	5.9[ab] (0.5)	6.8[b] (0.5)
RL	3.4[a] (0.8)	4.9[ab] (1.0)	4.5[a] (0.3)	5.5[ab] (0.2)	5.6[ab] (0.5)	6.9[b] (0.5)
RTB	12.9[ab] (1.2)	9.9[a] (1.6)	12.1[a] (0.5)	13.4[ab] (0.3)	14.5[ab] (0.8)	15.5[b] (0.8)
RM	2.3[a] (0.7)	3.3[ab] (1.0)	3.2[a] (0.3)	4.7[b] (0.2)	7.0[c] (0.4)	6.5[c] (0.5)
RGT	14.7[ac] (1.5)	12.9[a] (2.0)	14.1[a] (0.6)	16.1[a] (0.4)	19.4[cd] (1.0)	20.5[d] (1.0)
PRR	2.1[a] (0.4)	2.3[a] (0.5)	2.4[a] (0.2)	2.8[a] (0.1)	2.7[a] (0.3)	2.3[a] (0.3)
PRL	2.1[a] (0.4)	2.5[a] (0.5)	2.3[a] (0.2)	2.8[a] (0.1)	2.7[a] (0.3)	2.2[a] (0.3)
PRTO	6.9[ab] (0.7)	4.8[ab] (1.0)	5.4[ab] (0.3)	6.5[a] (0.2)	6.0[ab] (0.5)	4.7[b] (0.5)

1: TH., SW., KS., KF., RW. & BW. represents Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds, respectively.

2: Standard error within parenthesis.

a, b, c, d = Lsq means with different letter differ significantly ($P < 0.05$) within row.

Tharparkar, Sahiwal, Karan Swiss and Karan Fries cattle contained on an average of 60.5, 60.4, 57.4 and 44.0 beads, respectively (Table 27). The middle sector of Karan Fries breed differed significantly ($P<0.05$) from Tharparkar, Sahiwal, Karan Swiss, Red & White and Black & White cattle.

It was observed that the 20% area of the middle sector of Karan Swiss, Karan Fries, Red & White and Black & White cattle contained less number of beads than the base sector. On the contrary, the Tharparkar and Sahiwal cattle exhibited more beads in middle sector than the base sector.

Least square means of the upper sector beads were 127.4, 127.0, 142.6, 125.6, 85.0 and 92.1 beads, respectively, for Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle. The peculiarity of this characteristics was its maximum occurrence in Karan Swiss which differed significantly ($P<0.05$) from the beads present in other breeds. Non-significant differences were observed between Red & White and Black & White. But they differed significantly ($P<0.05$) from other breeds due to lesser structuring in the upper sector. Therefore, the results suggested the resemblance of upper sector between Tharparkar, Sahiwal and Karan Fries cattle which was not observed in Karan Swiss, Red & White and Black & White breeds.

The beads on the muzzle were studied by combining all the sectors together. The result revealed presence of 246.8, 242.9, 267.9, 228.7, 143.8 and 157.2 beads in the specified area of the muzzle of Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds, respectively (Table 27). The Red & White and Black & White cattle differed significantly ($P<0.05$) from Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds due to lesser number of beads present in the muzzle. Whereas, Karan Fries suggested its resemblance to Tharparkar and Sahiwal muzzle. It, however, was comparatively different from Karan Swiss cattle due to lesser structuring. On the contrary, the

Karan Swiss muzzle revealed similarities to Tharparkar and Sahiwal muzzle. Such similarities and dissimilarities of the muzzle related to beads can be attributed to the genetic make up of the breeds. The resemblance of the crossbreds to both Indian native breeds might be due to the presence of genetic material from Tharparkar and Sahiwal breeds. The difference between Karan Swiss and Karan Fries breeds could be attributed to the presence of either Brown Swiss or Holstein Friesian inheritance which were two different types of exotic breeds.

The least square means for the right ridges were 3.8, 5.0, 4.6, 5.3, 5.9 and 6.8 for Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle, respectively (Table 27). The right ridge indicated its maximum occurrence in Black & White cattle. The right ridges of the Black & White breed were indifferent from Sahiwal, Karan Fries and Red & White cattle, but, differed significantly ($P<0.05$) from Tharparkar and Karan Swiss breeds. The findings of the left ridges are almost similar to the right ridges. Some difference was observed between the least square means of right and left sides which indicated that there was no complete symmetry between the left and right halves of the muzzle.

The total ridges in the base sector of various patterns of the breeds ranged from 9.9 to 15.5 ridges. Highest and lowest amount was observed respectively in Black & White and Sahiwal cattle. The Karan Swiss breed differed significantly ($P<0.05$) from Black & White cattle for number of ridges in the base sector. The difference between Red & White and Black & White cattle on the other hand was not significant.

The ridges of the middle sector indicated its maximum occurrence in Red & White and Black & White cattle, i.e., 7.0 and 6.5 ridges, respectively. Whereas, comparatively less number of ridges, i.e., 2.3, 3.3, 3.2 and 4.7 were observed in Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds, respectively (Table 27). No apparent difference was observed between Red & White and Black & White breeds, but, they differed significantly ($P<0.05$) from Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds. The Karan Fries cattle, though it resembled Sahiwal but differed significantly ($P<0.05$) from Tharparkar and Karan Swiss breeds.

The total ridges in the muzzle indicated the presence of 14.7, 12.9, 14.1, 16.1, 19.4 and 20.5 ridges (Table 27) in Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle, respectively. Also, the total ridges in the muzzle indicated closeness between Red & White and Black & White cattle. Red & White breed has indicated its closeness to Tharparkar cattle. The Tharparkar breed suggest its resemblance to Sahiwal, Karan Swiss and Karan Fries breeds. The Black & White cattle were significantly different ($P<0.05$) from Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds. Whereas, Red & White breed suggested its difference with Sahiwal, Karan Swiss and Karan Fries breeds, respectively (Table 27).

Breed differences observed in right and left pattern ridges were not statistically significant. The total pattern ridges of various patterns revealed significant differences between breeds, whereas, maximum pattern ridges were observed in Tharparkar (6.9) and minimum in Black & White (4.7) cattle. A clear difference ($P<0.05$) in pattern ridges was observed between Black & White and Karan Fries cattle (Table 27).

4.6.2 BASED ON PATTERN RIDGE CHARACTERISTICS

The average number of pattern ridge characteristics, e.g., straight pattern ridges were 3.3, 2.2, 2.7, 2.8, 2.1 and 1.4 ridges for Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle, respectively (Table 28). Black & White cattle contained less straight pattern ridges in their muzzle and thus differed significantly ($P<0.05$) from Tharparkar,

Table 28. Least square means (LSQM) and standard error (SE) of the pattern ridge characteristics of breeds (n = 539).

Pattern ridge characteristics	Breeds					
	TH. LSQM	SW. LSQM	KS. LSQM	KF. LSQM	RW. LSQM	BW. LSQM
Major Class:						
Straight	3.3^{a} (0.4)[1]	2.2^{ab} (0.5)	2.7^{a} (0.2)	2.8^{a} (0.1)	2.1^{ab} (0.3)	1.4^{b} (0.3)
Curved	2.2^{a} (0.3)	2.1^{a} (0.4)	1.5^{a} (0.1)	1.9^{a} (0.1)	1.6^{a} (0.2)	1.7^{a} (0.2)
Tented	0.5^{a} (0.1)	0.3^{a} (0.2)	0.4^{a} (0.1)	0.3^{a} (0.0)	0.2^{a} (0.1)	0.3^{a} (0.1)
Undulated	0.9^{ab} (0.2)	0.2^{a} (0.3)	0.8^{ac} (0.1)	0.7^{ac} (0.1)	1.4^{b} (0.1)	1.2^{bc} (0.1)
Bifurcated	0.1^{a} (0.1)	0.2^{a} (0.1)	0.1^{a} (0.0)	0.2^{a} (0.0)	0.2^{a} (0.07)	0.04^{a} (0.07)
Length:						
Long	2.5^{a} (0.5)	2.1^{a} (0.6)	2.7^{a} (0.2)	3.0^{a} (0.1)	3.3^{a} (0.3)	2.7^{a} (0.3)
Medium	2.2^{ab} (0.4)	1.5^{ab} (0.5)	2.2^{ab} (0.1)	2.4^{a} (0.1)	2.0^{ab} (0.2)	1.5^{b} (0.2)
Small	3.1^{b} (0.3)	1.5^{ab} (0.4)	1.7^{a} (0.1)	1.4^{a} (0.1)	1.2^{a} (0.2)	1.0^{a} (0.2)
Shape:						
Club	2.3^{b} (0.3)	2.0^{ab} (0.3)	1.2^{a} (0.1)	1.1^{a} (0.1)	1.3^{a} (0.2)	1.0^{a} (0.2)
Cylindrical	5.5^{bc} (0.6)	3.1^{b} (0.7)	5.4^{cd} (0.2)	5.8^{ac} (0.2)	5.2^{abc} (0.4)	4.2^{bd} (0.4)
Type:						
Complete	1.1^{a} (0.5)	0.1^{a} (0.6)	0.7^{a} (0.2)	0.9^{a} (0.1)	0.7^{a} (0.3)	0.7^{a} (0.3)
Complete intercepted	4.8^{ab} (0.7)	3.2^{ab} (0.8)	4.9^{ab} (0.3)	5.5^{a} (0.2)	4.4^{ab} (0.4)	3.9^{b} (0.4)
Fragmented	0.15^{a} (0.1)	0.02^{a} (0.2)	0.13^{a} (0.1)	0.17^{a} (0.0)	0.11^{a} (0.1)	0.06^{a} (0.1)
Fragmented intercepted	1.6^{a} (0.2)	1.7^{a} (0.3)	0.9^{ab} (0.1)	0.3^{b} (0.1)	1.2^{ab} (0.2)	0.5^{b} (0.2)

TH., SW., KS., KF., RW. & BW. represents Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds, respectively.

a, b, c, d = Least square means with different letter within a row differ significantly ($P < 0.05$).

1 = Standard error within parenthesis.

Karan Swiss and Karan Fries cattle. No differences, however, were observed between Sahiwal and Red & White cattle.

The least square means for the curved pattern ridges were 2.2, 2.1, 1.5, 1.9, 1.6 and 1.7 for Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle, respectively (Table 28). The differences in curved pattern ridges among breeds were not statistically significant.

The tented pattern ridge indicated its occasional presence in the muzzle of all breeds. Undulated pattern ridges on the other hand were maximum in Red & White and Black & White cattle. Its occurrence in Sahiwal was rarer than all other breeds. The Red & White cattle differed significantly ($P < 0.05$) from Sahiwal, Karan Swiss and Karan Fries cattle. But, no difference was observed when it was compared with Tharparkar and Black & White cattle. The bifurcated pattern ridges were very rare in the muzzle of all breeds. Their presence was even less than tented and undulated pattern ridges. Overall, it was observed that the straight pattern ridges were maximum, the curved pattern ridges were higher than tented, undulated and bifurcated pattern ridges but lesser than straight pattern ridges.

The muzzle of Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White contained on an average 2.5, 2.1, 2.7, 3.0, 3.3 and 2.7 long pattern ridges in that order. The differences among breeds in long pattern ridges, however, were non-significant statistically. In general, the Red & White and Karan Fries breeds contained more long pattern ridges in their muzzle. The pattern ridges of medium length, though less than long pattern ridges, suggested significant difference ($P < 0.05$) between Karan Fries and Black & White cattle, where 2.2, 1.5, 2.2, 2.4, 2.0 and 1.5 medium pattern ridges were observed in Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White cattle, respectively (Table 28). The number of small length pattern ridges were higher than the long and medium pattern ridges in Tharparkar cattle. In Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds, only 1.5, 1.7, 1.4, 1.2 and 1.0 small length pattern ridges were observed, which were less than long and medium pattern ridges of same breeds. In Sahiwal, the number of small pattern ridges was equal to medium but lesser than long pattern ridges. Such variation in the small pattern ridges lead the Sahiwal breed to differ significantly ($P < 0.05$) from rest of the breeds (Table 28).

