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AD DESTINATUM PERSEQUOR

BREEDING TICK-REPELLENT CATTLE

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BY PROF JAN BONSMA

During the period Bonsma was a post-graduate student in Dr J L Lush's class at Iowa State University 1935-1936, he became aware of classic research on breeding disease-resistant plants and animals so that when he was put in charge of Mara and Messina research sta ons in 1937, he was cognizant of this work.

In a paper by Bonsma, Farming in South Africa, February 1944, Reprint 13, "Hereditary Heartwater-resistant Characters in Cattle", Bonsma reviewed some of the literature on this subject, because most cattle that died in the tropical and sub-tropical ranching areas in the Southern hemisphere died as a result of tick-borne diseases.

In 1944 Bonsma wrote as follows:

"The success achieved in the breeding of plants possessing a high degree of resistance to diseases is to be attributed to the application of methods based on the principles of genetics.

Farm animals fortunately also possess hereditary characters conferring on them a higher degree of resistance to certain diseases. Unfortunately, however, little has hitherto been done in the way of applying this knowledge experimentally in the control of diseases in animals. Considerable attention is, on the other hand, admittedly being given to the organisms causing diseases and to clinical measures for their control.

As a result of the success attained by the use of vaccines and the hypodermic needle, the possible control of certain diseases by hereditary selection is frequently lost sight of.

During the past few years the interest taken in the breeding of animals possessing a higher degree of resistance to certain diseases, has been stimulated as a result of the achievements of plantbreeders in the breeding of plants resistant to certain parasites and diseases.

Most breeders of animals are of the opinion that the process by which it will be possible to breed animals possessing a higher degree of resistance to certain diseases prevalent in certain areas, will be too slow and too expensive for general adoption.

The time factor and the costs involved in the application of breeding methods for the indirect control of certain diseases depend mainly on the effectiveness and ease with which the selection of the animals concerned can be carried out.

Genetics attempts to explain the differences and similarities of characters in related individuals. If any external characteristic of an animal, the inheritance of which is already known to some extent, is accompanied by resistance to any disease, the time and costs involved in the process of breeding such resistant animals can be considerably reduced. Not one of the infectious stock diseases is heritable as such, but the existence of hereditary factors controlling the physiological functions of the animal body and so affecting the animal's powers of resistance and susceptibility to such diseases is fully recognised.

The difference in natural resistance to parasites or diseases frequently found between individuals belonging to two different races or between various individuals belonging to the same race, can best be explained on the grounds of differences in the hereditary make-up of the individuals concerned.

The immunity of wild animals to certain diseases can be explained on the grounds of natural selection.

Several workers have in fact by selective breeding, with a view to greater immunity to certain diseases, succeeded in producing strains of fowls and mice possessing a high degree of resistance to these diseases.

Lambert's (1) work in connection with fowl typhoid illustrates in a striking manner how family lines possessing a very low susceptibility to the disease can be bred. After five generations he has succeeded in breeding fowls in which only 9,4 per cent. succumb when inoculated with the disease organisms, while amongst the original population the rate of mortality is approximately 85 per cent.

Similarly Hutt and Bruckner (²) succeeded after four generations in breeding strains of fowls possessing a much greater degree of resistance to malignant growths than fowls not selected for this purpose. During that period the rate of mortality due to malignant growths was reduced from 26 per cent. to 12 per cent.

Fowls belonging to the high resistance line which died as a result of malignant growths, succumbed at a higher average age than those belonging to the low resistance line. Natural infection was just as effective as artificial inoculation in distinguishing between high and low resistance groups.

By selective breeding Schott([3]) succeeded in reducing the rate of mortality among mice from rat typhoid in 6 years' time from 82 to 24 per cent.

As a result of research work with pigs, Cameron and others (4) were able to obtain results indicating that strains of pigs were developed possessing a considerable degree of resistance to contagious abortion caused by Brucella suis.

Lambert, Speelman and Osborn (5) some years ago indicated the existence of genetic differences in horses in regard to their susceptibility to a certain type of horsesickness (encephalomyelitis).

An example of racial differences in the resistance of man to malarial infection, which is transmitted by the mosquito, is found among Negroes and Europeans. It is practically impossible to infect certain Negro races with Plasmodium vivax and if they are infected the malaria attack is usually very mild, whereas Europeans are extremely susceptible to infection (6).

(The correctness of the above finding has, however, been challenged by several medical men in the Republic of South Africa, but their opinion is not necessarily in conflict with that of Cameron since the Negro tribes which are resistant to malaria, may have become so as a result of natural selection having taken place in severely infected malarial areas.)

Racial differences also exist between human beings in regard to their resistance to worm infestation (Helminthiases). Negroes in the United States of America apparently possess greater resistance to Hymenolepis nana than Europeans. The hookworm larva can penetrate the skin of whites much more easily than that of Negroes (7).

In the case of sheep it is known that Cheviot sheep are more resistant to wire worm (Haemonchus contortus) infestation than breeds of sheep originating from the lowlands (8).

In the case of cattle the opinion has been held since 1849 that Zebu cattle are immune to red water (Piroplasmosis). Isolated cases of the disease occur among Zebus, however. Yakimoff (9) points out that he could induce the disease in Zebus by injecting them with virulent blood or by allowing them to be bitten by infected ticks. He found, furthermore, that calves were more susceptible than adult animals.

TICK INFESTATION

Kelly (10) showed in the cross-breeding experiments carried out by him with Zebus and European breeds of cattle, that the former are infested to a lesser extent with ticks and possess a higher degree of immunity to tick-borne diseases.

In the same publication (10) we find the following quotation from Sir Arnold Theiler: "Hitherto I was under the impression that Indian cattle are immune to tick-borne diseases because they grew up in tick-infested areas. If this view is correct, the indigenous cattle of Tunisia should also be immune to those diseases, but this is not the case. Zebu cattle actually appear to possess heritable and not acquired characters which confer immunity to these diseases on them.

The tick-borne diseases of North Africa are caused by the following parasites: *Piroplasma bigemimum, Babesiella berbera, Theileria dispar, Theileria mutans* and *Anaplasma marginale*. The most remarkable fact is that Zebu cattle have proved to be protected against all of these parasites."

Zuravok (11) showed in experiments in which Zebus were crossed with Red German cattle, that the cross-bred animals possess greater resistance to redwater and gallsickness than the pure-bred German stock.

Curson (12) states in an article on Zulu cattle that these animals possess hereditary resistance to heartwater, redwater and gallsickness.

In 1936 the Animal Husbandry Section of the Division of Animal and Crop Production of the Department of Agriculture and Forestry began cattle breeding experiments at the Mara Experiment Station in an attempt to produce a new type of cattle which would offer a greater degree of resistance to tropical and sub-tropical conditions and which might also prove to be more resistant to tick-borne diseases.

The Mara Experiment Station is situated in the Zoutpansberg District, 900 metres (3000') above sea-level, longitude 29° 34'E and latitude 23° 09'S and thirty miles due west of Louis Trichardt. The vegetation is typically bushveld, with the result that the animals here are often attacked by heartwater (*Rickettsiosis*), redwater (*Piroplasmosis*) and gallsickness (*Anaplasmosis*). Experts were of the opinion that the rate of mortality among animals introduced into the area from elsewhere would be high.

In the breeding experiments being conducted at Mara, Afrikaner cows (*Bos indicus*) formed the foundation of the work, and as large numbers of cows were required, they had to be purchased in various parts of the country.

Many of the cows sent to the Experiment Station came from the Highveld areas where heartwater never occurs. Others again came from Lowveld areas where heartwater does occur. (Potgietersrust, the Lydenburg lowveld, Zoutpansberg District and Pienaars River in the Transvaal, and Adelaide in the Cape Province are considered to be heartwater areas, while Potchefstroom and Klerksdorp in the Transvaal, and Hoopstad and Theunissen in the Orange Free State are considered to be heartwater-free areas.)

Since the cattle sent to the Experiment Station included animals of the European breeds, a golden opportunity presented itself for carefully noting whether any real differences existed in the incidence of disease, and especially of heartwater, among the various groups of animals.

All animals which die on the Experiment Farm are thoroughly examined and the cause of death was determined as accurately as possible. Although not all of the post-mortem examinations were carried out by Government Veterinary Officers, they were called in for most of the doubtful cases to confirm the cause of death. It should be mentioned, however, that the officers at the Experiment Station were well acquainted with the symptoms and post-mortem lesions of tick-borne diseases. Where the cause of death was doubtful, particulars have not been included in the data collected in this connection.

The Afrikaner cows at the Experiment Station were divided into different groups, some of which were used for the breeding of pure-bred Afrikaner cattle, whilst others were put to bulls belonging to exotic beef breeds. The exotic beef-breed cows were put to similar bulls for the purpose of breeding pure exotic beef-breed cattle.*

There were, therefore, actually three classes of animals at the Experiment Station, viz. (a) Pure-bred Afrikaner cattle (*Bos indicus*), (b) cross-bred F_1 cattle, i.e., exotic beef-breed cattle x Afrikaner cattle (i.e., *Bos taurus* x *Bos indicus*), and (c) pure-bred exotic cattle (*Bos taurus*). All the above-mentioned cows could , however, also be sub-divided into two groups, viz., cows from heartwater areas and cows from heartwater-free areas.

