BLOOD POTASSIUM TYPES IN SHEEP IN RELATION TO ANIMAL PRODUCTION IN ARID ENVIRONMENT

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On the basis of concentration of potassium in the blood, sheep can be classified into high (HK) and low (LK) potassium types, there being no intermediate between the two. There are about 80 per cent HK sheep in the desert area.
The genetic studies on these blood types indicate that they are controlled by a single Mendelian gene, HK being recessive. The differences between breeds within potassium types (LK and HK) are significant for potassium concentration. There are, however, no differences between breeds for the percentage of HK and the estimated frequency of high potassium gene. It appears that the differences for potassium concentration are of genetic origin and perhaps minor genes may be operating in addition to major genes which places the animal high or low. The frequency of HK gene in Chokla breed does not change with change in age from 2½ months to 6½ years. Natural selection against any one of these types is apparently not operating in this flock.
With regard to their thermal regulation and water metabolism, LK sheep react much like camel whereas HK are similar to cattle. On an average LK animals drink less water and during stress they allow the body temperature to rise at the expense of saving in body water. LK is, therefore, regarded as the desert type sheep. HK has also certain advantages over LK since this type is more resistant to infection and is in better condition of health. This may explain the high proportion of HK in the desert sheep population. An important feature of this investigation is that LK sheep have 25 per cent fewer medullated fibres. The association of medullation with potassium type is further borne out from the fact that in this region the proportion of LK is more in Chokla, a fine wool breed of sheep, than in Marwari, a carpet wool type sheep. The results have, therefore, practical utility for improving wool quality in sheep in the country where sheep are largely of hairy type.

INTRODUCTION

The conventional method for livestock improvement is to select animals on the basis of performance of the individual, its progeny or its ancestor. Many problems, such as collection of data over several years, complexity of statistical analysis, lack of reliance placed on the data collectors, etc., are encountered by the Geneticists conducting breeding experiments on conventional methods of selection. It is recognized that the difficulties met with in these conventional methods are there and, therefore, there is a need to find out a short-cut method which could save time and also increase accuracy in prediction of the performance of the individual.

In recent years several non-conventional methods for direct selection of individuals based on the presence or absence of certain biochemical constituents and/or their concentrations in animals have been widely used. It is supposed that there may be three kinds of genetic associations between blood characters and productivity: (1) by linkage, (2) through pleiotrophy and (3) from interaction between alleles at a locus or between loci. The first two cases would probably lead to straightforward additive superiority or inferiority of certain genotypes over others. The third situation would result in over-dominance so that animals heterozygous for the alleles in question would possess some kind of measurable superiority over homozygous animals.

Recently, we have taken up a project on the role of sodium and potassium in the blood of sheep with a view to select animals on the basis of concentration of these electrolytes for higher production. When we first started this project in 1964 there was sufficient evidence in the literature suggesting that, on the basis of concentration of potassium in the blood, sheep can be classified into high or low potassium types (Evans 1954). In the highlands of Great Britain, which have a relatively colder climate, there is a relatively larger number of HK type animals whereas in an arid country like Australia the number of low potassium animals is very high (Evans and Mounib 1957; Evans *et al.* 1958*a*, *b*). These ecological distributions formed the basis of our study on the relative merits of these two potassium types in relation to their adaptation to arid areas and their performance under these conditions. This study led us to determine the genetic basis of the potassium type and their physiological differences in various breeds of sheep in Rajasthan in relation to their level of production and adaptation to arid conditions.

Observations

A survey of six sheep breeds of Rajasthan, viz. Marwari, Malpura, Chokla, Magra, Sardarsamand and Pugal, has shown that on the basis of concentration of potassium in the blood the animals in each breed can be classified into two distinct groups—high (HK) and low (LK) potassium types (Table I).