Some of the pattern ridges of Tharparkar cattle were club in shape which were similar to those from Sahiwal but significantly ($P < 0.05$) different from the club pattern ridges of Karan Swiss, Karan Fries, Red & White and Black & White breeds, respectively (Table 28). It was observed that the club shaped pattern ridges were lesser than cylindrical shape pattern ridges were 5.5, 3.1, 5.4, 5.8, 5.2 and 4.2, respectively for Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds (Table 28). The Karan Fries differed significantly ($P < 0.05$) from Black & White and Sahiwal cattle due to its maximum occurrence. A significant ($P < 0.05$) difference was also observed between Sahiwal and Karan Fries breed (Table 28).

The types of pattern ridge indicated prevalence of complete intercepted pattern ridges on the muzzle. However, the complete, fragmented and fragmented intercepted types did occur in the muzzle but less often than complete intercepted type. No breed difference was observed in complete type pattern ridges. Karan Fries animals contained maximum number of complete intercepted type of pattern ridges and thus, differed significantly ($P < 0.05$) only from Black & White cattle (Table 28). Breed differences in case of fragmented pattern ridges were non-significant (Table 28), whereas, the fragmented intercepted pattern ridge of Karan Fries and Black & White breeds differed significantly ($P < 0.05$)

from Tharparkar and Sahiwal cattle. Such differences may be related to negligible presence of these characteristics in Karan Fries and Black & White breed (Table 28).

4.7 CATEGORY DIFFERENCE

The category effect used in Model-I, was found significant ($P<0.05$) for the muzzle characteristics, namely, beads in middle sector, right and left ridges, right and left pattern ridges and total pattern ridges of the muzzle (Table 23). The category effect for the undulated pattern ridges, long and medium length pattern ridges, cylindrical shaped pattern ridges and complete intercepted type pattern ridges was significant ($P < 0.05$) (Table 24). The category differences, therefore, are discussed separately for the muzzle characteristics and pattern ridge characteristics as under:

4.7.1 BASED ON MUZZLE CHARACTERISTICS

As observed the grooved category contained less beads in the base sector than non-grooved category. The least square means were 51.7 and 54.7 beads in the base sector of grooved and non-grooved categories, respectively (Table 29), the differences were, however, non-significant. In case of beads of the middle sector higher least square means were observed for non-grooved category (47.9) than grooved category (42.4). The difference being statistically significant ($P<0.05$). The upper sector beads indicate slight differences between grooved and non-grooved categories (Table 29). The differences observed between categories when beads of all sectors were combined together were not statistically significant. However, the non-grooved category contained more beads than the grooved category (Table 29). Generally, the beads of all sectors of non-grooved category were higher than the grooved category.

Table 29. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of grooved and non-grooved categories.

Muzzle characteristics	Categories			
	Grooved		Non-grooved	
	LSQM	SE	LSQM	SE
BB	51.7[a]	1.7	54.7[a]	3.1
BM	42.4[a]	1.1	47.9[b]	2.0
BU	115.1[a]	1.5	118.2[a]	2.3
BTO	208.9[a]	3.1	220.2[a]	5.8
RR	6.8[a]	0.2	3.7[b]	0.5
RL	6.6[a]	0.2	3.7[b]	0.4
RTB	13.4[a]	0.4	12.7[a]	0.7
RM	4.9[a]	0.2	4.1[a]	0.4
RGT	16.4[a]	0.5	16.2[a]	0.9
PRR	3.4[a]	0.1	1.4[b]	0.2
PRL	3.4[a]	0.1	1.4[b]	0.2
PRTO	6.8[a]	0.2	4.7[b]	0.4

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$).

The least square means of right ridges were 6.8 and 3.7 ridges, respectively, for grooved and non-grooved categories. In case of left ridges, the grooved and non-grooved categories contained 6.6 and 3.7 ridges, respectively (Table 29). The differences between grooved and non-grooved categories for right and left ridges were significant ($P < 0.05$). More ridges in base sector were observed in grooved category than non-grooved category (Table 29), the category difference, however, was not significant. The categories revealed closeness between one another with reference to middle sector ridges. Overall, the ridges of muzzle (RGT) suggested non-significant difference between categories. Such findings pointed towards the necessity of sectorial division of the muzzle. The right and left pattern ridges, compared separately, revealed significant difference between grooved and non-grooved categories, their number being higher in grooved category than that in non-grooved one (Table 29). The least square means corresponding to grooved and non-grooved categories in total pattern ridges were 6.8 and 4.7 ridges. The category difference was significant ($P < 0.05$).

In context with the muzzle characteristics of two categories, a general trend of more beads in all sectors was observed in non-grooved category, whereas, number of ridges and pattern ridges tended to be more in case of grooved category.

4.7.2 BASED ON PATTERN RIDGE CHARACTERISTICS

The number of straight pattern ridges were not significantly ($P < 0.05$) different between grooved and non-grooved categories (Table 30). Similar finding was also observed in case of curved and tented pattern ridges. The undulated pattern ridges were significantly ($P < 0.05$) different between grooved and non-grooved categories (Table 30). Bifurcated pattern ridges appeared occasionally in both categories and no significant difference was observed

The least square means of right ridges were 6.8 and 3.7 ridges, respectively, for grooved and non-grooved categories. In case of left ridges, the grooved and non-grooved categories contained 6.6 and 3.7 ridges, respectively (Table 29). The differences between grooved and non-grooved categories for right and left ridges were significant (P< 0.05). More ridges in base sector were observed in grooved category than non-grooved category (Table 29), the category difference, however, was not significant. The categories revealed closeness between one another with reference to middle sector ridges. Overall, the ridges of muzzle (RGT) suggested non-significant difference between categories. Such findings pointed towards the necessity of sectorial division of the muzzle. The right and left pattern ridges, compared separately, revealed significant difference between grooved and non-grooved categories, their number being higher in grooved category than that in non-grooved one (Table 29). The least square means corresponding to grooved and non-grooved categories in total pattern ridges were 6.8 and 4.7 ridges. The category difference was significant (P < 0.05).

In context with the muzzle characteristics of two categories, a general trend of more beads in all sectors was observed in non-grooved category, whereas, number of ridges and pattern ridges tended to be more in case of grooved category.

4.7.2 BASED ON PATTERN RIDGE CHARACTERISTICS

The number of straight pattern ridges were not significantly (P< 0.05) different between grooved and non-grooved categories (Table 30). Similar finding was also observed in case of curved and tented pattern ridges. The undulated pattern ridges were significantly (P < 0.05) different between grooved and non-grooved categories (Table 30). Bifurcated pattern ridges appeared occasionally in both categories and no significant difference was observed between them. The long, medium and small length pattern ridges were always higher in grooved category. Significant ($P<0.05$) differences were observed in long and medium pattern ridges of grooved and non-grooved categories (Table 30). In case of shape, the cylindrical pattern ridges indicated significant ($P<0.05$) differences between categories, with an average of 5.8 and 3.9 ridges, respectively, in grooved and non-grooved categories (Table 30). The fragmented pattern ridge indicated its occasional presence in both categories. The complete intercepted pattern ridges were higher in grooved category than non-grooved category. The differences were statistically significant ($P<0.05$). However, no apparent difference was observed in case of fragmented intercepted pattern ridges in two categories.

4.8 CATEGORY DIFFERENCE WITHIN BREED

Within breed, the ridges and pattern ridges of the right and left side indicated significant ($P<0.05$) differences between categories (Table 23). In case of pattern ridge characteristics, the undulated pattern ridge exhibited category difference within breed (Table 24).

4.8.1 BASED ON MUZZLE CHARACTERISTICS

The muzzle characteristics of Tharparkar and Sahiwal muzzle were not significantly different between categories (Table 31). A general tendency of more beads in all sectors of non-grooved category than grooved category was observed in Tharparkar and Sahiwal muzzle. In case of right and left ridges as well as pattern ridges zero value was observed in non-grooved category of Tharparkar cattle. This indicated complete absence of those pattern which were governed by such characteristics. The ridges of base sector, despite being insignificantly different between categories, were higher in grooved category. The middle sector ridges between categories were not significant different. Though, the ridges and

Table 31. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of grooved and non-grooved categories of Tharparkar and Sahiwal breeds.

Muzzle characteristics	Breeds			
	Tharparkar		Sahiwal	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
BB	52.1[a] (4.1)[1]	65.8[a] (9.8)	58.9[a] (2.9)	52.3[a] (13.9)
BM	60.3[a] (2.7)	60.7[a] (6.5)	53.6[a] (1.9)	67.3[a] (9.1)
BU	126.2[a] (3.7)	128.7[a] (8.8)	119.0[a] (2.6)	135.0[a] (12.5)
BTO	238.5[a] (7.7)	255.2[a] (18.5)	231.1[a] (5.4)	254.7[a] (26.2)
RR	7.5[a] (0.6)	0.0[b] (1.4)	4.6[a] (0.4)	5.3[a] (2.1)
RL	6.8[a] (0.6)	0.0[b] (1.4)	4.3[a] (0.4)	5.7[a] (2.0)
RTB	14.4[a] (0.9)	11.5[a] (2.3)	8.9[a] (0.7)	11.0[a] (3.2)
RM	2.4[a] (0.5)	2.2[a] (1.3)	3.3[a] (0.4)	3.3[a] (1.8)
RGT	15.7[a] (1.1)	13.7[a] (2.8)	11.5[a] (0.8)	14.3[a] (3.9)
PRR	4.2[a] (0.3)	0.0[b] (0.7)	2.3[a] (0.2)	2.3[a] (1.0)
PRL	4.2[a] (0.3)	0.0[b] (0.7)	2.2[a] (0.2)	2.7[a] (1.0)
PRTO	8.4[a] (0.5)	5.5[a] (1.3)	4.5[a] (0.4)	5.0[a] (1.8)

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Tharparkar and Sahiwal breeds.

1 = Standard error within parenthesis.

pattern ridges of the muzzle were higher in grooved category, they did not differ statistically between categories (Table 31). In Sahiwal, all ridges and pattern ridges were higher in non-grooved category than grooved category.

The beads of all sectors as well as in muzzle of Karan Swiss cattle suggested non-significant difference between categories though slightly higher in grooved category. Contrarily, high least square means for the beads of all sectors as well as in muzzle were observed in non-grooved category of Karan Fries muzzle. The beads of middle sector differed significantly ($P < 0.05$) between categories in Karan Fries breed (Table 32).

The right and left ridges of Karan Swiss and Karan Fries breed differed significantly ($P < 0.05$) between grooved and non-grooved categories. The ridges of the base sector of Karan Swiss and Karan Fries cattle were similar for the two categories. Similar result was also observed in case of middle sector ridges of Karan Swiss breed. Middle sector ridges of Karan Fries cattle differed significantly ($P < 0.05$) between grooved and non-grooved categories (Table 32). The ridges in the muzzle of Karan Swiss and Karan Fries breed showed non-significant difference between categories. The right and left pattern ridges of Karan Swiss and Karan Fries breed were significantly ($P < 0.05$) different between categories. But, total pattern ridges of Karan Fries muzzle were significantly ($P < 0.05$) different between grooved and non-grooved categories.

The beads present in all sectors as well as in muzzle of Red & White and Black & White cattle were not significantly different ($P < 0.05$) between grooved and non-grooved categories, although higher least square means were observed in non-grooved category of both breeds (Table 33). In case of right ridges higher least square means were observed in grooved category of Red & White and Black & White cattle, but, the difference were not significant statistically. These two breeds differed significantly ($P < 0.05$) when left ridges

Table 32. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of grooved and non-grooved categories of Karan Swiss and Karan Fries breeds.