Two theories were generally advanced to explain the increased resistance of young animals to diseases to which their dams have already become naturally immunized, viz. (i) that the animals acquired passive immunity from the naturally immune dams, and (ii) that hereditary differences exist.

(a) Some authorities are of the opinion that the progeny of immune dams acquire immunity to disease by reason of the inter-change of blood which occurs between the mother and the foetus and further through the colostrum which the young animal obtains from its mother.

* The exotic beef-breed cattle used for this purpose were: Sussex, Aberdeen Angus, Hereford, Shorthorn and Red Polls.

Ehrlich (13) showed as long ago as 1892 that young mice acquire passive immunity to poisonous proteins mainly through the colostrum of their mothers, but partly also through the interchange of blood which occurs between mother and unborn young (foetus).

Similar observations were made in 1907 by Hohlfeld (14) in respect of dogs, goats and young guinea-pigs.

Famulener (15) repeated Ehrlich's experiments and showed among other things that the colostrum of sheep is twice or three times as rich in anti-bodies as their blood serum.

Little and Orcutt (16) found that colostrum of cows provides the agglutinin of *Brucellus abortus* contained in calf's blood.

Smith and Little (17) also showed that colostrum prevents the kidneys, spleen, liver and small intestines from being attacked by *Bacillus coli*.

The above-mentioned research workers have, therefore, shown the importance of the role played by colostrum in the effective protection of young animals against specific organisms.

It is clear from the foregoing that increased immunity to heartwater in calves of naturally immune dams might possibly be attributed to the acquisition of passive immunity through the blood or the colostrum.

(b) Certain animals within a species or even within a breed possess certain hereditary characters which are closely related to or even responsible for a higher resistance to disease.

IMMUNITY TO HEARTWATER

If the hereditary differences in resistance to heartwater are attributable to certain breed differences in respect of such characters as type of hair, skin thickness, looseness of skin, etc., then comparisons in regard to the transmission of passive immunity between animals of the same breeds from heartwater-free areas only need to be ascertained.

Sufficient classes of animals were maintained at the Mara Experiment Station to test out the two theories named in regard to the increased resistance in the progeny of animals which proved resistant to heartwater.

If the first theory (a) be correct, namely, that the progeny of cows which have acquired natural immunity, possess a higher resistance to heartwater by reason of the fact that they have inherited passive immunity from their dams through the placenta or through the colostrum a difference would exist in the percentage of deaths among the calves of cows from heartwater and from heartwater-free areas. The following table (No. 1) reflects the differences in the percentage of deaths among calves of the various classes of cattle:-

Table I Mortality among Calves due to Heartwater

† Class of Cows (dams)	Number of Calves born	Number of Calves Died	Percentage of Calves Died
			Per Cent.
From heartwater-free areas	389*	30*	7,7
From heartwater areas	224	23	10,3
Born at Mara Experiment Station.	115	7	6,1
Totals	728	60	8,33

† Includes all breeds of cows and calves, viz., Afrikaners, cross-bred and exotic beef breeds).

The above differences in the mortality figures are not significant. (For N = 2/P lies between 0,5 and 0,3 which is not significant).

(*70 of the cows calved within two months after their arrival at Mara. Four of the seventy calves died of heartwater, i.e., nearly 6 per cent).

The above table, therefore, reveals that the theory in regard to the acquisition of passive immunity through, for example, the colostrum of naturally immune dams, will not play an important rôle in rendering calves less susceptible to heartwater.

In a representative group of animals, i.e., one consisting of a sufficient number of specimens of the various breeds involved in the investigations, a large variety of characters such as, e.g., colour, type of coat, skin thickness, looseness and structure of the skin, is found.

Some of these characters may justify the sub-division of such a group of animals into two classes, viz., those which are resistant to a certain disease (heartwater in this case) and those which succumb to it.

Where the survivors are used for breeding purposes, their progeny should possess proportionately more characters conferring resistance against the disease concerned, than the original group.

If animals of the latter generation are exposed to the disease concerned (heartwater), there would be a larger proportion of survivors than was the case in the previous generation.

By continuing to breed from survivors, natural selection for characters conferring resistance to the disease takes place, and by repeating this process through several generations, the rate of mortality would gradually decrease. Each succeeding generation would possess a larger proportion of hereditary factors which increase their resistance above that of their ancestors.

If the above suppositions are correct, one would expect that Afrikaner and other indigenous cattle by natural selection have inherited a higher degree of resistance to the diseases indigenous to this country and not in the British Isles.

Since heartwater, redwater and gallsickness, are diseases which occur in several of the Lowveld areas of Africa the study of the disease should throw an interesting light on the problem of the inheritance of characters producing resistance. Heartwater is responsible for a higher percentage of deaths among cattle than the other two diseases, and, consequently, the deaths due to this disease among the various classes of animals can be calculated on a percentage basis.

Table II A Mortality among Cattle at Mara due to Heartwater
Cattle from Heartwater-free Areas

Breed of Cattle	Number	Number of Deaths	Number of Survivors	Percentage Deaths
* Afrikaner	206	32*	174	15,5
† Exotic breeds	34	14†	20	41,2
Totals	240	46	194	-

* Twenty-nine of the 32 cattle which died succumbed within the first two years, i.e. 13,6 per cent. died within two years.

† All 14 died within two years.
(These differences are statistically highly significant, $P < ,01$).

Table II B Mortality among Cattle at Mara due to Heartwater
Cattle from Heartwater Areas

Breed of Cattle	Number Purchased	Number of Deaths	Number of Survivors	Percentage Deaths
Afrikaners	207	0	207	0
*Exotic breeds	19	6	13	31,3
†Exotic breeds	49	0	49	0

*Cattle from farms where dipping is carried out very regularly.
†From farms where dipping is not carried out regularly.
(The differences in the mortality between * and †, Table II B, are highly significant $P < ,01$).

From Table II A it is clear that Afrikaner cattle are far more resistant to heartwater than exotic breeds of cattle, which have not been specially selected as low tick-carriers.

Cattle from heartwater areas where dipping was not carried out very regularly, showed such high natural resistance to the disease that among 256 head of exotic and indigenous cattle not a single death due to heartwater occurred over a period of several years.

In the case of a number of exotic cattle breeds obtained from farms where dipping was carried out regularly, 31,3 per cent. died from heartwater.

Cattle obtained from farms where dipping is carried out with great regularity, probably do not possess any natural resistance or immunity to heartwater. The impression of immunity is created by the fact that the animals were never exposed to real infection. As soon as such apparently heartwater-immune animals are exposed to a sporadic infestation of infected heartwater ticks, a large number of them succumb to the disease. Compulsory dipping would protect such apparently immune cattle.

Before an animal can acquire any measure of immunity to certain diseases, it should first be exposed to natural infection, i.e., the host animal be exposed to infestation by a comparatively large number of heartwater ticks in order to ensure with a certain measure of certainty that there will be some infected ticks among them.

If there are breeds or types of animals within breeds which are definitely tick-repellent as a result of hereditary characters such as thickness or structure of skin, glossiness and shortness of coat, such breeds and types of animals convey the impression of natural immunity to heartwater. The "apparent" immunity may be due merely to the fact that such animals possibly carry far fewer ticks than animals of other breeds or other types (smooth coat, thick and loose skin as against long coat and thin skin) within the same breed.

Since Afrikaner cattle in particular differ very greatly from the exotic beef breeds in regard to skin thickness, skin structure and coat, it would be interesting to determine how the mortality among calves, which are F1 crosses between the two breeds, compares with that of calves belonging to the two pure-bred parental breeds.

Table III. Mortality due to Heartwater among Cattle born at Mara Experiment Station, up to the age of 2½ years

A. HEIFERS.

Breed of Cattle	Number Born	Number Dead	Number of Survivals	Percentage Deaths
Afrikaners	124	5	119	4,0
3/4 Afrikaner, plus 1/4 exotic ..	48	2	46	4,2
½ Afrikaner, plus ½ exotic	206	17	189	8,3
Pure exotic	17	8	9	47,1
Totals	395	32	363	8,1

(The differences in mortality between the pure-bred Afrikaners and Afrikaner crosses are not significant. The difference between the exotic breeds and the Afrikaners and Afrikaner crosses is highly significant P < ,01).

B. BULLS.

Breed of Cattle	Number Born	Number Died	Number of Survivals	Percentage Deaths
Afrikaners	122	8	114	6,6
3/4 Afrikaner and 1/4 exotic	38	4	34	10,5
½ Afrikaner and ½ exotic	191	21	170	11
Pure exotic	11	9	2	81,8
Totals	362	42	320	11,6

(The differences in mortality in Table IIIB are of the same order as in the case of Table IIIA. The differences between Afrikaners and Afrikaner crosses are not significant; between Afrikaners and Afrikaner crosses and exotic beef breeds the differences are highly significant P < ,01).