Table I

Distribution of HK sheep in various breeds of Rajasthan

Breed	Number of sheep	% HK sheep
Chokla ..	259	57
Malpura ..	99	65
Magra ..	115	65
Marwari ..	113	72
Sardarsamand ..	12	66
Pugal ..	24	79

The distribution of potassium concentration for two breeds (Marwari and Chokla) for which the data are voluminous is shown in Fig. 1. It is apparent

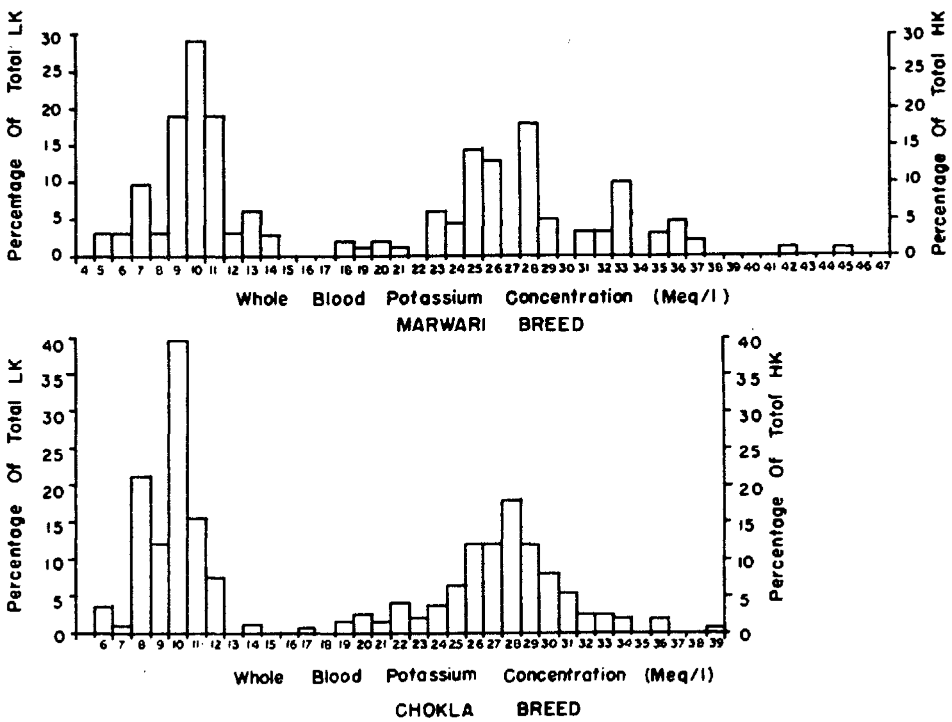

FIG. 1. Distribution of high (HK) and low (LK) potassium types.

from this figure that there is no intermediate type between high and low, although the tail ends of the two normal distributions tend to meet each other and the animals lying on the tail ends sometime pose a problem in deciding whether they may be classified as high or low. Such cases are, however, rare.

TABLE II

Cellular potassium types in the three flocks of Marwari sheep

Flock	Sex	LK alfa	HK beta	HK gamma	HK delta
Jodhpur	Male	9	1	12	nil
Pali	Male	8	nil	28	1
Mandore	Male	2	nil	15	1
	Female	9	2	35	nil
	Total	28	3	90	2

Results in Table II indicate that, when sheep are differentiated on the basis of concentration of potassium and sodium in the red blood cells, four groups emerge (Taneja and Ghosh 1965). These are called alpha, beta, gamma and delta. LK is termed as alpha and HK is subdivided into three groups—beta with equal concentration of sodium and potassium, gamma with less sodium and more of potassium as compared to that of beta and delta with nearly the same amount of sodium as beta but less of potassium when compared with beta. Therefore, the concentration of sodium plus potassium is similar in the cells of alpha, beta and delta but in gamma sheep it is much lower. The study of various breeds of sheep in Rajasthan has shown that these animals have a high proportion of alpha and they rarely appear to be beta. Delta is quite common in our stock although it is rare in British breeds.