Muzzle characteristics	Breeds			
	Karan Swiss		Karan Fries	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
BB	71.2[a] (2.9)[1]	66.1[a] (3.2)	59.6[a] (2.1)	60.1[a] (2.2)
BM	57.8[a] (1.9)	56.9[a] (2.1)	39.3[a] (1.4)	48.8[b] (1.5)
BU	145.7[a] (2.6)	139.5[a] (2.8)	124.7[a] (1.9)	126.5[a] (2.0)
BTO	274.8[a] (5.4)	260.9[a] (5.9)	223.1[a] (3.9)	234.3[a] (4.2)
RR	6.3[a] (0.4)	2.9[b] (0.5)	6.7[a] (0.3)	3.8[b] (0.3)
RL	6.2[a] (0.4)	2.8[b] (0.5)	7.1[a] (0.3)	3.9[b] (0.3)
RTB	12.7[a] (0.7)	11.4[a] (0.7)	13.9[a] (0.5)	12.9[a] (0.5)
RM	3.4[a] (0.4)	2.9[a] (0.4)	5.9[a] (0.3)	3.6[b] (0.3)
RGT	14.4[a] (0.8)	13.8[a] (0.9)	16.8[a] (0.6)	15.4[a] (0.6)
PRR	3.1[a] (0.2)	1.3[b] (0.2)	3.9[a] (0.2)	1.7[b] (0.2)
PRL	3.3[a] (0.2)	1.4[b] (0.2)	3.8[a] (0.1)	1.7[b] (0.2)
PRTO	6.5[a] (0.4)	4.9[a] (0.4)	7.7[a] (0.3)	5.2[b] (0.3)

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Karan Swiss and Karan Fries breeds.

1 = Standard error within parenthesis.

were compared between them (Table 33). The ridges of the base sector between the categories of Black & White cattle were not significantly different. Higher least square means were observed for the ridges of middle sector of grooved category of Red & White and Black & White breeds, but, the differences between categories were non-significant. The right and left pattern ridges indicated significant difference between categories of Red & White cattle which were not significantly different in both the categories of Black & White breed. The pattern ridges of Red & White cattle were significantly different ($P < 0.05$) between categories. In Black & White cattle, the differences were non-significant though higher least square means were observed in grooved category.

4.8.2 BASED ON PATTERN RIDGE CHARACTERISTICS

All pattern ridge characteristics of Tharparkar and Sahiwal breed expressed similarities between categories (Table 34). The major pattern ridge characteristics of Tharparkar muzzle indicated higher least square means for grooved category (Table 34). The cylindrical shaped pattern ridges of Karan Swiss breed denoted variation between grooved and non-grooved categories. The curved pattern ridges, medium length, cylindrical shaped and complete intercepted type pattern ridges of grooved category differed significantly ($P < 0.05$) from non-grooved category of Karan Fries breed (Table 35). The undulated pattern ridges, long length and cylindrical shape pattern ridges suggested large variation between categories of Red & White cattle. All pattern ridge characteristics revealed non-significant difference between categories of Black & White breed (Table 36).

4.9 <u>CORRELATION STUDIES</u>

4.9.1 ASSOCIATION BETWEEN CHARACTERISTICS OF MUZZLE

The correlation analysis suggest low to moderate association among the beads of each sector. The correlation analysis revealed highly significant

Table 33. Least square means (LSQM) and standard error (SE) of the muzzle characteristics of grooved and non-grooved categories of Red & White and Black & White breeds.

Muzzle characteristics	Breeds			
	Red & White		Black & White	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
BB	32.3[a] (5.4)[1]	39.6[a] (4.4)	35.8[a] (5.9)	44.2[a] (4.2)
BM	20.2[a] (3.5)	25.9[a] (2.9)	23.3[a] (3.8)	28.1[a] (2.8)
BU	81.0[a] (4.8)	89.06[a] (3.9)	93.9[a] (5.2)	90.3[a] (3.8)
BTO	132.9[a] (10.1)	154.6[a] (8.3)	153.0[a] (11.1)	161.3[a] (7.9)
RR	7.3[a] (0.8)	4.5[a] (0.6)	8.2[a] (0.9)	5.5[a] (0.6)
RL	7.5[a] (0.8)	3.7[b] (0.6)	7.5[a] (0.9)	6.3[b] (0.6)
RTB	14.8[a] (1.2)	14.2[a] (1.0)	15.7[a] (1.4)	15.4[a] (1.0)
RM	7.5[a] (0.7)	6.5[a] (0.6)	7.1[a] (0.7)	5.9[a] (0.5)
RCT	19.1[a] (1.5)	19.9[a] (1.2)	20.8[a] (1.6)	20.3[a] (1.2)
PRR	3.8[a] (0.4)	1.6[b] (0.3)	3.1[a] (0.4)	1.4[a] (0.3)
PRL	4.1[a] (0.4)	1.2[b] (0.3)	2.6[a] (0.4)	1.7[a] (0.3)
PRTO	7.9[a] (0.7)	4.2[b] (0.6)	5.8[a] (0.8)	3.6[a] (0.5)

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Red & White and Black & White breeds.

1 = Standard error within parenthesis.

Table 34. Least square means (LSQM) and standard error (SE) of the pattern ridge characteristics of grooved and non-grooved categories of Tharparkar and Sahiwal breeds.

Pattern ridge characteristics	Breeds			
	Tharparkar		Sahiwal	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
Major Class:				
Straight	3.8^{a} (0.3)[1]	2.8^{a} (0.8)	2.5^{a} (0.2)	2.0^{a} (1.0)
Curved	2.2^{a} (0.2)	2.2^{a} (0.6)	1.5^{a} (0.2)	2.7^{a} (0.8)
Tented	0.7^{a} (0.1)	0.4^{a} (0.3)	0.3^{a} (0.1)	0.3^{a} (0.3)
Undulated	1.0^{a} (0.2)	0.8^{a} (0.4)	0.4^{a} (0.1)	0.0^{a} (0.6)
Bifurcated	0.2^{a} (0.1)	0.0^{a} (0.2)	0.3^{a} (0.1)	0.0^{a} (0.2)
Length:				
Long	3.2^{a} (0.3)	1.8^{a} (0.9)	1.8^{a} (0.2)	2.3^{a} (0.2)
Medium	3.1^{a} (0.3)	1.2^{a} (0.7)	1.9^{a} (0.2)	1.0^{a} (0.9)
Small	2.7^{a} (0.2)	3.6^{a} (0.6)	1.4^{a} (0.2)	1.7^{a} (0.8)
Shape:				
Club	2.0^{a} (0.2)	2.6^{a} (0.5)	1.3^{a} (0.1)	2.7^{a} (0.7)
Cylindrical	7.0^{a} (0.4)	4.0^{a} (1.1)	3.9^{a} (0.3)	2.3^{a} (1.4)
Type:				
Complete	0.9^{a} (0.3)	1.4^{a} (0.9)	0.1^{a} (0.2)	0.0^{a} (1.1)
Complete intercepted	6.3^{a} (0.5)	3.4^{a} (1.2)	3.8^{a} (0.3)	2.7^{a} (1.6)
Fragmented	0.3^{a} (0.1)	0.0^{a} (0.3)	0.04^{a} (0.07)	0.0^{a} (0.3)
Fragmented intercepted	1.5^{a} (0.2)	1.8^{a} (0.5)	1.1^{a} (0.1)	2.3^{a} (0.6)

b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Tharparkar and Sahiwal breeds.

1 = Standard error within parenthesis.

Table 35. Least square means (LSQM) and standard error (SE) of the pattern ridge characteristics of grooved and non-grooved categories of Karan Swiss and Karan Fries breeds.

Pattern ridge characteristics	Breeds			
	Karan Swiss		Karan Fries	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
Major Class:				
Straight	2.8[a] (0.2)[1]	2.6[a] (0.2)	3.2[a] (0.1)	2.4[b] (0.2)
Curved	1.8[a] (0.2)	1.3[a] (0.2)	2.3[a] (0.1)	1.5[b] (0.1)
Tented	0.6[a] (0.1)	0.3[a] (0.1)	0.3[a] (0.05)	0.2[a] (0.06)
Undulated	1.0[a] (0.1)	0.5[a] (0.1)	0.8[a] (0.1)	0.7[a] (0.1)
Bifurcated	0.1[a] (0.05)	0.1[a] (0.06)	0.2[a] (0.04)	0.1[a] (0.04)
Length:				
Long	3.2[a] (0.2)	2.2[a] (0.3)	3.5[a] (0.2)	2.6[a] (0.2)
Medium	2.3[a] (0.2)	2.2[a] (0.2)	2.8[a] (0.1)	2.0[b] (0.2)
Small	1.9[a] (0.2)	1.5[a] (0.2)	1.7[a] (0.1)	1.2[a] (0.1)
Shape:				
Club	1.2[a] (0.1)	1.2[a] (0.2)	1.2[a] (0.1)	1.0[a] (0.1)
Cylindrical	6.2[a] (0.3)	4.6[b] (0.3)	6.8[a] (0.2)	4.8[b] (0.2)
Type:				
Complete	1.0[a] (0.2)	0.3[a] (0.2)	1.2[a] (0.2)	0.6[a] (0.2)
Complete intercepted	5.2[a] (0.3)	4.6[a] (0.4)	6.2[a] (0.2)	4.9[b] (0.3)
Fragmented	0.1[a] (0.07)	0.2[a] (0.08)	0.3[a] (0.05)	0.04[a] (0.06)
Fragmented intercepted	1.1[a] (0.1)	0.7[a] (0.1)	0.3[a] (0.1)	0.3[a] (0.1)

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Karan Swiss and Karan Fries breeds.

1 = Standard error within parenthesis.

Table 36. Least square means (LSQM) and standard error (SE) of the pattern ridge characteristics of grooved and non-grooved categories of Red & White and Black & White breeds.

Pattern ridge characteristics	Breeds			
	Red & White		Black & White	
	Grooved LSQM	Non-grooved LSQM	Grooved LSQM	Non-grooved LSQM
Major Class:				
Straight	2.1[a] (0.4)[1]	2.1[a] (0.3)	1.5[a] (0.4)	1.4[a] (0.3)
Curved	1.8[a] (0.3)	1.3[a] (0.3)	2.1[a] (0.3)	1.3[a] (0.3)
Tented	0.2[a] (0.1)	0.2[a] (0.1)	0.4[a] (0.1)	0.1[a] (0.1)
Undulated	2.1[a] (0.2)	0.7[b] (0.2)	1.2[a] (0.2)	1.2[a] (0.2)
Bifurcated	0.3[a] (0.10)	0.1[a] (0.09)	0.05[a] (0.1)	0.03[a] (0.09)
Length:				
Long	4.4[a] (0.4)	2.2[b] (0.4)	3.2[a] (0.5)	2.2[a] (0.4)
Medium	2.4[a] (0.4)	1.5[a] (0.3)	1.6[a] (0.4)	1.5[a] (0.3)
Small	1.0[a] (0.3)	1.4[a] (0.3)	0.9[a] (0.3)	1.0[a] (0.3)
Shape:				
Club	1.3[a] (0.3)	1.3[a] (0.2)	1.1[a] (0.3)	0.8[a] (0.2)
Cylindrical	6.6[a] (0.6)	3.7[b] (0.5)	4.6[a] (0.6)	3.8[a] (0.5)
Type:				
Complete	1.2[a] (0.4)	0.2[a] (0.4)	0.8[a] (0.5)	0.6[a] (0.4)
Complete intercepted	5.2[a] (0.6)	3.7[a] (0.6)	4.2[a] (0.7)	3.6[a] (0.5)
Fragmented	0.1[a] (0.1)	0.1[a] (0.1)	0.05[a] (0.1)	0.07[a] (0.1)
Fragmented intercepted	1.4[a] (0.2)	0.9[a] (0.2)	0.6[a] (0.2)	0.4[a] (0.2)

a, b = Least square means with different letter within a row differ significantly ($P < 0.05$) in the categories of Red & White and Black & White breeds.

1 = Standard error within parenthesis.

(P < 0.01) association between beads of all sectors. The correlation between number of beads of base (BB) and middle (BM) sectors was 0.58. A small correlation was observed between beads of base and upper sector. Base sector beads were positively correlated (r = 0.35). The correlation between beads of middle and upper sector was 0.51 (Table 37). On the contrary, the beads of each sector were highly correlated with beads of muzzle (BTO). The association between base and middle sector indicated the presence of similar characteristics in both sectors. It, however, did not indicate similar distribution of characteristics in concerned sectors. Similar indication was provided by the correlation between beads of middle and upper sectors. The medium level correlation of base and upper sector beads to the beads of middle sector indicated that the distribution and arrangement of such characteristics got altered in middle sector. This hypothesis got strengthened by observance of low correlation between beads of base and upper sector (r = 0.35) (Table 37). The beads of each sector showed dependencies to the beads of muzzle (BTO) due to their common origin but revealed difference of distribution in each sector.