Table III C Totals of each breed, i.e., all the Bulls and Heifers taken together

Breed of Cattle	Number Born	Number Died	Number of Survivals	Per Cent. Deaths	Average Age of Calves which Died
Afrikaners	246	13	233	5,3	11 months
3/4 Afrikaner and 1/4 exotic	86	6	80	7,0	8 months
½ Afrikaner and ½ exotic ...	397	38	359	10,2	6 months
Exotic	28	17	11	60,7	5 months
Totals	757	74	683	9,8	-

(The differences in mortality between Afrikaners and Afrikaner crosses in comparison with the exotic breeds are highly significant $P < ,01$).

The fact that Afrikaner calves succumb to heartwater at a higher average age, is, in itself, striking evidence that animals belonging to this breed possess a character which is apparently responsible for a higher degree of resistance to the disease than animals belonging to the other breeds.

All the calves of the various breeds were exposed to the same tick-infestation.

The reason why more bull calves than heifers died of heartwater, must probably be ascribed to the fact that after the calves are weaned at the age of eight months, the bull calves are transferred to an isolation camp where they are not dipped until such time as they are sold at the age of 2 to 2½ years, and are, consequently exposed to a greater degree of infestation. The bulls are protected, however, by hand-dressing them as soon as the tick-infestation becomes too severe.

There is no doubt that the bulls acquire a high degree of immunity (apart from hereditary immunity) as a result of the exposure to tick-infestation. More than 150 bulls have been sold to farmers in heartwater areas, and although regular enquiries are made regarding the mortality of the bulls as a result of heartwater, not a single death from this disease has hitherto been reported."

During 1939 it was decided to do determinations of the incidence of ticks on the different types and breeds of cattle maintained at Mara research station, because ticks play such an important role in transmitting the three most important tick-borne diseases in South Africa, namely Heartwater (*Rickettsiosis*) Redwater (*Piroplasmosis*) and Gallsickness (*Anaplasmosis*) to cattle.

During 1939 and 1940 the incidence of tick-infestation on the various breeds and types of cattle was fairly accurately estimated by carefully inspecting every animal on the weighbridge and also when the cattle are brought in to dip. All the cattle at Mara were weighed once a month and were dipped once a week when the incidence of ticks was high and once a month when the incidence was low.

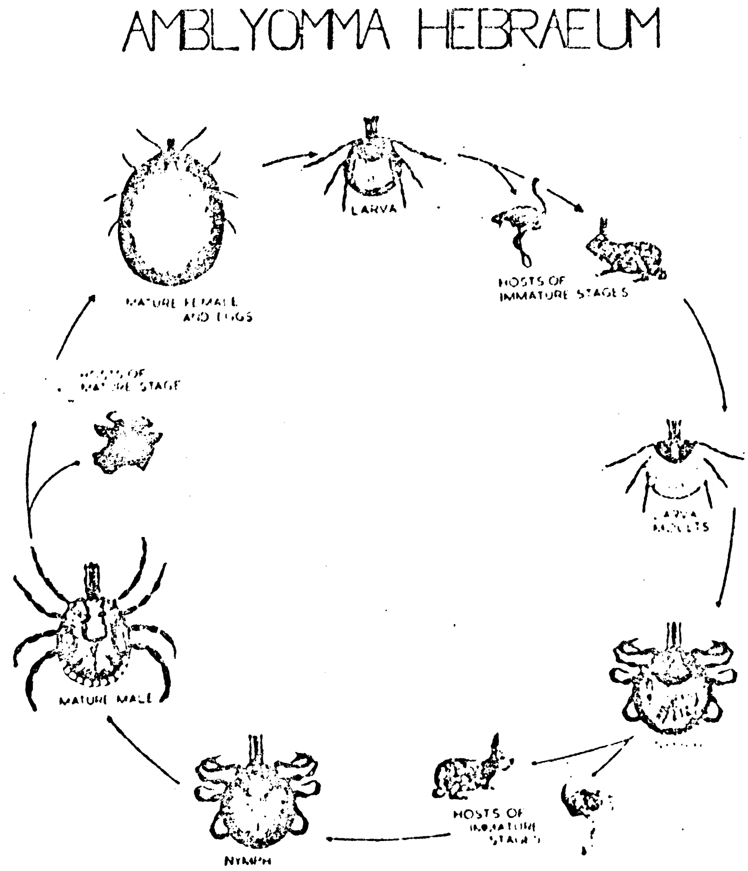
As a result of these preliminary observations it became very obvious that some cattle are far more susceptible to tick infestation than others.

It was therefore decided to do tick counts on cattle of different breeds and types within breeds.

The tick counting experiments were started in October 1941, these counts were made on twelve Afrikaner (*Bos indicus*) and twelve Aberdeen Angus, Hereford, Shorthorn and Sussex . (*Bos taurus*) cattle.

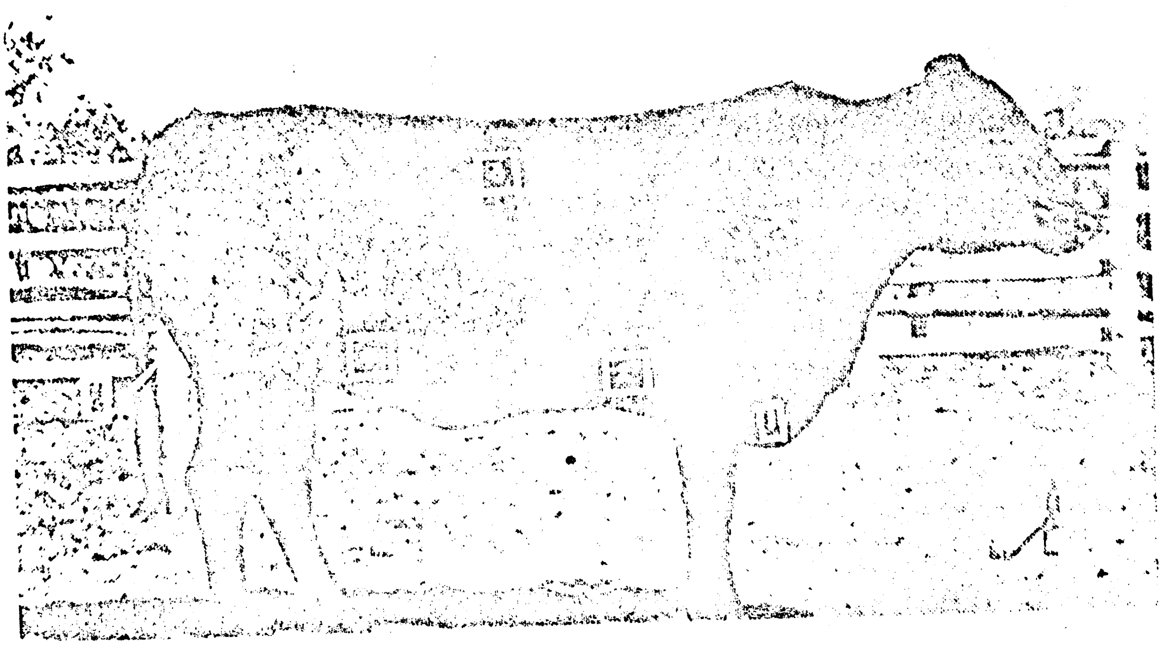
Before the author could proceed with the tick counts on individual cows he had to acquaint himself with the different species of ticks, their sex and of the different stages of development. He also had to be well versed in which ticks were one-host ticks and which were three-host ticks. Once the technique of classification was fairly accurately mastered, it became possible to count ticks and classify them accordingly to male and female and species.

Figure I



On each of the twenty-four animals, eight hundred square centimetre areas were marked off with a ten by ten centimetre wire frame which was put in a thick lime solution. Two areas were marked off on the escutcheon areas and the ticks under the tail were also counted.

Figure II



The reason why ticks were counted on both sides was that open cows, bulls and steers give an eighty percent preference to lying on the right side, while heavily pregnant cows give an approximately seventy percent preference to lying on the left side.

The author was of the opinion that there was a higher incidence of ticks on the side which cattle lie.

All the cattle were run in the same paddock, were dipped once a month and put through the plunge dip immediately after the tick counts were made. All the demarcated areas were erased after the animal had gone through the dip.

All the ticks that were visible through a loupe (medical magnifying lens) were removed, each area's ticks were placed in separate bottles with a preservative in it. The dip through which the cattle were put was a fourteen day arsenicum dip testing 0,16 percent As_2O_3.