The proportion of HK type varies from 57 to 79 per cent in different breeds (Table I). In Rajasthan, the HK type predominates over LK and this led us to postulate that, if the ecological distribution of potassium types on a global basis as reported in the literature (Evans and Mounib 1957; Evans *et al.* 1958*a*, *b*; Evans 1961) is accepted, the only possible likelihood of the high proportion of HK type in Rajasthan desert could be due to migration in the past of sheep flocks from the colder desert areas of Afghanistan to this region (Taneja and Ghosh 1965). Another possible explanation for the high proportion of HK type in our desert could be that, under these conditions, HK has certain advantages which outweighed those of LK. This suggested to us to study the relative differences between these two types in their adaptation to desert conditions.

How these two potassium types are adapted to meet the stress of various kinds prevalent in the region is one of the basic questions. The answer to this we thought should explain the differences in these two types for adaptation to desertic conditions. One of the stresses prevalent in this region is that produced by scarcity of water. Therefore, we first measured the normal water intake in these two types. We found that on equal body weight basis the LK type sheep drank a relatively lesser quantity of water (Taneja 1967). On a larger sample, when potassium types were adjusted for variations in body weight, the differences between types for water intake were, however, not statistically significant, but the interaction between season and type was significant. The differences in water intake by the two types of animals, therefore, varied from season to season. Detailed studies on water balance in sheep have shown that there are no significant differences between the two potassium types in their water intake. The differences in water loss through faeces, urine and evaporation from skin and respiratory tract were also not significant. An examination of the data in two of the experiments revealed that actually the differences between the two types for water intake were largely in mode than in mean. That is, there were more animals in the LK than in the HK group which drank lesser quantities of water (*see* Fig. 2). These differences were reflected in the urine output, LK sheep urinated significantly lesser than HK. The urine differences were only significant for

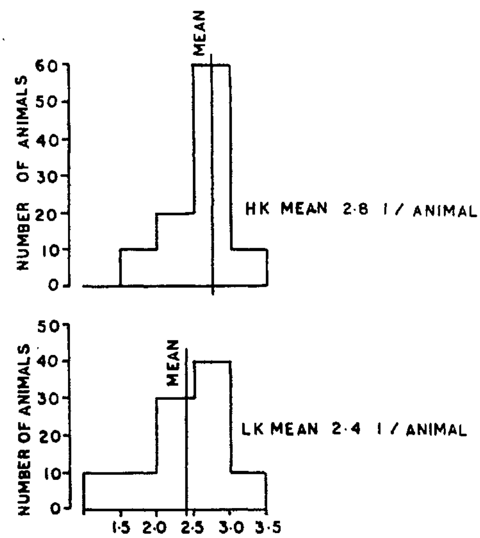

FIG. 2. Quantity of water (l) consumed/animal/day.

female and not for male. This is not clear. This indicated an evolutionary trend in the process of adaptation to water restriction. This led us to investigate whether there are any differences between these two types for tolerance to water restriction. It was observed that during water deprivation the differences in loss in body weight between high and low potassium types are practically nil. It is, therefore, apparent that high proportion of HK in Rajasthan desert cannot be attributed to water stress in this region.

Another kind of stress which is frequently experienced by sheep in the desert is that these animals are driven daily for several miles for grazing and watering. The effect of this stress on animals belonging to the two potassium types was, therefore, investigated by trotting these animals at various speeds. It was found that during exercise the rise in body temperature in the LK type was significantly higher than in the HK type (Table III). This rise in body temperature of LK animals was related to their ability to conserve body water as, after the exercise, these animals did not drink as much as the HK type animals. Physiologically, a rise in body temperature above normal limits is detrimental to an animal and while selecting animals preference is given to those in which the rise in body temperature during stress is less. Although regulation of body temperature is generally considered to have priority over water balance, yet it may be logical to conjecture that in chronically water-deficient areas the evolution of physiological adaptive mechanisms might have been directed primarily towards saving of body water. This would mean a necessary shift in the prerogatives for the stability of different physiological parameters. The thermo-regulatory behaviour of LK sheep, as discussed here, is probably a manifestation of such a generalized physiological principle aimed at fitting it properly into its desert niche (Taneja *et al.* 1966).