The number of right (RR) and left (RL) ridges were highly associated with base sector ridges (RTB) due to their common origin. Moreover, it indicated maximum occurrence of ridges in the base sector. Low coefficients of correlation of 0.4 was observed for both right and left ridges with middle sector ridges (Table 38). The right and left ridges were highly correlated with right (PRR) and left (PRL) pattern ridges. The correlation coefficients among ridges and pattern ridges of respective sides were 0.8 in both the cases (Table 38). The high correlation among them indicate concordance between ridges and pattern ridges of both sides. Therefore, the ridges which were arranged around particular point of the muzzle to form pattern were called pattern ridges. This arrangement was thus used as an asset to classify

Table 37. Correlation between number of beads of all sectors and standard deviation of beads of all sectors (n=596).

Sectors	sd	BM	BU	BTO
BB	25.8	0.58***	0.35***	0.79***
BM	19.6		0.51***	0.83***
BU	27.4			0.77***
BTO	58.3			

*** = Significant at P < 0.001.

Table 38. Correlation between number of ridges of all sectors and standard deviation of the ridges of all sectors (n=598).

Sectors	sd	RL	RTB	RM	RGT	PRR	PRL	PRTO
RR	3.9	0.8***	0.7***	0.4***	0.6***	0.8***	0.7***	0.6***
RL	3.9		0.7***	0.4***	0.6***	0.7***	0.8***	0.6***
RTB	3.8			0.5***	0.9***	0.5***	0.5***	0.7***
RM	3.4				0.7***	0.4***	0.4***	0.4***
RGT	7.2					0.5***	0.5***	0.6***
PRR	2.1						0.8***	0.8***
PRL	3.4							0.8***
PRTO								

*** = Significant at P < 0.001.

and identify the individual muzzle. Otherwise, there was no marked difference between ridges and pattern ridges of the muzzle.

The base sector ridges were significantly ($P < 0.01$) correlated with middle sector ridges and the correlation coefficient was 0.5. The observed medium level correlation was due to the distribution of base sector ridges to middle sector which is similar to the findings in case of the association between beads of base and middle sectors. Thus, middle sector was the common area affected by the characteristics of base as well as upper sector and, therefore, most of the patterns were located in the lower half of the muzzle. The correlation coefficient of 0.9 was observed between ridges of base sector and ridges of muzzle. The middle sector ridges were also correlated ($r = 0.7$) with the ridges of muzzle. The high correlation between base and middle sector ridges with muzzle indicated prevalence of ridges in lower half area of the muzzle. The middle sector ridges were slightly associated with right, left and total pattern ridges (PRTO) where the correlation coefficients of 0.4 were observed for right, left and total pattern ridges, respectively (Table 38). The lower degree of association was due to presence of those pattern ridges which were long enough to cross the base sector.

The correlation coefficients among beads and ridges of all sectors are presented in Table 39. The ridges of all sectors including both sides were negatively associated with beads of base sector. The correlation were highly significant ($P < 0.01$) and ranged from -0.3 to -0.6 (Table 39). The right and left ridges as well as pattern ridges (right and left) were also slightly associated with beads of base sector. The correlation coefficients were -0.4 for both right and left ridges and -0.4 and -0.3 for right and left pattern ridges. The low correlation indicate minor bead effect on the distribution of ridges and pattern ridges of both sides. The correlation between total ridges and beads of

Table 39. Correlation between beads and ridges of all sectors (n = 596).

Sectors/ sides	BB	BM	BU	BTO
RR	-0.4***	-0.3***	0.02 NS	-0.3***
RL	-0.4***	-0.3***	0.03 NS	-0.2***
RTB	-0.6***	-0.4***	-0.002 NS	-0.4***
RM	-0.4***	-0.7***	-0.2***	-0.5***
RCT	-0.6***	-0.5***	-0.06 NS	-0.5***
PRR	-0.4***	-0.2***	0.05 NS	-0.2***
PRL	-0.3***	-0.2***	0.07 NS	-0.2***
PRTO	-0.4***	-0.3***	0.08*	-0.2***

* = Significant at $P < 0.05$.

*** = Significant at $P < 0.001$.

NS = Non-significant.

base sector was higher (r = -0.6) than that between right and left ridges and pattern ridges and beads of the base sector. This variation exhibited effect of beads on the ridges quantitatively but distribution of ridges and pattern ridges remained unaltered. Since most of the ridges on the muzzle were present in base sector, relatively high correlation (r = -0.6) was observed between ridges of the muzzle and beads of the base sector (Table 39).

The correlation between beads of middle sector and ridges of all sectors including both sides ranged between -0.2 and -0.7 (Table 39). The highest correlation (r = -0.7) was observed between ridges and beads of middle sector (Table 39). The correlation between ridges of the muzzle and beads of the middle sector was moderate and negative (r = -0.5). The correlations among upper sector beads and ridges were largely non-significant and very low. This indicated that the ridges had little influence on the beads of the upper sector. In addition, the upper sector was the area where only beads were disturbed and no such pattern existed.

4.9.2 ASSOCIATION BETWEEN PATTERN RIDGE CHARACTERISTICS

The correlation among major class of pattern ridge characteristics are presented in Table 40. The correlations were generally low and in most of the cases non-significant. This suggest that the pattern ridges of major class were entirely different from each other.

The correlations between pattern ridge characteristics and other ridge characteristics, namely, length, shape and types are presented in Table 41. A highly significant correlation of 0.5 was observed between long and undulated pattern ridges. Thus, it indicated that the undulated pattern ridges would be longer than the other pattern ridges of major class. The association of same magnitude (r = 0.5) was also observed between small and straight pattern ridge, which points to the fact that most of the small pattern ridges were straight

Table 40. Correlation between pattern ridge characteristics (n=539).

Pattern ridges (major class)	Curved	Tented	Undulated	Bifurcated
Straight	0.007^{NS}	0.02^{NS}	-0.13***	0.006^{NS}
Curved		0.06^{NS}	0.0006^{NS}	0.06^{NS}
Tented			0.008^{NS}	0.06^{NS}
Undulated				0.05^{NS}

*** = Significant at $P < 0.001$. NS = Non-significant.

Table 41. Correlation between pattern ridges of major class and other characteristics of the pattern ridges (n=539).

Other characteristics	Major class				
	Straight	Curved	Tented	Undulated	Bifurcated
Length:					
Long	0.1**	0.3**	0.2***	0.5***	0.3***
Medium	0.4***	0.4***	0.2***	0.05^{NS}	0.06^{NS}
Small	0.5***	0.2***	0.03^{NS}	-0.1**	-0.06^{NS}
Shape:					
Club	0.2***	0.2**	0.1***	0.1***	0.1**
Cylindrical	0.5***	0.5***	0.2***	0.3***	0.2***
Type:					
Complete	0.1^{NS}	0.2***	0.1***	0.2***	0.1**
Complete intercepted	0.5***	0.3***	0.1***	0.2***	0.1**
Fragmented	0.1***	0.1*	-0.04^{NS}	0.02^{NS}	0.06^{NS}
Fragmented intercepted	0.1*	0.1*	0.1**	0.07^{NS}	0.04^{NS}

* = Significant at $P < 0.05$.

** = Significant at $P < 0.01$.

*** = Significant at $P < 0.001$.

NS = Non-significant.

ones. The cylindrical shape was better associated with straight and curved pattern ridges. The correlation coefficients were 0.5 for both straight and curved pattern ridges. Overall, the pattern ridges of major class showed greater affinity towards cylindrical shape than club shape.

4.9.3 MUZZLE CHARACTERISTICS AND MILK YIELD

First lactation yield (305 days) was correlated subsequently with all muzzle characteristics and their correlation coefficients are presented in Table 42. The beads of all sectors as well as muzzle were negatively correlated with first lactation yield. The coefficients of correlation between them were significantly low and ranged between -0.2 and -0.4 (Table 42). On the contrary, the ridges of base (RTB), middle (RM) and muzzle as a whole (RCT) were positively correlated with first lactation (305 days) milk yield, but their correlations were low. *Correlations in case of ridges and pattern ridges of both sides,* were observed to be non-significant.

In general, the low correlations between first lactation yield and beads as well as ridges can be attributed to the colinearity among the characteristics. Moreover, the low association suggest phenotypic nature of the characteristics which may only have their bearing on morphological characteristics and little effect on traits largely determined by genotype of the animal within an environment.

4.9.4 PATTERN RIDGE CHARACTERISTICS AND MILK YIELD

The straight and undulated pattern ridges were significantly associated with first lactation yield (Table 43). Straight pattern ridges were negatively ($r = -0.2$) and undulated pattern ridges were positively ($r = 0.3$) associated with first lactation yield (305 days). The rest of the characteristics were not associated significantly with first lactation yield. This result also support

Table 42. Correlation between first lactation yield (305 days) and muzzle characteristics (n=251).

Muzzle characteristics	First lactation yield (305 days)
BB	-0.2***
BM	-0.4***
BU	-0.3***
BTO	-0.4***
RR	0.03[NS]
RL	0.1[NS]
RTB	0.2**
RM	0.3***
RGT	0.2***
PRR	-0.04[NS]
PRL	0.03[NS]
PRTO	-0.02[NS]

** = Significant at $P < 0.01$.

*** = Significant at $P < 0.001$.

NS = Non-significant.

Table 43. Correlation between first lactation yield (305 days) and pattern ridge characteristics (n=229).

Pattern ridge characteristics	First lactation yield (305 days)
Major Class:	
Straight	-0.2**
Curved	-0.04^{NS}
Tented	0.01^{NS}
Undulated	0.3***
Bifurcated	-0.03^{NS}
Length:	
Long	0.1^{NS}
Medium	-0.06^{NS}
Small	-0.1^{NS}
Shape:	
Club	-0.1^{NS}
Cylindrical	0.01^{NS}
Type:	
Complete	-0.004^{NS}
Complete intercepted	0.01^{NS}
Fragmented	-0.04^{NS}
Fragmented intercepted	-0.08^{NS}

** = Significant at $P < 0.01$.

*** = Significant at $P < 0.001$.

NS = Non-significant.

morphological nature of the pattern ridge characteristics. Similar indications were earlier obtained in all comparison of milk yield and muzzle characteristics.

4.9.5 ASSOCIATION BETWEEN RESIDUALS OF FIRST LACTATION YIELD (305 DAYS) AND MUZZLE AND PATTERN RIDGE CHARACTERISTICS

The residuals, which are independent from their nuisance effects, for first lactation yield (305 days) were calculated applying Model-II, whereas, Model-III was used to calculate the residuals for muzzle and pattern ridge characteristics. The residuals of muzzle and pattern ridge characteristics were then correlated with the residuals of first lactation yield. The coefficients of correlation among the residuals of muzzle characteristics and first lactation yield are presented in Table 44 which indicate their extremely low and non-significant association with first lactation yield. Similar results were also observed among various pattern ridge characteristics, where none of the pattern ridge characteristics were significantly correlated with first lactation yield (Table 45).

4.9.6 MUZZLE CHARACTERISTICS AND AGE AT FIRST CALVING

The coefficients of correlation between age at first calving and muzzle characteristics are presented in Table 46. Beads of all the sectors were positively correlated with age at first calving. The beads of middle (BM) and upper (BU) as well as total beads on the muzzle (BTO) were significantly ($P < 0.05$) correlated. The correlation coefficients were 0.2, 0.1 and 0.1, respectively, for the beads of middle and upper sectors as well as muzzle. On the contrary, the ridges were negatively correlated with age at first calving, where significant ($P < 0.05$) correlations were observed for the ridges of base (RTB) and middle (RM) sectors as well as muzzle (RGT). The pattern ridges were positively correlated. Overall, the correlation coefficients were very low and thus, no proper conclusions can be drawn.

Table 44. Correlation between residuals of first lactation yield (305 days) and muzzle characteristics (n=241).