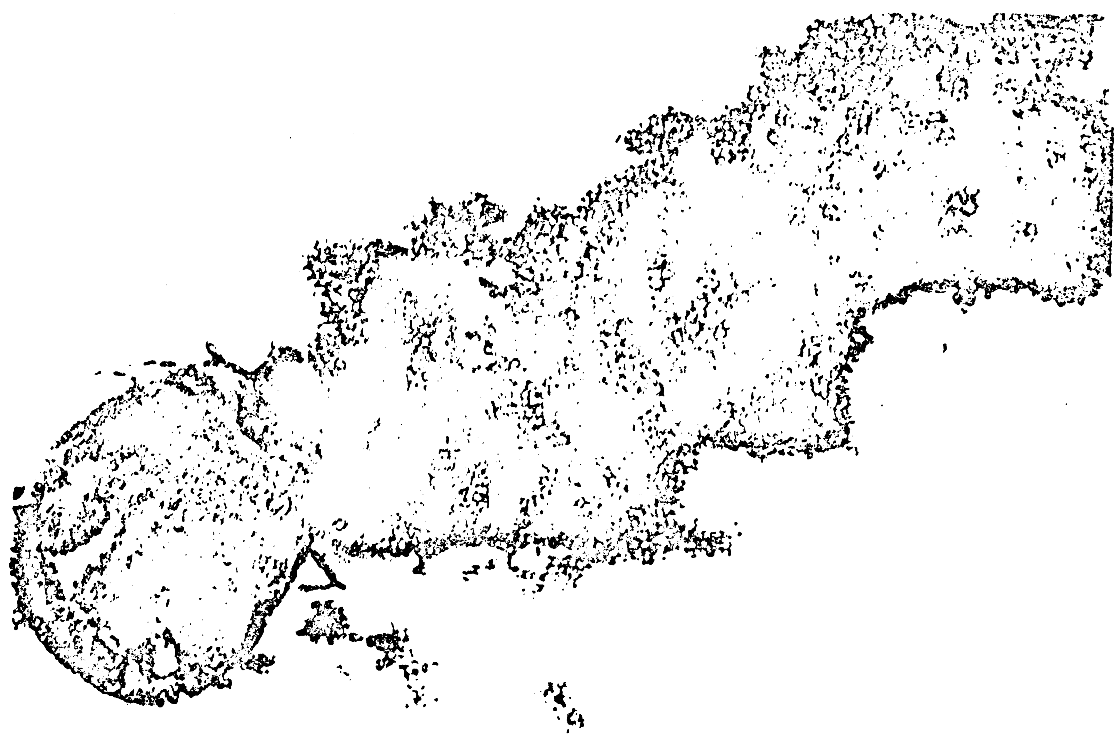
The ticks were counted once a month. A monthly count gives a good account of the number of ticks on an animal. Larvae, nymphs and mature heartwater ticks take 4 to 7 days, 4 to 20 days and 10 to 20 days respectively to engorge and to go through the various processes of metamorphosis. The ticks in the various stages of development, if fortunate enough, attach themselves to different hosts.

In the case of the female ticks they usually engorge themselves within a period of ten to twenty days.

The female ticks on *Bos taurus* cattle usually engorge themselves in approximately ten days while those on thick-haired, smooth-hided cattle take approximately twenty days to engorge, before they drop off. The female ticks engorged on the *Bos taurus* cattle are much larger than those engorged on the *Bos indicus* cattle.

The large, fully engorged females that drop from the *Bos taurus* cows lay from 15 000 to 18 000 eggs, while those female ticks which engorge on *Bos indicus* type cattle in approximately twenty days, are much smaller and lay approximately 1/3 the number of eggs the large females lay.

Figure III



The respective average weights of the female ticks fully engorged on *Bos taurus* and *Bos indicus* type cattle are ± 3,0 - 3,15 gm as against 1,0 gm for small ticks. The total number of ticks laid by fully engorged females varies from 6 366 to 18 765, mean 14 711. (0,25 - 0,5 gm and 1,25 gm of eggs respectively).

The ticks counted on the different parts of the animal's body were classified in three classes namely Heartwater ticks (*Amblyomma hebraeum*), Blue ticks (*Boophilus decoloratus*) and Bontleg ticks (*Hyaloma aegyptium*).

The separation of ticks in different species collected from different parts of the body enabled the author to determine the preference areas to which the different ticks attach themselves.

During the period 1938-1949 a large amount of data were collected on the climatological reactions of cattle of different breeds and types within breeds. It then became obvious that smooth-coated cattle succeeded much better than woolly-coated cattle within the same breed to maintain a state of homeothermy. The data on the mortality rates of these large herds at the research stations also revealed that the mortality rate of the woolly-coated cattle was appreciably higher than that of the smooth-coated cattle within a breed. The mortality data also revealed that the mortality rate of the *Bos taurus* breeds of cattle was much higher than that of the *Bos indicus* and *Bos indicus* x *Bos taurus* cross-bred cattle.

At the time the author did the climatological work on the different types of cattle at the Messina research station, he became aware of the fact that for animals to maintain a state of homeothermy on very hot days (+ 29°C (85°F)) ease of excess metabolic heat dissipation is essential.

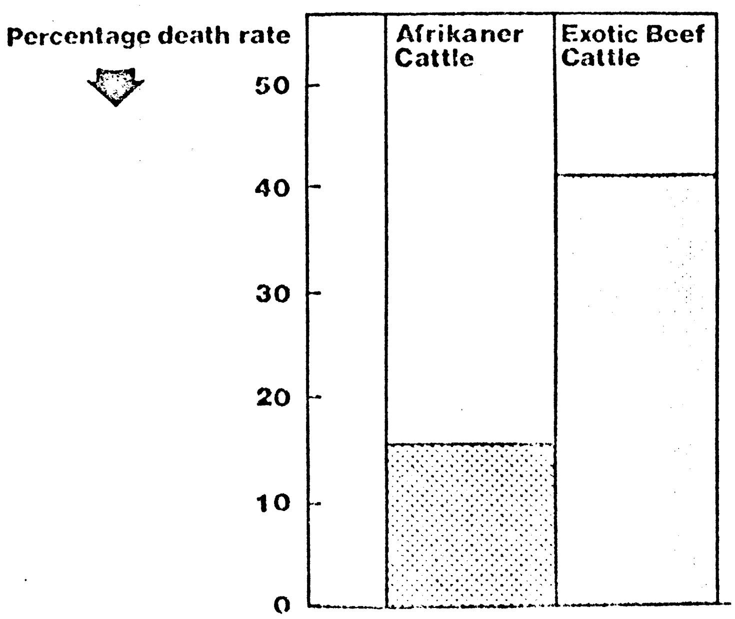
It also became very obvious that those animals which could not dissipate heat readily became hyperthermic and were often in a state of stress, their body temperatures often went up to as high as 40,0° - 41,1°C (104° - 106°F), they drivelled profusely and stood in the shade.

As a result of the fact that the author at that time (1937 - 1940) took fourteen body measurements every three months on all the cattle at Mara and Messina research stations, he came in very close contact with the cattle of all breeds and types within breeds. The fact that two hide thickness measurements, one on the shoulder and one on the thirteenth rib, were taken and that hair counts per square centimetre were taken on the loin and mid-rib region of the various types of cattle, gave the author a fair idea how the hides and hair of the different types of cattle differed. The felting tests on the hair of the different types of cattle gave an index of the ratio of medullated to non-medullated hair on the hide.

The data taken on the mortality rate of all the cattle that were transferred to Mara research station from heartwater and non-heartwater areas during the period 1936-40 revealed that the mortality rate amongste the *Bos taurus* (British breeds) cattle was much higher than that amongst the *Bos indicus* (Afrikaner) and Afrikaner cross-breds. (See Tables I-IIIc).

FIGURE IV

The diagnosis of the cause of death of these cattle was done by Drs Edwards, Wheeler and P R Mansvelt, state veterinarians, Louis Trichardt.

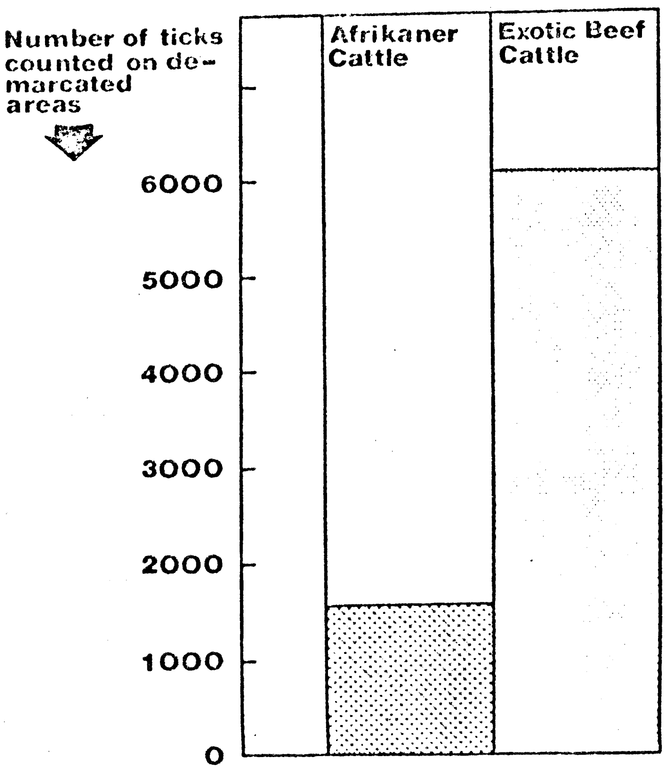


PERCENTAGE DEATH RATE DUE TO HEARTWATER AMONGST CATTLE DERIVED FROM NON-HEARTWA-

On each animal the ticks on a 1000 sq.cm were counted. During the period October 1941 - September 1942 the total number of ticks counted on these twenty-four animals was 14 867. Of these 10 961 were on the exotic beef breeds while 3 906 were on the Afrikaner cattle.