TABLE III

Results of analysis of variance of data on rise in body temperature in sheep during exercise

Source	Experiment No. 1			Experiment No. 2		
	d.f.	M.S.		d.f.	M.S.	
Between exercise group	1	15·070**		1	–	
Between LK and HK	1	1·500*		2	4·792**	
Between days (replicate)	2	0·540	2·60	2	0·376	0·19
Error	43	0·250		50	0·192	

** Significant at 5 per cent level of probability.
* Significant at 1 per cent level of probability.

Two more important factors which may possibly explain the high proportion of HK in the Rajasthan desert are: (1) HK animals are resistant to diseases and (2) they are in better health condition. The HK animals have a significantly higher density of white blood cells. It would seem logical to conclude that HK sheep have a relatively better built-in-disease resistance mechanism (Taneja *et al.* 1965). We are now working out the differential counts which will throw more light on the subject.

Another significant advantage of HK over LK animals is that the former remains in a sound condition of health. Our experiments have shown that, regardless of the fluctuations in the pastoral condition during the year, the concentration of haemoglobin and the density of red blood cells are higher in the HK animals than in the LK. This is shown in Table IV. A better health condition and resistance to diseases in HK animals should partly explain the high proportion of these animals in the Rajasthan desert.

Since our aim is to determine the physiological differences between animals of the two blood potassium types in relation to their adaptation, and wool and mutton production, the results achieved would naturally remain unused unless the genetic basis of these potassium types is investigated so that the knowledge gained on these types can be fully utilized by propagating the proper type and segregating and culling the undesirable one. We, therefore, investigated the genetic control of these two potassium types. Our

TABLE IV

Mean values along with standard errors for packed cell volume per cent (PCV), haemoglobin and red blood cell count in LK and HK of Marwari breed of sheep

Type	Packed cell volume per cent (PCV)	Haemoglobin (gm/100 ml blood)	R.B.C. (millions/cmm)
LK	29·73±0·29	9·11±0·26	10·62±0·20
HK	31·05±0·38	10·06±0·20	11·51±0·15

Differences between LK and HK are significant at 5 per cent level of probability.

results have shown that the blood potassium types are controlled by a single mendelian gene (Taneja and Abichandani 1966, 1967). Results in Table V indicate that all HK×HK matings resulted in HK progeny, whereas HK×LK

TABLE V

Potassium type of progeny from matings of ram and ewes of various phenotypes

Identi-fication number	Ram Potassium type	Ewes LK (9·27)		Ewes HK (25·20)	
		Progeny			
		LK	HK	LK	HK
G 75	HK (26·24)	2(9·60)	2(29·22)	–	11(29·65)
G423	HK (32·64)	1(9·60)	1(26·24)	–	10(30·78)
G475	HK (32·64)	2(9·20)	4(34·08)	–	3(30·29)
G988	LK (9·60)	2(10·21)	2(35·84)	3(30·62)	3(31·36)

Figures in parenthesis represent blood potassium concentration in mE_q/l.

and LK×LK resulted in both HK and LK types. This indicates that HK is inherited as a simple recessive character and LK animals may be either homozygous or heterozygous. Our findings, therefore, confirm the results of earlier workers (Evans and King 1955; Kidwell *et al.* 1959). Results presented in Table VI indicate that the differences between breeds within potassium type (LK and HK) were significant for potassium concentration. But there were no differences between breeds, the percentage of HK and for the estimated frequency of high potassium gene. It is possible that the differences between breeds for potassium concentration are of genetic origin and perhaps minor genes may be operating in addition to major genes which determine the

TABLE VI

Mean values for percentage medullation in L.K. and H.K. in Marwari breed

Position	September 1965		March 1966	
	LK	HK	LK	HK
Neck ..	54·2	63·2	65·4	74·6
Mid-side ..	66·4	80·0	85·6	87·8
Britch ..	69·2	87·2	75·8	91·0
Wither ..	53·6	63·2	62·2	64·6
Shoulder ..	66·8	84·0	73·0	87·4
Back ..	61·8	71·0	60·8	67·2