Muzzle characteristics	First lactation yield (305 days)
BB	-0.1[NS]
BM	-0.1*
BU	-0.002[NS]
BTO	-0.1[NS]
RR	0.03[NS]
RL	0.03[NS]
RTB	0.07[NS]
RM	0.08[NS]
RCT	0.09[NS]
PRR	0.04[NS]
PRL	0.08[NS]
PRTO	0.06[NS]

* = Significant at $P < 0.05$.

NS = Non-significant.

Table 45. Correlation between residuals of first lactation yield (305 days) and pattern ridge characteristics (n=216).

Pattern ridge characteristics	First lactation yield (305 days)
Major Class:	
Straight	0.1^{NS}
Curved	-0.02^{NS}
Tented	0.05^{NS}
Undulated	0.2^{NS}
Bifurcated	-0.007^{NS}
Length:	
Long	0.08^{NS}
Medium	0.02^{NS}
Small	-0.03^{NS}
Shape:	
Club	0.04^{NS}
Cylindrical	0.05^{NS}
Type:	
Complete	-0.06^{NS}
Complete intercepted	0.07^{NS}
Fragmented	-0.05^{NS}
Fragmented intercepted	-0.1^{NS}

NS = Non-significant.

Table 46. Correlation between age at first calving, age at first service and muzzle characteristics.

Muzzle characteristics	Age at first calving (305 days) n=375	Age at first service n=296
BB	0.05[NS]	-0.06[NS]
BM	0.20***	0.1[NS]
BU	0.1*	-0.07[NS]
BTO	0.1**	-0.02[NS]
RR	-0.06[NS]	-0.04[NS]
RL	-0.08[NS]	-0.05[NS]
RTB	-0.1*	-0.04[NS]
RM	-0.1**	-0.1[NS]
RCT	-0.1*	-0.04[NS]
PRR	0.01[NS]	-0.01[NS]
PRL	0.01[NS]	-0.03[NS]
PRTO	0.04[NS]	0.01[NS]

* = Significant at P < 0.05.

** = Significant at P < 0.01.

*** = Significant at P < 0.001.

NS = Non-significant.

4.9.7 PATTERN RIDGE CHARACTERISTICS AND AGE AT FIRST CALVING

All other pattern ridge characteristics except straight (r = 0.2), small length (r = 0.1), club shaped (r = 0.1) and fragmented intercepted type (r = 0.1) pattern ridges (Table 47) were associated non-significantly with age at first calving. The magnitude of association in general was very small and, therefore, no conclusion could be drawn.

4.9.8 MUZZLE AND PATTERN RIDGE CHARACTERISTICS AND AGE AT FIRST SERVICE

Various muzzle characteristics were negatively associated with age at first service. The correlation coefficients were extremely low and have been presented in Table 46. In case of pattern ridge characteristics, a significant association was observed with small length and fragmented intercepted pattern ridges. The correlation coefficients were 0.1 for both small length and fragmented intercepted type pattern ridge (Table 47). The low association further strengthen the possibility of the morphological nature of the pattern ridge characteristics.

4.9.9 MUZZLE AND PATTERN RIDGE CHARACTERISTICS AND CALVING INTERVAL

The association of calving interval with all muzzle characteristics was non-significant. However, it was observed that the beads of all sectors and muzzle were negatively correlated (Table 48). In case of pattern ridge characteristics also, similar correlations were observed, where straight (r = -0.08), undulated (r = -0.03), bifurcated (r = -0.04), long (r = -0.01), small length (r = -0.02), club shape (r = -0.1), complete intercepted (r = -0.03) and fragmented (r = -0.08) type pattern ridges were negatively correlated with calving interval (Table 49).

4.9.10 ASYMMETRY OF THE MUZZLE

In most of the patterns, the ridges and pattern ridges were distributed into right and left halves of the muzzle, therefore, asymmetry may be

Table 47. Correlation between age at first calving, age at first service and pattern ridge characteristics.

Pattern ridge characteristics	Age at first calving (305 days) n=336	Age at first service n=266
Major Class:		
Straight	0.2**	0.1 NS
Curved	0.001 NS	-0.01 NS
Tented	0.05 NS	0.02 NS
Undulated	-0.08 NS	-0.01 NS
Bifurcated	0.01 NS	-0.01 NS
Length:		
Long	-0.07 NS	-0.1 NS
Medium	0.08 NS	0.05 NS
Small	0.1**	0.1**
Shape:		
Club	0.1*	0.1 NS
Cylindrical	0.02 NS	-0.02 NS
Type:		
Complete	-0.08 NS	-0.09 NS
Complete intercepted	0.07 NS	0.05 NS
Fragmented	-0.03 NS	-0.07 NS
Fragmented intercepted	0.1**	0.1**

* = Significant at $P < 0.05$.

** = Significant at $P < 0.01$.

NS = Non-significant.

Table 48. Association between calving interval and muzzle characteristics (n=217).

Muzzle characteristics	Calving interval
BB	-0.1[NS]
BM	-0.09[NS]
BU	-0.004[NS]
BTO	-0.08[NS]
RR	0.01[NS]
RL	0.03[NS]
RTB	0.09[NS]
RM	0.1[NS]
RCT	0.1[NS]
PRR	-0.04[NS]
PRL	0.02[NS]
PRTO	0.03[NS]

NS = Non-significant.

Table 49. Correlation between calving interval and pattern ridge characteristics.

Pattern ridge characteristics	Calving interval n = 195
Major Class:	
Straight	-0.08^{NS}
Curved	0.05^{NS}
Tented	0.05^{NS}
Undulated	-0.03^{NS}
Bifurcated	-0.04^{NS}
Length:	
Long	-0.01^{NS}
Small	-0.02^{NS}
Medium	0.02^{NS}
Shape:	
Club	-0.1^{NS}
Cylindrical	0.03^{NS}
Type:	
Complete	0.01^{NS}
Complete intercepted	-0.03^{NS}
Fragmented	-0.08^{NS}
Fragmented intercepted	0.06^{NS}

NS = Non-significant.

suspected. The asymmetry can also be suspected between 40 percent area of the base and upper sectors of the muzzle. This problem was diagnosed by studying association between characteristics for right and left halves as well as between base and upper sectors. Though the correlation between right and left ridges was 0.8 (Table 38) which was very high and highly significant, but it was not enough to prove complete symmetry between right and left halves. In case of symmetry, the association between them should be unity. Similar results was also observed in case of right and left pattern ridges which further reflected asymmetry between two respective halves. The association between beads of the upper and base sector was low (r = 0.3, Table 37). This proves marked difference between 40 percent area of the base and upper sector. These observations indicated that the muzzle exhibited complete symmetry neither area-wise nor the right and left halves are symmetrical.

4.9.11 CANONICAL CORRELATION

The correlations among muzzle characteristics were moderate, the largest being -0.7 between ridges and beads of the middle sector (Table 39). There were within characteristics correlations of the order of 0.8 between beads of all sectors (BB, BM, BU) and beads of the muzzle (BTO) (Table 37), 0.8 between right and left ridges, 0.7 between ridges of base sector and right as well as left ridges, 0.9 between ridges of base sector and ridges of muzzle (RCT), 0.6 between ridges of muzzle and right and left ridges. The pattern ridges were also correlated with other ridge characteristics at near same magnitude except with the ridges of middle sector (Table 38). Whereas, the association between pattern ridges of major class and other pattern ridge characteristics were low to moderate (Table 41). The correlation coefficients indicated colinearity among them. Due to dependencies the phenotypic association between the muzzle as well as pattern ridge characteristics and first lactation yield may be ambiguous. The canonical correlation was, therefore, attempted to correlate the muzzle and pattern ridge characteristics by reducing dependencies among them with the residuals of first lactation yield (305 days). Model-II was applied in order to obtain first lactation free from nuisance effects. The canonical correlation between muzzle characteristics and first lactation yield (residuals) was 0.2 with standard error of 0.06. The likelihood ratio of 0.96 indicated non-significant canonical correlation (Table 50). The canonical correlation of 0.3 was observed between pattern ridge characteristics and residuals of first lactation yield (Table 50). The standard error was 0.06 and the likelihood ratio of 0.9 indicated non-significant association between them.

4.10 CLASSIFICATION OF GENUSES

The measurements from a total of twenty-four characteristics of muzzle including pattern ridge characteristics were used to classify the zebu, taurus and their crosses from each other. The least square means and standard errors of such characteristic, namely, total number of beads at base, middle and upper sectors, total number of ridges in middle sector and muzzle, total number of pattern ridges in muzzle, number of straight, curved, tented, undulated, bifurcated, long, medium and small length pattern ridges, complete, complete intercepted, fragmented, fragmented intercepted types, club and cylindrical shaped pattern ridges are given in Table 25 and 26. The percentage of straight, long, small and cylindrical pattern ridges were calculated and subsequently included in the observation. A total of 537 observations were included in this analysis. The generalized squared distance (Mahalanobis distance) were calculated and have been presented in Table 51.

It was observed that the Mahalanobis distance between Bos Indicus and Bos Taurus was very high (7.9). The distance between Bos Taurus and

Table 50. Canonical correlation between residuals of first lactation yield (305 days) and muzzle as well as pattern ridge characteristics.

Characteristics	Canonical correlation	SE	Likeli- hood ratio	Approx. F	Num.* df.	Den.* df.	F
Muzzle (n=241)	0.2	0.06	0.96	0.82	11	229	0.6^{NS}
Pattern (n=216)	0.3	0.06	0.91	1.35	14	201	0.2^{NS}

NS = Non-significant.
Num.* = Numerator.
Den.* = Denominator.

Table 51. Mahalanobis distance between genuses (n=537).

Genus/crossbred	Generalized squared distance
Bos Indicus - Crossbred	2.8
Bos Indicus - *Bos Taurus*	7.9
Bos Taurus - Crossbred	7.2

crossbred was also high (7.2). On the contrary, the distance between Bos Indicus and crossbred was less (2.8). The generalized squared distance was used as classification criterion to classify the genuses and crossbred. The number of observations and percentage of classification of each genus and crossbred exactly into their respective classes including number and percentage of misclassification are presented in Table 52.

The classification result revealed high percentage of exact classification of Bos Indicus (zebu) into their respective class. The percentage of classification was 78.6 (Table 52). Whereas, the percentage of misclassification of zebu into crossbred and taurus class were 17.5 and 3.9. In case of crossbred, only 76.3 percent animals were accurately classified into their class and 17.3 and 6.4 percent animals were misclassified into zebu and taurus classes. The classification analysis thus indicated around same percentage of misclassification of zebu into crossbred and vice-versa. Comparatively high percentage (84.1) of animals were classified as taurus cattle where the rate of misclassification into zebu and crossbred cattle were 6.8 and 9.1 percent. The analysis indicated maximum percentage of misclassification of animals into zebu and crossbred class which can be attributed to the similarities of some muzzle characteristics among them. Further, it also suggested the influence of zebu inheritance on crossbreds. No proper inference could be drawn in case of some percentage of misclassification observed in taurus and zebu except that it might indicate common ancestry of the cattle.

4.11 CLASSIFICATION OF BREEDS

Similar characteristics were used to classify the breeds. The least square means and standard errors for such characteristics are presented in Tables 27 and 28. Since the classification criterion was based on generalized squared distance, the Mahalanobis distance between breeds were calculated and are presented in Table 53. The generalized squared distance between Tharparkar

Table 52. Number and percentage of observation classified and misclassified into genus/crossbred.

Genus/ crossbred	Bos Indicus n	Bos Indicus %	Crossbred n	Crossbred %	Bos Taurus n	Bos Taurus %
Bos Indicus	81	78.6	18	17.5	4	3.9
Crossbred	60	17.3	264	76.3	22	6.4
Bos Taurus	6	6.8	8	9.1	74	84.1

Table 53. Mahalanobis distance between breeds (n=537).