That is, approximately seventy-three percent (73%) of the total number of ticks counted were on the exotic beef breeds (*Bos taurus* cattle) while approximately twenty-six percent (26%) were on the Afrikaner cattle.

Figure V



RATIO BETWEEN NUMBER OF TICKS ON AFRIKANER AND EXOTIC BEEF CATTLE.
(Tick counts were made on five demarcated areas of 200 sq.cm. each on 12 head of cattle of each of the different breeds for the period October 1941 - September 1942)

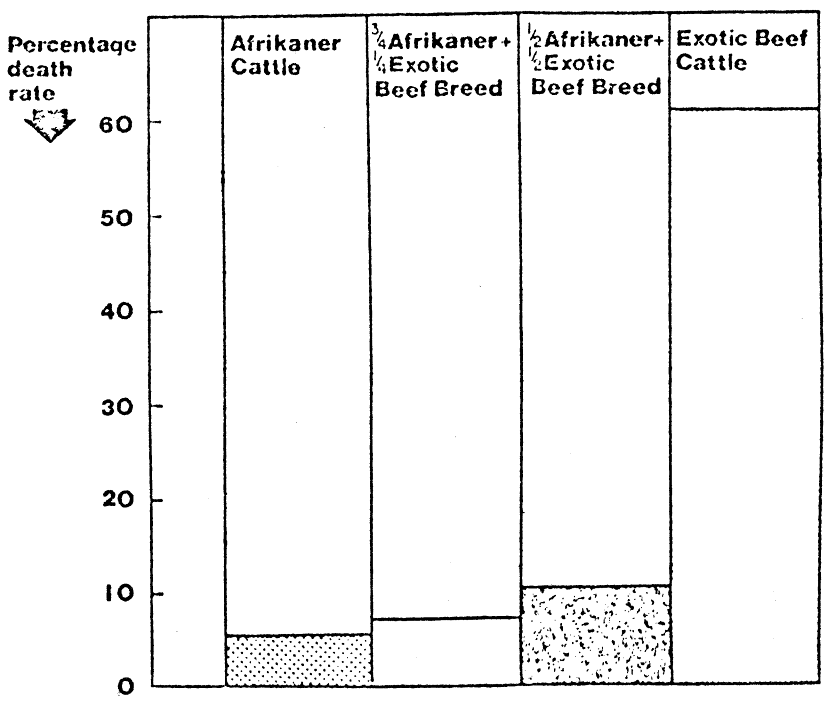
During the summer months the proportion of ticks found on the two types of cattle differed very greatly namely, 7,4 percent of all the ticks counted during January, February and March were on Afrikaner cattle while 92,6 percent of the ticks were on the British beef breed (*Bos taurus*) cattle.

During the winter months, June, July and August, the proportion of ticks were 17 percent and 83 percent respectively on the Afrikaners and the British beef breeds.

It would therefore appear that during the summer months when the coat of the Afrikaner is smooth and when they probably produce more sebum, they are less susceptible to tick infestation because it is possibly more difficult for ticks to attach themselves to Afrikaners. The short hair and greasy coat afford little protection to the ticks which do not like to be exposed to direct solar radiation.

The different types of cattle born at Mara research station, namely, pure-bred Afrikaner, first cross Afrikaner x British Beef Breed i.e. ½ Afrikaner x ½ Exotic; 3/4 Afrikaner x 1/4 Exotic Beef Breed and pure exotics, mainly Herefords, had different percentages of mortality rate.

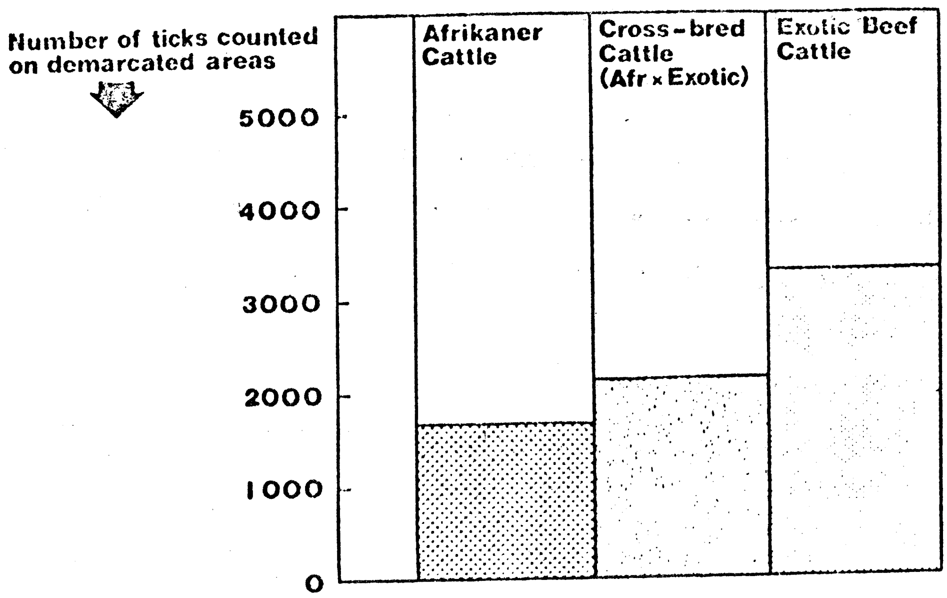
Figure VI



PERCENTAGE DEATH RATE DUE TO HEARTWATER AMONGST CATTLE BORN AT MARA.

The differences in mortality rate between the different types of cattle throw interesting light on the problem of the inheritance of characteristics in the external morphology of cattle which make them tick-repellent.

Figure VII



RATIO BETWEEN NUMBER OF BLUE TICKS (Boophilus Decoloratus) ON AFRIKANER, CROSS-BRED AND EXOTIC BEEF CATTLE. (Tick counts were made on eight demarcated areas of 200 sq.cm. each on 12 head of cattle of each of the different groups for the period October 1942 – September 1943.)

Figure VII clearly illustrates that the number of ticks on the cross-bred cattle is appreciably lower than that on the British beef breeds.

The histograms show a close relationship between the number of ticks on the cattle and their mortality rate.

In 1944 the author wrote as follows:

"Before an animal can acquire any measure of immunity to certain diseases it should first be exposed to natural infection, i.e. the host animal must be exposed to a comparatively large number of heartwater ticks in order to ensure with a certain measure that there will be some infected ticks among them.

If there are breeds or types within breeds which are definitely tick-repellent as a result of hereditary characteristics such as thickness or structure of the hide, glossiness and shortness of coat, such breeds and types of animals convey the impression of natural immunity to heartwater. The "apparent" immunity may be due merely to the fact that such animals possibly carry far fewer ticks than animals of other breeds or other types (smooth coat, thick and loose skin as against long, woolly coat and thin skin) within the same breed."

The 1944 paper by the author "Hereditary Heartwater-resistant characters in cattle" was severely criticised by W. O. Neitz and R.A. Alexander, section of Protozoology and virus diseases, Onderstepoort, in a paper "Immunization of Cattle against Heartwater and the control of tick-borne diseases, Redwater, Gallsickness and Heartwater." "Onderstepoort Journal of Veterinary Science and Animal Industry Vol. 20, No. 2 April 1945."

The research work done by these two illustrious scientists was done at Roodekuil Estates in the Northern Transvaal (Long E. 28°21', Lat. S 24°56', Altitude 1110m, Average Annual Isotherm 19°C).

With regards the methods of research, the researchers made the following statement:

"All records are maintained with the greatest care and accuracy: and finally the original undertaking of the Company to consult us in respect of all measures to combat disease, furnish detailed progress reports and to carry out all recommendations was faithfully honoured through their most able Superintendent, Mr Thos Grierson."

About the breeding of the cattle the following statement was made: "Hand-serving is not practised except in the case of stud herds. Bulls are allowed to run with the various herds so that calving is restricted to three periods, January and February, April and May, and July. Fertility is high."