Data transformed into arcsin $\sqrt{\text{percentage}}$ showed statistically highly significant differences ($< 0{\cdot}01$) within types within region.

potassium type of an individual. Experiments are now in progress to determine the relative importance of genetic and environmental factors responsible for variations in potassium concentration within types. We have also made some observations on the frequency of HK gene at different ages in a flock of Chokla breed. The animals on which the gene frequency has been established varied in age from $6\frac{1}{2}$ years to $2\frac{1}{2}$ months. Results in Fig. 3 indicate that,

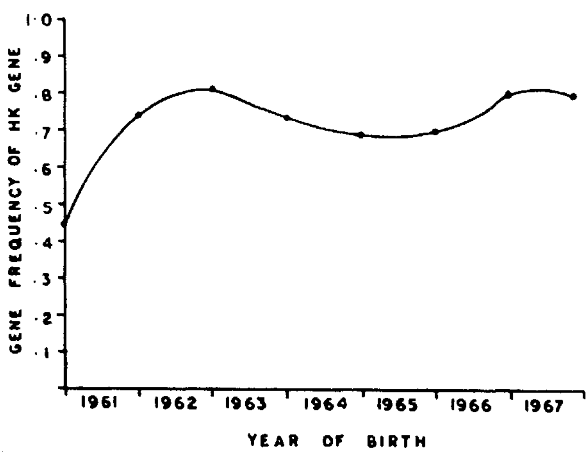

FIG. 3. Change in frequency of HK gene in relation to age of animal (year of birth) in Chokla flock.

except for those which were $6\frac{1}{2}$ years old, the frequency for HK gene did not change with change in age and the observed low frequency of this gene at $6\frac{1}{2}$

years of age may be due to sampling errors. It is, therefore, concluded that natural selection against these types is not operating in the flock under study.

Although our studies have given us adequate information with regard to possible reasons for the higher proportion of the HK animals in the Rajasthan desert, regarding the differences between the HK and LK types in adaptation to arid conditions and on their genetic background, the purpose of this study will not be fully served unless we find out the utility of the potassium type for improvement of wool and mutton production. In one of our experiments in which the potassium types were further subdivided, the beta and delta sub-types showed higher body and wool weight but the occurrence of these sub-types was rare (Taneja and Ghosh 1966).

We have recently collected data on body weight and fleece weight of sheep of several breeds and have determined their potassium types and the work which is in progress will elucidate whether potassium types have any association with the economic traits. However, results are now available from repeated experiments which clearly indicate that the low potassium type animals have, on an average, 16 per cent lesser medullated fibres than HK type animals. In the britch and shoulder regions of the body LK animals have 20 to 26 per cent less medullated fibres than HK (Table VI). Since our studies have also confirmed that LK are both heterozygous and homozygous whereas the HK animals are only homozygous recessive, the breeding of LK sheep and subsequent culling of HK segregating from LK×LK mating in each generation should result in raising flocks yielding true wool fibres. Survey of different breeds of Rajasthan has shown that the percentage of high potassium type (HK) is high (79 per cent) in coarse wool producing breeds (Pugal, Marwari, Malpura and Magra) and is low (59 per cent) in a fine wool producing breed (Chokla). The association of LK with fine wool is, therefore, very apparent. These results, therefore, may have immediate application for the rapid improvement of wool in most of the developing countries where sheep are largely of the hairy type.

Conclusions

The important points that emerge from our studies are: (1) HK is inherited as a simple recessive and LK may be either homozygous or heterozygous. There are significant differences between the breeds in respect of potassium levels in both LK and HK, (2) LK sheep are more suited to stressful condition of arid environment and have lesser medullated fibres and therefore have relatively finer wool, and (3) HK are more resistant to diseases and are in better health condition. It is tempting to believe that propagation of the LK type under optimum husbandry conditions may lead to a rational solution of the complex problem of wool production under arid conditions of Rajasthan.

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