Breeds	Generalized squared animals
Tharparkar - Sahiwal	4.1
Tharparkar - Karan Swiss	3.1
Tharparkar - Karan Fries	5.2
Tharparkar - Red & White	12.0
Tharparkar - Black & White	14.0
Sahiwal - Karan Swiss	4.0
Sahiwal - Karan Fries	4.1
Sahiwal - Red & White	7.8
Sahiwal - Black & White	10.1
Karan Swiss - Karan Fries	1.8
Karan Swiss - Red & White	11.8
Karan Swiss - Black & White	12.4
Karan Fries - Red & White	6.9
Karan Fries - Black & White	7.5
Red & White - Black & White	2.3

and Red & White as well as Tharparkar and Black & White breeds were 12 and 14 (Table 53) which are quite high. Therefore, no percentage of the Tharparkar breed was misclassified into Red & White and Black & White breed. Similarly, Sahiwal showed high distance with Red & White (7.8) and Black & White (10.1) breeds and hence, low percentage of Sahiwal breed was misclassified into Red & White and Black & White breeds. The percentage of misclassification into both the breeds were 1.5 (Table 54). Karan Swiss breed have also indicated high generalized squared distance with Red & White (11.8) and Black & White (12.4) breeds thus resulting in 0.9 percent of misclassification into both Red & White and Black & White breeds. In case of Karan Fries breed, the distance with Red & White and Black & White breeds were 6.9 and 7.5, respectively, where 3.8 and 6.8 percent animals were misclassified into Red & White and Black & White breeds, respectively (Table 54). The generalized squared distance of 1.8 was observed between Karan Swiss and Karan Fries breeds (Table 53). Due to less generalized squared distance between Karan Swiss and Karan Fries, a high percentage of misclassification of Karan Swiss cattle into different breeds were observed. The percentage of misclassification of Karan Swiss into Tharparkar, Sahiwal and Karan Fries breeds were 18.8, 12.5 and 17.0, respectively (Table 54). Only 50 percent Karan Swiss animals were accurately classified into their own class. In case of Karan Fries breed, the percentage of misclassification were 3.8, 7.7, 19.7, 3.8 and 6.8, respectively, into Tharparkar, Sahiwal, Karan Swiss, Red & White and Black & White cattle. Only 58.1 % animals were exactly classified into their own class. The less generalized squared distance between Red & White and Black & White cattle (2.3) resulted in high percentage (20) of misclassification of Red & White cattle into Black & White cattle. Moreover, the Red & White cattle were also misclassified into Tharparkar, Sahiwal and Karan Fries breed where the percentage of misclassification was 6.7 in Tharparkar and Sahiwal breeds and 8.9 percent animals were misclassified into Karan Fries breed. Only 57.8 percent animals were exactly classified as Red & White breed. In case of Black & White breed, 60.5 percent animals were exactly classified as Black & White breed. The classification analysis indicated 23.3 percent Black & White animals were misclassified as Red & White animals. The percentage of misclassification of Black & White breed into Sahiwal and Karan Fries breeds were 4.6 and 11.6 percent.

Table 54. Number and percentage of observations classified and misclassified into breeds.

Breeds	TH.*		SW.		KS.		KF.		RW.		BW.	
	n	%	n	%	n	%	n	%	n	%	n	%
Tharparkar	26	68.4	7	18.4	4	10.5	1	2.6	0	0.0	0	0.0
Sahiwal	8	12.3	46	70.8	5	7.7	1	1.5	4	6.1	1	1.5
Karan Swiss	21	18.8	14	12.5	56	50.0	19	17.0	1	0.9	1	0.9
Karan Fries	9	3.8	18	7.7	46	19.7	136	58.1	9	3.8	16	6.8
Red & White	3	6.7	3	6.7	0	0.0	4	8.9	26	57.8	9	20.0
Black & White	0	0.0	2	4.6	0	0.0	5	11.6	10	23.3	26	60.5

* Indicate, TH. = Tharparkar, SW. = Sahiwal, KS. = Karan Swiss, KF. = Karan Fries, RW. = Red & White and BW. = Black & White breeds.

The percentage of exact classification of Tharparkar and Sahiwal breeds were 68.4 and 70.8 (Table 54). Around 18.4, 10.5 and 2.6 percent Tharparkar animals were misclassified as Sahiwal, Karan Swiss and Karan Fries breeds, respectively. Similar finding was observed in Sahiwal breed, where 12.3 and 7.7 percent animals were misclassified into Tharparkar and Karan Swiss breeds.

4.12 TO DETERMINE THE AGE WHEN MUZZLE DERMATOGLYPH BECOME PERMANENT

The least square means for the number of beads in each age group were calculated applying Model-IV. The least square means for each age group are presented in Table 55. The least square means ranged between 45.7 and 13.1 for 0 to 144 months of age. The result indicated continuous decreasing trend in number of beads in the middle area of the muzzle of each age class. The least square means of the beads revealed that the number of beads were higher in younger aged animals as compared to that in the older animals. The least square means of the beads in specified area of 1.5 cm^2 were 45.7 at 0 to 6 months age and 30.9 at 6 to 12 months. The least square means of these two age classes differed significantly ($P<0.05$) (Table 55).

Table 55. Least square means (LSQM) and standard error (SE) of the beads in specified area of 1.5 cm^2 of the muzzle print of animals (n=469).

Sl. No.	Age groups (months)	n	Beads LSQM	SE
1.	0 - 6	49	45.7^{a*}	1.1
2.	6 - 12	47	30.9^{b}	1.1
3.	12 - 18	21	24.3^{a}	1.7
4.	18 - 24	34	24.5^{c}	1.3
5.	24 - 36	106	21.8^{ce}	0.8
6.	36 - 48	67	18.7^{de}	0.9
7.	48 - 60	48	17.9^{de}	1.1
8.	60 - 72	26	17.8^{cdef}	1.5
9.	72 - 84	26	16.1^{df}	1.5
10.	84 - 96	17	16.4^{de}	1.9
11.	96 - 120	17	11.5^{f}	1.9
12.	120 - 144	11	13.1^{df}	2.3

* = a, b, c, d, e, f least square means with different letter within column differ significantly ($P < 0.05$).

This difference indicated that the number of beads in specified area of the muzzle declined as the age advanced. A significant reduction was also observed at 12 to 18 months of age, where the least square means of the beads were 24.3. Differences between the least square means of the beads of 12 to 18 months and 18 to 24 months age class were non-significant. The least square means of the beads for 18 to 24 months age class was 24.5 (Table 55). Thus, the reduction was more marked till 12 to 18 months of age and very less after this age. There appears to be a constant rate of bead development upto a given age of the animal. In the present study, this critical age appeared to be upto 18 or 24 months of age from where on the change in the number of beads was negligible. Therefore, the changes between 18 and 24 months, and 24 and 36 months age class were not significant. The least square means of 18.7, 17.9, 17.8, 16.1 and 16.4 beads were observed for 36 to 48, 48 to 60, 60 to 72, 72 to 84 and 84 to 96 months age groups, respectively, and the differences among each other were non-significant (Table 55). After 96 months of age, the reduction on the number of beads were irregular which may be due to less number of animals in that class.

The correlation coefficient between age and number of beads was highly significant ($P < 0.01$) and indicated moderate association between age and the number of beads. However, the correlation coefficient was negative. Thus, as the animal advanced in age, the total number of beads was reduced gradually (Table 56). This confirmed the earlier findings that the presence of beads on the muzzle were age related and got reduced as the age advanced.

Table 56. Correlation coefficient of the beads and the age of the animal.

Characteristics	Age
Beads	-0.6***

*** = Significant at $P < 0.001$.

The result indicated continuous decreasing trend of number of beads in the specified area of the muzzle. This decreasing trend suggested the possibility of age determination. Non-significant difference observed between 12 to 18 and 18 to 24 months age class suggested no change in the size of muzzle characteristics after this age. Therefore, it is deduced that after 18 to 24 months of age, the muzzle will have little change in the size of the characteristics. The muzzle print taken before the recommended age may bring confusion due to change in the size of the muzzle characteristics. However, the muzzle print taken after the recommended age may not be ambiguous.

Thus, the present investigation revealed that various muzzle and pattern ridge characteristics were significantly different among all the breeds studied in the present study. Most of the muzzle and pattern ridge characteristics of Karan Swiss and Karan Fries indicated same concordance with Sahiwal and Tharparkar breeds. While that of Red & White and Black & White breeds revealed great concordance among them. These results were confirmed by discriminant analysis procedure, where the muzzle and pattern ridge characteristics were studied together. The result of discriminant analysis indicated high percentage of misclassification of Karan Swiss and Karan Fries breeds in Sahiwal and Tharparkar cattle. A high percentage of misclassification was also observed in Red & White into Black & White and vice-versa. In Karan Swiss and Karan Fries breeds, the high percentage of misclassification appeared to be related to genetic make up of these breeds. The misclassification of Red & White into Black & White and vice-versa also seemed related with genetic structure of these breeds. Another reason for the breeds exhibiting different degrees of misclassification can be attributed to common ancestry of all cattle breeds. The results obtained in this study thus, indicated a possibility of breed characterisation based on muzzle characteristics. In order to achieve very high percentage of classification rate, a further investigation in this direction is required, where the muzzle and pattern ridge characteristics may be combined with those most important morphological or anatomical traits of body confirmation of the animal which are considered for breed characterisation.

The correlation between characteristics indicated general distribution of various characteristics on the muzzle. The association of the muzzle and pattern ridge characteristics with first lactation 305 days milk yield, age at first calving, age at first service and calving interval suggest that there appears to be no genetic association between muzzle characteristics and those responsible for productive and reproductive performance and these traits only appeared to determine the phenotype of thc animals.

CHAPTER - 5

SUMMARY AND CONCLUSIONS

5. SUMMARY AND CONCLUSIONS

The studies on the characteristics of the dermatoglyphics of muzzle in dairy cattle are very scant. An attempt was, therefore, made to observe various characteristic features and muzzle patterns on dairy cattle. The identified characteristics and patterns are helpful in identifying the animals. These findings can be of great help in solving the disputes pertaining to correct identification of animals.

The muzzle prints of Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White animals were taken by modified cyclostyle ink procedure of study various characteristics, patterns and possible use in identifying the animals. The muzzle prints of all the animals (n = 602) were divided into three main sectors, namely, base, middle and upper sector. The sectorial division was based on the length of muzzle print. The distribution and arrangement of ridges, pattern ridges and beads were studied in order to examine patterns on the muzzle. At the beginning, the muzzle prints were divided into three main categories, namely, grooved, non-grooved and special category. These categories were further divided into various classes called patterns. Out of 14 identified patterns, the grooved category comprised of 6 patterns. The non-grooved and special categories were classified into 5 and 3 patterns, respectively. Altogether, around 90% animals confirmed to 3 categories of patterns based on the arrangement of pattern ridges. The animals distributed into the patterns based on distributed ridges and beads were less, i.e., 5.8 and 3.8 percent, respectively. The percentage (0.67) of animals falling in special category were very less. The criterion for classification followed here indicate the importance of the pattern ridges in identifying the animals.

Based on their characteristic features, the pattern ridges were classified into 6 major classes, namely, straight, curved, tented, undulated, bifurcated and miscellaneous class. Each class was further classified into minor classes. Moreover, the length, shape and type of pattern ridges were also recorded and classified. The length of the pattern ridges was classified into 3 groups, i.e., long, small and medium. Two shapes, namely, club and cylindrical were observed. The pattern ridge types were classified into 4 classes, namely, complete, complete intercepted, fragmented and fragmented intercepted.

The classification of pattern ridge characteristics will be of immense help in solving the disputes arising out of identical nature of the muzzle prints of whom the angle is also the same.

The secondary classification of muzzle prints was developed for individual identification of animals. The basis of secondary classification was the maximum utilisation of highly variable characteristics from all sectors to develop easy and reliable identification system. The coefficients of variation for beads at base and middle, ridges at base and middle as well as pattern ridges in the muzzle were very high. The pattern ridges were used to code the base sectors in the secondary classification. The extended pattern ridges and number of beads available in middle sector were used for coding the middle sector. In case of upper sector, the beads were classified into five different ranges and each range was assigned a Latin letter. The pattern ridge numbers were used to code the base sector. The frequency distribution of pattern ridge combination indicate great concordance among animals. One animal confound to more than one class. This indicates fragile and irresolute nature of secondary code. Thus, the secondary code may not be helpful in uniquely identifying the animal. A system of sub-secondary classification was developed to strengthen the coding system.