Upon doing the heartwater immunization research at Roodekuil, the authors of the paper saw fit to criticise Bonsma as follows:

"Had the work and the article been confined to an investigation of the tick-repellent characteristics of either breeds of cattle or individuals of different breeds, adequate recognition could have been accorded a valuable contribution. Unfortunately the author digressed to a dissertation on immunity unsupported by adequate data or based upon incomplete observation. But it is quite certain that relative insusceptibility to tick infestation is correlated in no way with immunity to disease, and it must be fully appreciated that if a single tick sets up infection in a susceptible animal the resulting disease may be no less severe than that produced by the simultaneous feeding of ticks."

Fortunately Bonsma did not take any notice of this criticism for the following reasons:

(a) It was obvious that Neitz and Alexander were not acquainted with Bonsma's work on climatology and ecology and on the work he did on the equinoxial breeding seasons of cattle, hence they allowed Mr Thos Grierson to calve down his cows during February, March and April, the worst months of the year to calve down cows. Hence the statement "Fertility is high" could not be accepted. At that time the cows at Mara and Messina research stations were calved down during December and January and again during May and June as a result of adopting the equinoxial breeding seasons 15 February - 30 March and again 15 August - 30 September.

(b) The author's knowledge of statistics taken at a post-graduate level at Iowa State University, made him realise that the probability that a heartwater susceptible tick "sets up infection in a susceptible animal resulting in disease" is much greater if hundred ticks are attached to an animal instead of ten.

(c) The following statement in the paper by Neitz and Alexander proved beyond doubt that all the conclusions they came to with regards to heartwater susceptibility were obtained in the laboratory by the injection of heartwater blood in cattle. "Immunization of a mixed group of purebred Afrikaner cattle showed that the Afrikaner is no more resistant to heartwater than the Aberdeen Angus or Hereford."

What utter nonsense under natural conditions, as the following figures prove:

+ CALVING PERCENTAGES AND MORTALITY RATES ON CATTLE RANCHES IN THE NORTHERN TRANSVAAL AND ZIMBABWE

Ranch	Locality	Altitude metres	Average Annual Temperature °C	Average Rainfall mm	Breed of Cattle	Average No. of Breeding Cows	Average % Calf Crop	Average Mortality %
A	Long. E 26°53' Latitude S 24°21'	853	21,0	648	Herefords	1477 for 22 yrs	39	18
* B	Longitude E 28°21'	1110	19,0	964	Aberdeen Angus	3143 for 5 yrs	56	23
C	Longitude E 29°45' Latitude S 20°45'	1345	18,3	984	Sussex	17400 for 20 yrs	55	14
MARA	Long. E 29°34' Latitude S 23°09'	914	19,5	642	Adaptable types	416 for 6 yrs	83,5	10,6

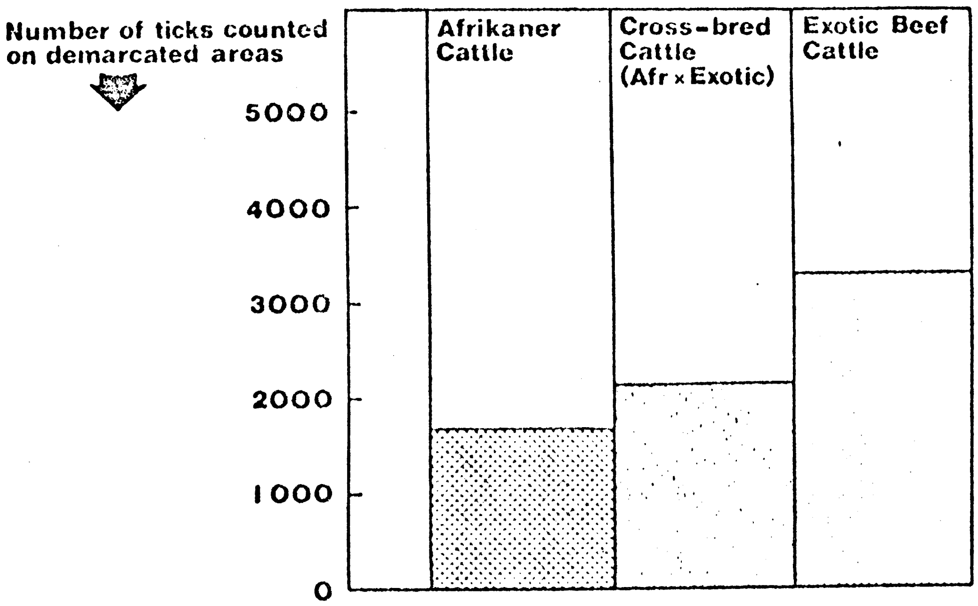
(+ Empire Journal of Exper. Agric. Vol. 21, No. 83, 1953)

* B - Roodekuil Estates where Neitz and Alexander did their research work and where Mr Thos Grierson "carried out all recommendations faithfully in a most able way." The company for economic reasons had to sell out in 1951.

All the data taken on the livestock at Mara and Messina research stations indicate that the total mortality rate amongst the non-adaptable cattle is appreciably higher than that amongst the adaptable cattle. Because the largest percentage of cattle, according to the veterinarians, die as a result of tick-borne diseases, it was considered absolutely essential to breed cattle that are tick-repellent.

In an effort to find out what makes cattle tick-repellent, it was essential to study livestock behaviour carefully and also to determine on which parts of the body as previously indicated, ticks give preference to attach themselves and also where do the various type of ticks attach themselves.

Figure VIII illustrates the ratio between heartwater ticks (*Amblyomma Hebraeum*) on Afrikaner, Crossbred and exotic beef cattle (*Bos taurus*).



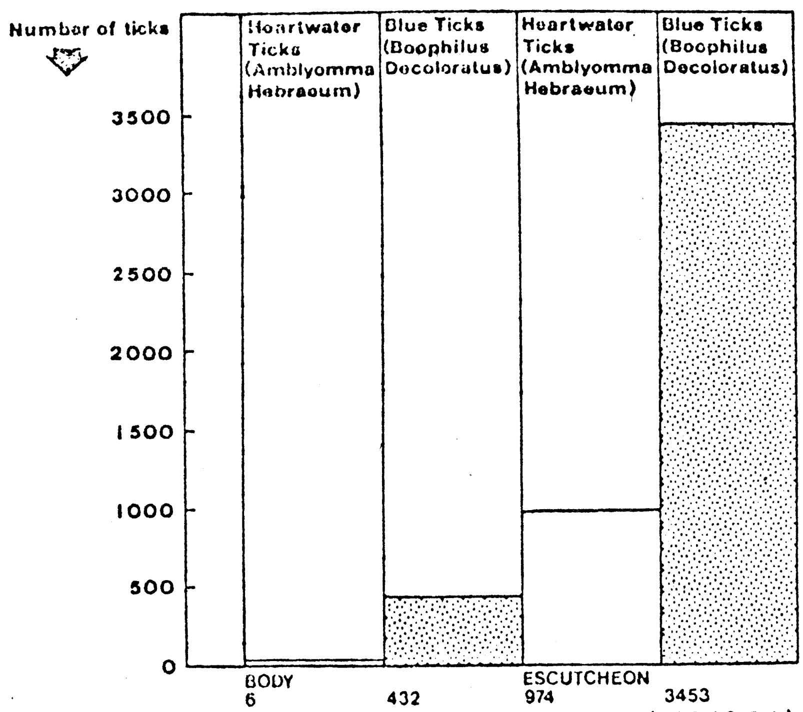
RATIO BETWEEN NUMBER OF BLUE TICKS (*Boophilus Decoloratus*) **ON AFRIKANER, CROSS-BRED AND EXOTIC BEEF CATTLE. (Tick counts were made on eight demarcated areas of 200 sq.cm. each on 12 head of cattle of each of the different groups for the period October 1942 - September 1943.)**

The division of ticks into kinds according to the various parts of the animal's body on which they occur, has shown what parts of the body the various kinds of ticks prefer. It was found for instance that 86 percent of the ticks found under the animal's tail, were bont-legged ticks, 11 percent heartwater-ticks and only 3 percent blue ticks, and that on every animal there were three to five times as many male ticks as female ticks.

According to Prof G B Whitehead, Head, Tick Research Unit Grahamstown, there are as many male as female ticks in nature, the ratio is 1:1, but the males accumulate on cattle because they often stay on cattle for sixty to ninety days, while the engorged females drop off. (Personal communication , 1981).

During the period 1941-1942 ticks were counted on 12 Afrikaner and 12 British beef cows. The counts were made on the body on 8x100 sq.cm areas, 2x100 sq.cm areas on the escutcheon and the number under the tail. These counts revealed that ticks give preference to attaching themselves to those areas of the hide that are thin and where the hide is not fully exposed to direct radiation. The ratio of ticks on the 800 sq.cm of the body was 1:7,5 in the case of the Afrikaner and *Bos taurus* cattle respectively, while on the escutcheon, where the hide is thin, the ratio was 1:2,9 and under the tail 1:2,2.