In this system, pattern ridge angles were used instead of their numbers. The concept of using pattern ridge angle was to obtain a wide diversity on the pattern ridges for individual identification. Alphabetic codes were used instead of pattern ridge angles. An alphabetic index was developed where all possible angles ranging from 0 to 180° were specified by separate alphabetic codes. Thus, the final code for sub-secondary classification was developed by combining the alphabetic code of the pattern ridges of base sector. Combination of extended pattern ridge angle and number of beads present in middle sector and Latin alphabet for upper sector. The final code so developed was the most effective of all the codes and thus, it was possible to uniquely identify those 89.70 percent animals in whom patterns were formed by pattern ridges. The grooved and non-grooved categories were distinguished by drawing straight line between numerator and denominator position indicating right and left halves of the muzzle in case of grooved category. The absence of the straight line in that position indicated non-grooved category. The pattern based on distributed ridges as well as beads were coded by writing total number of distributed ridges in base sector in non-grooved category. The total number of distributed ridges present in right and left halves were written and were separated by drawing straight line between numerator and denominator position in grooved category. The code for middle sector comprised of number of distributed ridges and beads present in middle sector. The number of beads present in upper sector were noted and used to code the upper sector. The final code was developed by combining base, middle and upper sector codes. The final code thus developed uniquely identified 5.80 percent animals belonging to this pattern. The pattern formed by beads only were exhibited in 3.8 percent cases. The final code for such pattern was the combination of the codes of base, middle and upper sector, where number of beads present in each sector were written. The developed code have thus uniquely distinguished each animal falling in this class.

The code for the patterns of special category were developed by combining the pattern abbreviation and print number. Since, there were very few animals (0.67%) falling in this category, the developed coding system have perfectly identified each muzzle print of animal belonging to this category.

The sub-secondary classification has thus resulted in development of a compact and unique coding system. The final code developed through this system has no concordance with the codes of other animals and was unique of each animal. The data was subjected to statistical analysis using least square analysis of variance by General Linear Model Procedures (SAS, 1992). The results obtained are summarised as under:

> The muzzle characteristics, namely, beads at base (BB), beads at middle (BM), beads at upper (BU), beads in muzzle (BTO), ridges right side (RR), ridges left side (RL), ridges at base (RBT), ridge middle (RM), ridge grand total (RGT), pattern ridge right (PRR), pattern ridge left (PRL) and total pattern ridge (PRTO) were significantly ($P<0.05$) different between zebus, taurus and their crosses. The muzzle characteristics of zebu and crossbred indicated a very little difference among them. However, beads at middle sector (BM), ridge at middle sector (RM) were significantly ($P<0.05$) different between zebu and crossbreds. The muzzle characteristics of crossbreds were much closer to the zebus. Most of the muzzle characteristics, namely, beads at base (BB), beads at middle (BM), beads at upper (BU), beads total (BTO), ridge right (RR), ridge left (RL), ridge base (RTB) and ridge middle (RM) were statistically different ($P<0.05$)

between zebu and taurus cattle. Though, the ridge grand total (RGT), pattern ridge right (PRR), pattern ridge left (PRL) and total pattern ridge (PRTO) between two genuses and crossbreds were statistically indifferent.

The major class of pattern ridge characteristics were statistically indifferent. The straight and undulated pattern ridges of zebu and crossbreds were significantly ($P<0.05$) different from taurus cattle. The long length pattern ridges were equally distributed in both the genuses and crossbreds, while the medium length pattern ridges were relatively higher ($P<0.05$) in crossbreds than the zebu and taurus cattle. The two *genuses and their crossbreds differ significantly ($P<0.05$) for small* length pattern ridges.

The differences in muzzle characteristics, namely, beads at base sector (BB) and beads at middle sector (BM) among Tharparkar, Sahiwal and Karan Swiss were non-significant, whereas, Karan Fries was significantly ($P<0.05$) different from Tharparkar, Sahiwal, Karan Swiss, Red & White and Black & White breeds for these characteristics. In general, it was observed that breeds Red & White and Black & White contained less number of beads in the base and middle sectors. Therefore, they differed significantly ($P<0.05$) from Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds. No differences were observed between Red & White and Black & White breeds with respect to their muzzle characteristics. The beads of upper sector of Tharparkar, Sahiwal and Karan Fries indicated concordance among these three breeds. Similarly, the beads of the upper sector of Karan Swiss were similar to Sahiwal but were significantly ($P<0.05$) different from Tharparkar, Karan Fries, Red & White and Black & White breeds. Although no significant difference was observed between Red & White and Black & White breeds but they were significantly ($P<0.05$) different from Tharparkar, Sahiwal, Karan Swiss and Karan Fries breeds. Overall, it was observed that Red & White and Black & White breeds contained less number of beads in the upper sector than the other breeds. The right and left pattern ridges of Black & White breed were similar to Red & White, Karan Fries and Sahiwal breeds, but differed significantly from Tharparkar and Karan Swiss breeds. Similarities in total number of ridges at base sector (RTB) were observed between Black & White, Red & White, Karan Fries and Tharparkar breeds. The ridge at base sector of Black & White cattle differed significantly from Sahiwal and Karan Swiss breeds. Red & White and Black & White cattle breeds contained more number of ridges in the middle sector which differed significantly ($P<0.05$) from all other breeds. In general, it was observed that the breeds Red & White and Black & White contained more ridges in right and left halves, base and middle sectors than the other breeds. The number of right (PRR) and left (PRL) pattern ridges were non-significantly different among all breeds. On the contrary, the number of total pattern ridges (PRTO) between Karan Fries and Black & White breeds differed significantly ($P < 0.05$).

The pattern ridge characteristics, namely, curved, tented and bifurcated did not suggest significant breed differences, whereas, the straight pattern ridge of Black & White breed differed significantly ($P<0.05$) from Tharparkar, Karan Swiss and Karan Fries breeds. They were similar in Black & White, Red & White and Sahiwal breeds. Number of undulated pattern ridges in Sahiwal, Karan Swiss and Karan Fries breeds was very less but they were higher in Red & White and Black & White breeds. The long length pattern ridges were almost equally distributed in all breeds. Whereas, medium and small pattern ridges were statistically different (P < 0.05) among breeds. The medium pattern ridges differed significantly (P<0.05) between Karan Fries and Black & White breeds. The small pattern ridges of Tharparkar were similar to Sahiwal breed but differed significantly (P < 0.05) from Karan Swiss, Karan Fries, Red & White and Black & White breeds. The number of cylindrical shaped pattern ridges was higher than the club shaped pattern ridges. However, they were differing significantly (P < 0.05) between breeds. The club shaped pattern ridges of Tharparkar which is closer to Sahiwal by virtue their common species, were significantly (P<0.05) different from Karan Swiss, Karan Fries, Red & White and Black & White breeds. The cylindrical shaped pattern ridges were less in Sahiwal and were in concordance with Tharparkar, Red & White and Black & White breeds, but were significantly (P<0.05) different from Karan Swiss and Karan Fries breeds. The complete and fragmented pattern ridges did not indicate any difference among breeds. The complete intercepted pattern ridges, which were higher than the other types, were significantly different between Karan Fries and Black & White breeds. The fragmented intercepted pattern ridges were very less in Karan Fries and Black & White breeds, and differed significantly (P < 0.05) from Tharparkar and Sahiwal breeds.

The muzzle characteristics chiefly, beads at middle sector (BM), ridge right (RR), ridge left (RL), pattern ridge right (PRR), pattern ridge left (PRL) and total pattern ridge (PRTO) were significantly (P<0.05) different between grooved and non-grooved categories. The undulated pattern ridges, long and medium length of pattern ridges, cylindrical shaped and complete intercepted type pattern ridges were significantly different ($P < 0.05$) between grooved and non-grooved categories.

Sahiwal and Tharparkar animals falling in grooved and non-grooved categories did not differ significantly for all the muzzle characteristics. In Tharparkar, the right (RR) and left (RL) ridges as well as right (PRR) and left (PRL) pattern ridges indicated significant ($P < 0.05$) difference between two categories. This difference was due to complete absence of those patterns which were formed by the right and left arrangement of pattern ridges. The right and left ridges as well as pattern ridges were significantly different between grooved and non-grooved categories of Karan Swiss breed. The beads at the middle sector (BM), ridge right (RR) and ridge left (RL), ridges at middle sector (RM), pattern ridge right (PRR) and total pattern ridges (PRTO) of muzzle characteristics of Karan Fries breed were significantly ($P < 0.05$) different between grooved and non-grooved categories. In case of Red & White breed, the muzzle characteristics, namely, ridge left (RL), pattern ridge right (PRR), pattern ridge left (PRL) and total pattern ridges (PRTO) were significantly ($P < 0.05$) different between grooved and non-grooved categories of Black & White breed.

The differences in pattern ridge characteristics were insignificant between grooved and non-grooved categories of Tharparkar and Sahiwal breeds. The cylindrical shaped pattern ridges were the only characteristics which differed significantly between grooved and non-grooved categories within Karan Swiss breed. While straight, curved, medium length, cylindrical shaped and complete intercepted pattern ridgess of Karan Fries breed were significantly ($P < 0.05$) different between grooved and non-grooved categories. In case of Red

& White breed, the undulated, long length and cylindrical shaped pattern ridges were significantly ($P < 0.05$) different between two categories. On the contrary, the differences in pattern ridge characteristics of Black & White breed were non-significant respective of grooved and non-grooved categories.

The various muzzle and pattern ridge characteristics which are specific to a particular genus, breed or class of animal can be utilised for their characterisation based on these categories.

The correlation coefficients among beads of all sectors were low to moderate. The beads of all the sectors were positively and highly significantly associated with beads of the muzzle. The correlation coefficients among the ridges and pattern ridges were moderate to high. Whereas, the ridges and pattern ridges of all sectors were negatively correlated with beads at base (BB) and middle (BM) sectors as well as muzzle as a whole (BTO). The coefficients of correlation of ridges and pattern ridges with beads of upper sector (BTO) were extremely low and non-significant in majority of the cases. This indicated the absence of ridges and pattern ridges in the upper sector. The correlation coefficients among pattern ridge characteristics (major class) were non-significant which indicated independent distribution of the pattern ridge characteristics. The beads of all sectors as well as muzzle (BTO) were negatively associated with 305 days first lactation milk yield. While the ridges and pattern ridges except pattern ridge right (PRR) and total pattern ridge (PRTO) were positively associated, the correlation coefficients for all the muzzle characteristics were very low. The relationships between pattern ridge characteristics and 305 days first lactation milk yield were almost non-significant except in case of straight and undulated pattern ridges. The straight and undulated pattern ridges were negatively and positively correlated in that order and correlation coefficients in both cases were very low. The low correlation of all the muzzle and pattern ridge characteristics with first lactation milk yield suggested that there appear to be no genetic association between these characteristics and those responsible for milk production and these traits simply determine the phenotype of the respective animals.

The correlation coefficients between residuals of first lactation milk yield and all muzzle characteristics were non-significant except beads at middle sector (BM). However, it was observed that the beads of all the sectors as well as muzzle were negatively associated and ridges and pattern ridges were positively associated with first lactation milk yield. The degrees of association of residuals of first lactation yield (305 days) with all the pattern ridge characteristics were non-significant.

The muzzle characteristics chiefly, beads at middle (BM) and upper (BU) sectors as well as beads of the muzzle as a whole (BTO) were significantly ($P < 0.05$) and positively associated with age at first calving but the correlation coefficients for these muzzle characteristics were very low. The ridges at base (RTB) and middle (RM) as well as total ridges in muzzle (RGT) were significantly and negatively associated with age at first calving. However, the correlation coefficients for these muzzle characteristics were very small. The correlation coefficients for the other muzzle characteristics were non-significant.

Only straight, small length, club shaped and fragmented intercepted type pattern ridges were significantly ($P < 0.05$) and positively associated with age at first calving, though, the correlation coefficients were very small.

The degrees of association between all the muzzle characteristics and age at first service were non-significant. Moreover, the correlation coefficients between pattern ridge characteristics and age at first service were also non-significant. Only small and fragmented intercepted type of pattern ridge, in this particular case were significantly ($P < 0.05$) associated with age at first service but the correlation coefficients were very small.

In general, the association between age at first calving and muzzle and pattern ridge characteristics as well as age at first service and muzzle and pattern ridge characteristics in most of the cases were non-significant. However, some of the muzzle and pattern ridge characteristics were significant ($P < 0.05$) and positively associated with age at first calving and age at first service but their correlation coefficients were very small to draw worthy conclusions. Similar trend was also observed in case of association between 305 days first lactation yield and muzzle and pattern ridge characteristics.

The correlation among muzzle and pattern ridge characteristics point towards general dependencies among them. The canonical correlation between 305 days first lactation yield and muzzle as well as pattern ridge characteristics were attempted. The correlation coefficients obtained from canonical correlation analysis were non-significant for both muzzle as well as pattern ridge characteristics. These findings, therefore, only indicate the phenotypic nature of the muzzle and pattern ridge characteristics and their possible application in characterisation of the breeds.

The association between the ridge and pattern ridges of rigt and left halves were less than unity. Further, the associations between beads of the upper and base sector were very low thereby indicating asymmetry of the muzzle.

A general trend towards reduction in the number of beads in the specified area of 1.5 cm^2 were observed as age advanced. The animals aged from 0 to 144 months were classified into 12 different age groups. The correlation coefficient between age and number of beads in specified area was -0.6. A significant reduction in number of beads was observed till 18 to 24 months age. After this age, the reduction in number of beads was negligible and non-significant. Therefore, the muzzle print taken before the recommended age may give contradictory picture on the muzzle as well as beads during growth period will develop in size thereby containing different number of beads per unit area at different age groups which will to a large extent stabilize by the recommended age.

The identified muzzle and pattern ridge characteristics were subjected to discriminant analysis in order to classify/diagnose the genuses and their crossbreds as well as breeds, separately. The classification criterion was based on Mahalanobis distance (generalized squared distance). Based on this criterion, 78.6 percent animals were exactly classified as zebus. Whereas, 76.3 and 84.1 percent animals were exactly classified as crossbreds and taurus cattle. The misclassification of zebu into crossbred and crossbred into zebu indicate little association among them. Similarly, the muzzle and pattern ridge characteristics were further analysed to classify the breeds. Based on the classification criterion 68.4, 70.8, 50.0, 58.5, 57.8 and 60.5 percent animals were classified exactly as Tharparkar, Sahiwal, Karan Swiss, Karan Fries, Red & White and Black & White breeds, respectively. Comparatively high and low percentage of misclassification was also observed in all the breeds. The high percentage of misclassification was observed in Karan Swiss, Karan Fries, Red & White and Black & White breeds. In Karan Swiss and Karan Fries breeds, the high percentage of misclassification is related to genetic make up of these breeds. Whereas, the misclassification of Red & White and Black & White breeds and vice-versa is also related with genetic structure of these breeds. The another reason for the breeds exhibiting different degrees of misclassification can be attributed to common ancestry of the breeds.

To conclude, the muzzle and pattern ridge characteristics may prove very important in identifying the animals uniquely. The coding system developed in the present investigation may have an important application in those areas, where chances of forgery, mischief and false identification of animals are very common. The muzzle and pattern ridge characteristics indicate possibility of breed characterisation. In order to achieve very high percentage of classification rate, a further investigation in this direction is required, where the muzzle and pattern ridge characteristics may be combined with those most important morphological or anatomical traits of body confirmation of animals which are considered for breed characterisation. The correlation between characteristics indicated general distribution of various characteristics on the muzzle. The association of muzzle and pattern ridge characteristics with milk yield and associated productive and reproductive parameters indicate an absence of any significant relationship between these traits, thus indicating that muzzle characteristics are only phenotypic in origin with little genetic association with economic traits. Their importance in animal identification and breec characterisation, however, may be of immense value and may act as a fillip to plug the gap of information in this direction.

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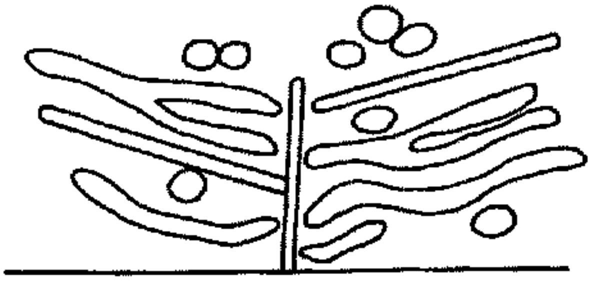
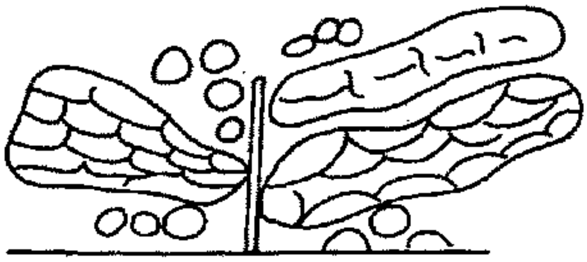
APPENDIX

A. Grooved category

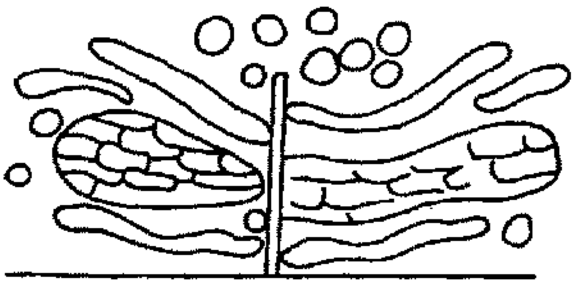
1. Alternate simple ridge arrangement



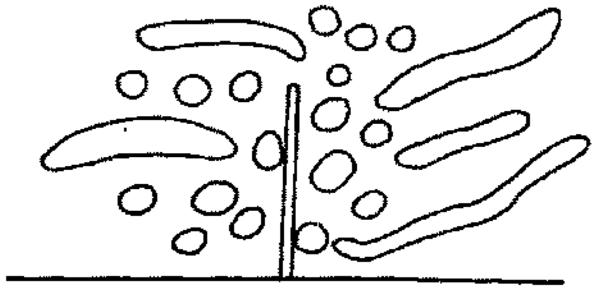
2. Alternate compound ridge arrangement



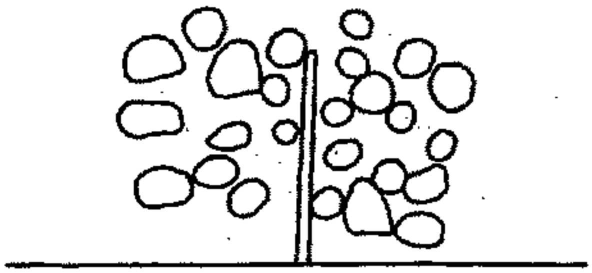
3. Pattern with simple and compound ridge arrangement



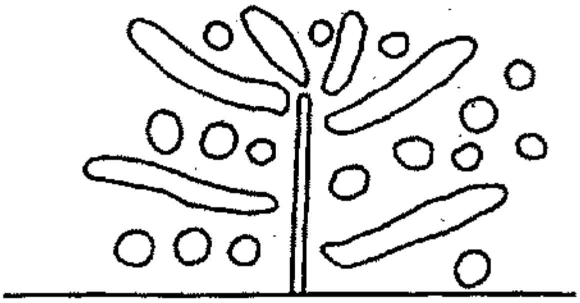
4. Ridge distributed without pattern



5. Only beads are available without pattern



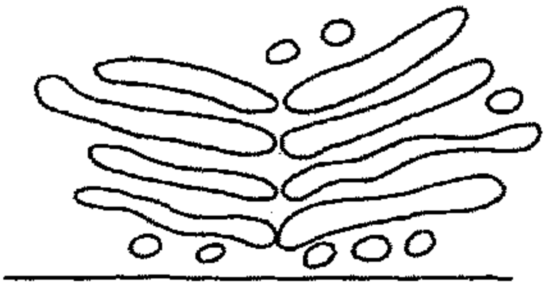
6. Ridge arrangement from the top of the central valley



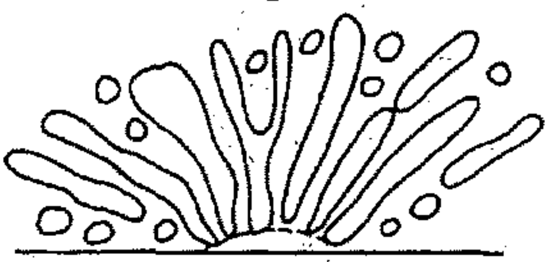
B. Non grooved category

A. Branched type

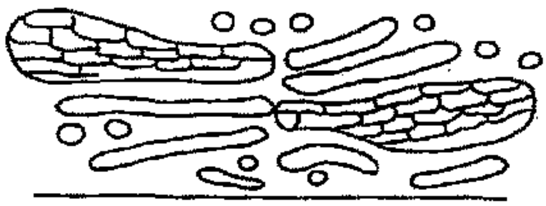
1. Alternate simple ridge arrangement



2. Simple ridge origin from same point

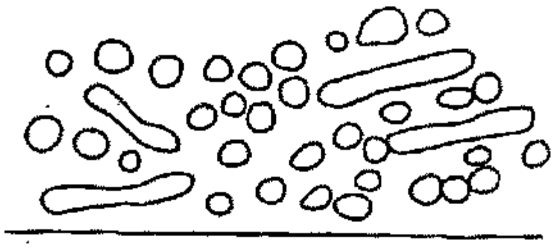


3. Pattern with simple and compound ridge arrangement

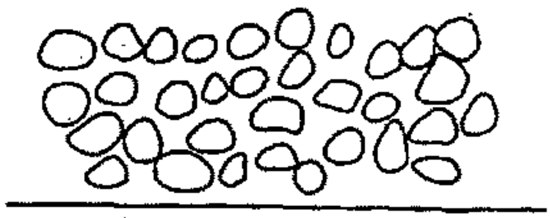


B. Unbranched Type

1. Ridge available without pattern

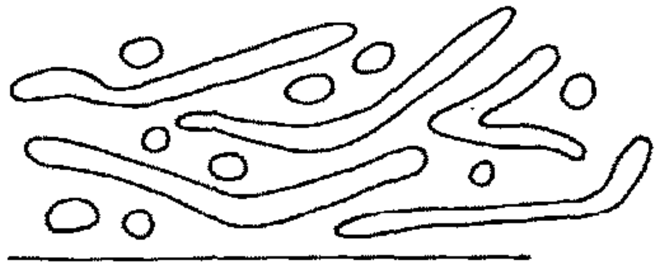


2. Only beads are available

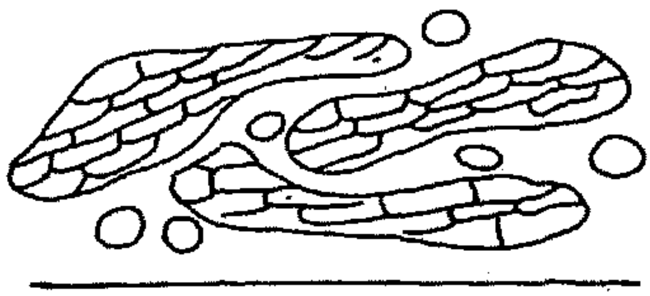


C. Special type

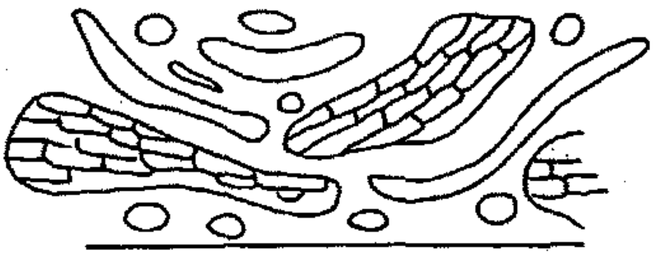
1. Containing simple ridge



2. Containing compound ridge



3. Containing mixture of simple and compound ridge



Diagrammatic Representation of Various Patterns of Grooved, Non-grooved and Special Categories.