Figure IX



RELATIVE INTENSITY OF TICK INFESTATION PER UNIT AREA (200 SQ.CM.) ON THE BODY AND ESCUTCHEON. (Total of all three groups of cattle)

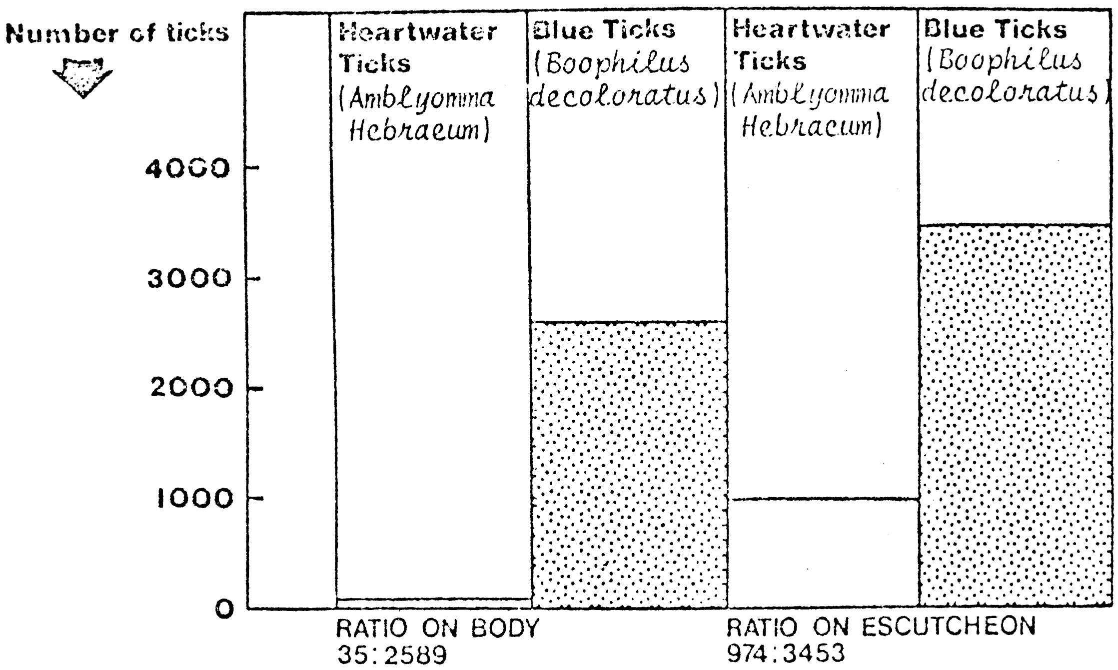
A total of 14 867 ticks were counted on the 12 Afrikaners and 12 British beef breed cows during the period October 1941 - September 1942; 27 percent of the total number of ticks counted were attached to the Afrikaner cows while 73 percent were attached to the British beef breed cows.

In an effort to find out what makes cattle tick-repellent, tests had to be done on the hides of these cattle and also on the behaviour of animals.

It was also essential to determine whether the different types of ticks give preference to attaching themselves on different parts of the body and to explain why.

Figure IX shows the difference in the ratios of ticks on the body and escutcheon of Afrikaner and *Bos taurus* cows.

Figure X



RATIO OF HEARTWATER TICKS TO BLUE TICKS ON THE DEMARCATED AREAS ON THE BODY AND THE ESCUTCHEON. (Total of all three groups of cattle)

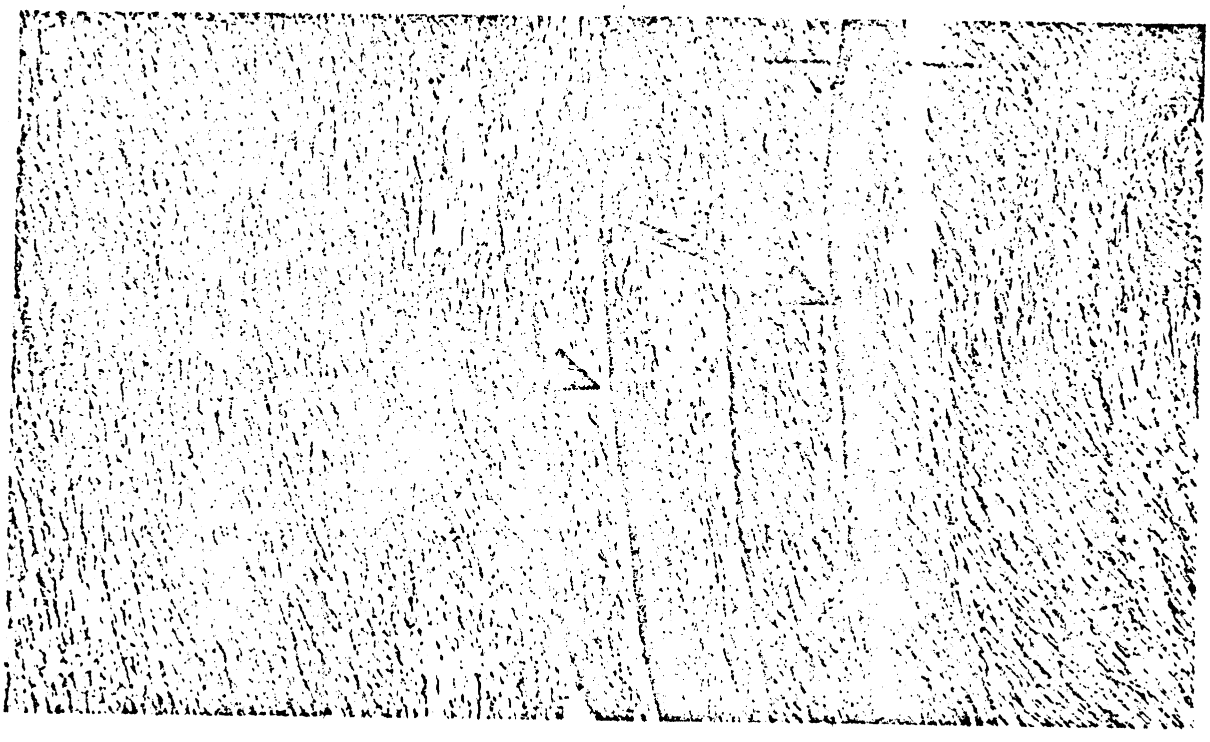
From the above illustration it is clear that ticks prefer to attach themselves on the areas of the body where the hide is thin and less exposed to solar radiation, and also where the skin movement due to an impulse is less vigorous. On the areas of the body where the sub-cutaneous muscles are well developed and on the hide where flickering is intense upon the slightest impulse, very few ticks are attached.

To determine the sensitivity of the hide to the slightest impulse, the author tickled his cattle with a culm of grass from which the seeds had been stripped. This thin point of the grass culm lightly touching the animal's hide, causes a tremendously strong flickering of the hide in the tick-repellent animal.

The skin reaction of cattle to external parasites varies according to the degree of adaptability.

Rigorous skin movements at the slightest irritation in adapted types of cattle serve as an effective repellent. This type of reaction is always found in cattle with thick hides, short, smooth coats and well-developed sub-cutaneous muscle development. The sub-cutaneous muscles in tick-repellent cattle lie very prominently horizontally across the hide like thick whip wales. This characteristic is inherited in cattle as a dominant, hence *Bos indicus* x *Bos taurus* crossbred cattle have thick hides with short, glossy hair and well-developed sub-cutaneous muscles. It is so easy to select for hide thickness in cattle, even in young calves. When the animal is approached from the side, and it looks at you, the slight bending of the side will show prominent skin folds.

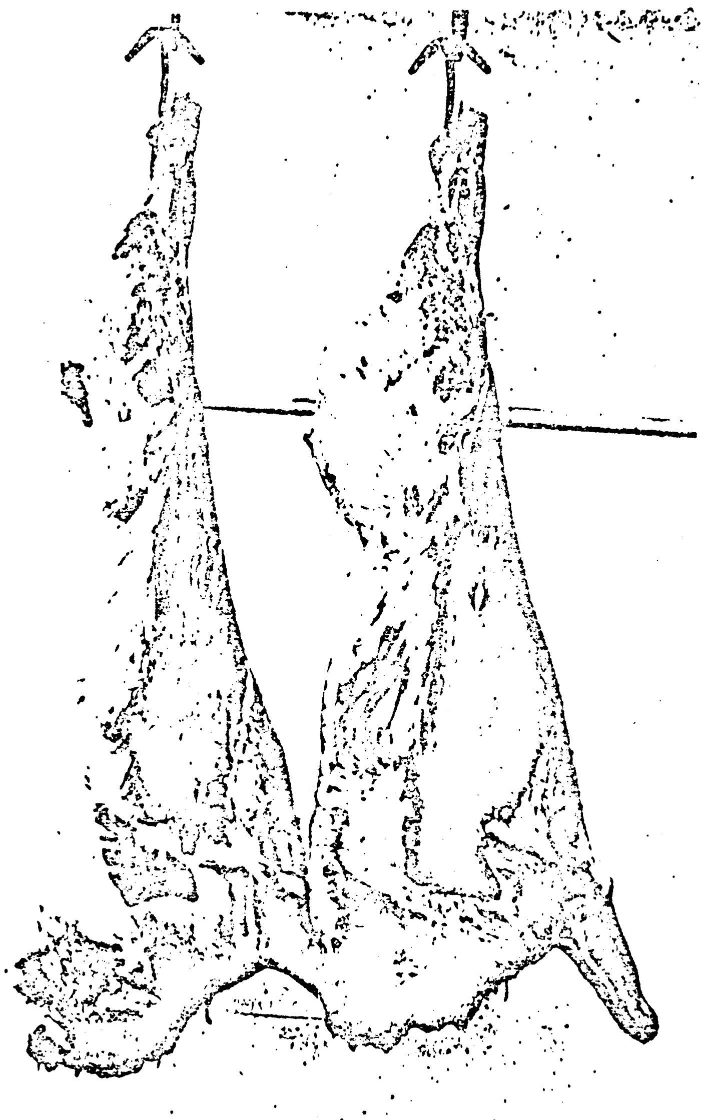
Figure XI The downward skin folds of a calf with a tremendously thick hide.



The animals with thick, moveable hides and short, glossy, greasy hair have in addition pilomotor activity and erection of the hair over large areas of the body.

(Miss M N Harris, University of Durban - Westville, informed the author at the International Conference on Tick Biology and Control, 27-29 January 1981 - Grahamstown, that the mouth parts of a heartwater tick cannot pene-

FIGURE XII



The carcasses of two animals, the one on the left of an animal which is not tick-repellent and the one on the right of an animal that is tick-repellent. Note the muscles on the sub-cutaneous fat.

trate the hide of a bovine by more than 2 mm, while a hypodermic needle goes through the hide of an animal with a hide-thickness of over 5,0mm. ((Reference paper: The mouth parts and alimentary canal of the Bont tick, *Ablyomma hebraeum.* (Koch))

That the ticks cannot penetrate the hides of smooth-coated, thick-skinned cattle as well as that of thin-skinned, woolly-coated cattle is very obvious.

The sub-cutaneous muscle or panniculus carnosas is a large waist-coat-like muscle extending from the neck to the buttock region of animals. (See Figure X). It's posterior attachment is to the capsule of the shoulder joint. It is supplied by a nerve derived from the brachial plexus with motor fibres. It's sensory nerve supply is from the intercostal and inter-lumbar nerves.

In the case of *Bos taurus* cattle it might therefore be possible that in the case of cattle which are not sensitive to tickling, that those nerves are incompletely myelinated, with the result that the sub-cutaneous muscle contraction is diminished and not nearly as vigorous as in the case of *Bos indicus* cattle. (Personal communication Prof Trevor-Jones, 1981).

Many fewer ticks attach themselves on the smooth, thick, moveable hides of adapted cattle, and these ticks are seldom as fully engorged as those on the woolly-coated cattle.

These adaptability phenomena in adaptable cattle types make attacks and penetration by external parasites so much more difficult. This is also one of the reasons why Neitz and Alexander's immunization with hypodermic needles did not show up differences in heartwater susceptibility.

In so far as the affixing habits of ticks are concerned, the data reveal several interesting features. For the total marked off surface areas on the body (viz. 1 200 sq.cm) the proportions of the various kinds of ticks were as follows:

Blue ticks	Heartwater	Bont-legged
67	3	1

on the escutcheon the proportions were:

Blue ticks	Heartwater	Bont-legged
6,4	1,8	1,0

These figures reveal that far fewer heartwater ticks than blue ticks attach themselves to the areas marked off on the body.

The reason for this may be that the heartwater tick is less tolerant of exposure to sunlight because the parts where the ticks are found are usually protected against the direct rays of the sun. Another reason may be that heartwater ticks prefer to attach themselves to the host on parts of the body where the skin is thinner.

The following ratios reveal that the skin thickness may possibly play an important role in the tick's choice of, or attachment to, a host: On the escutcheon where the skin is thin, 9,4 times as many blue ticks and 60 times as many heartwater ticks are found per unit of surface as on the body where the average skin thikcness is 40 per cent. greater than on the escutcheon (see Figures IX and X).

Table IV reflects the average double skin thickness of the 12 animals in each group on the various parts on which ticks were counted. The double skin thicknesses were measured by means of a caliper slipping at a constant pressure.

TABLE IV

Breed of Cattle	DOUBLE-SKIN THICKNESS IN MILLIMETRES ON VARIOUS PARTS						Averages	
	Brisket mm	Front Rib below mm	Front Rib upper mm	13th Rib mm	Flank mm	Escutcheon mm	Thick-skinned Areas mm	Thin-skinned Areas mm
Afrikaner	6,87	6,76	11,00	12,30	12,80	7,81	12,03	7,15
Cross	5,21	6,07	11,50	10,70	10,60	6,99	10,93	6,09
Exotic	5,82	5,84	10,25	9,67	9,76	6,99	9,89	6,22
AVERAGES	6,00	6,20	11,00	11,00	11,00	7,25	10,95	6,49

(The differences in skin thicknesses between Afrikaners and exotic beef breeds and between the various areas, viz., thick skin and thin skin, are statistically significant, P being $<$,01. The other differences are not.)

NOTE: An interesting additional feature in connection with the nature and type of coat of the cattle breeds concerned is the quantity of dip which cattle with different types of hair remove from the dipping tank. In the Mara experiment in which the cattle were put through the dipping tank after all visible ticks had been removed, the following results were obtained: After the animals of each group had been kept in the drying pen for 10 minutes, the Afrikaners removed an average quantity of 3,41 litres of dipping material per head from the tank in summer, while the average quantity removed by the exotic beef breeds was 5,69 litres. In the winter the figures in respect of Afrikaners and exotic beef breeds were 3,78 litres and 6,83 litres respectively. The average weight of the animals was approximately the same, namely 544 Kg per animal.

The above table clearly shows that the hides of Afrikaner cattle were considerably thicker than those of the British beef breeds.

These data also reveal that blue ticks are less discriminating than heartwater ticks against a thick skin and that a fair percentage of the blue ticks found on an animal occur on the body, where the hide is thick and from where the dipping material rapidly drains off. It may, therefore, be possible that the ticks found on certain parts of the animal's skin are not destroyed as easily as others occurring on parts where the skin is thin and from which the dipping material drains and dries more slowly, as e.g. on the escutcheon.

Another interesting feature observed during the period October, 1942 to September, 1943, in which the ticks were counted, is that only 19,4 per cent. of the heartwater ticks counted were females, while 80,6 per cent. were males. At no stage during the year did the percentage of female heartwater ticks exceed 30 per cent. Adult heartwater ticks take from 10 to 20 days to engorge themselves, so that it is possible that the female ticks drop off sooner than the males in order to oviposit, and this might to some extent account for the differences in the numbers of male and female ticks. The differences between the two sexes are always so great, however, that the fact that the females drop off to oviposit, cannot be considered a sufficient explanation for the very considerable differences.

It is obvious that type of skin and coat and related characters, such as glands in the skin, play an important part in connection with the susceptibility of cattle to tick infestation.

At the beginning of the October, 1942 to September, 1943 test, before any tick counts were made, a number of British beef-breed cattle, viz., six Hereford cows, were divided into two groups, namely those which in the writer's opinion would be low tick carriers and those which would be high carriers.

The division into two groups was based primarily on type and structure of skin, and type of coat.

The following table (No.IV A) reflects the actual differences in skin-thickness measurements between the two groups of animals. It should be pointed out that the measurements were taken after the animals had been selected according to external characteristics only.

On the three animals in each class, 18 skin measurements were taken, and only in the case of 2 out of the 18 comparative measurements did animals in group A have a thicker skin than animals in group B, these two differences are not statistically significant.

Animals with thick, loose skins covered with a short, glossy coat were considered to be low tick carriers. Thickness and looseness of skin, i.e., mobility of skin, are closely correlated with the number of visible, vertical skin folds present on the animal. In some animals the vertical skin folds extend from behind the shoulder to the flank. A correlation coefficient of r = +,866 was found between the number of vertical lines or folds and skin thicknesses. It is clear, therefore, that animals with numerous skin folds, especially in the region of the flank have very thick skins. Usually very few ticks are found on animals with a very thick, loose skin and a glossy coat.

At the end of the period the average number of ticks on the low carriers was only 36 per cent of that on the group which was considered more susceptible to tick infestation. The high tick-count cattle had three times as many ticks on them.

It is, therefore, possible even in the case of exotic beef breeds to select individual animals which by virtue of their skin thickness, skin structure, and shortness and glossiness of coat, will not be readily attacked by ticks. By selective breeding the proportion of such animals in a breed could be considerably increased. In selective breeding, animals with the best tick-repellent characteristics should be mated. The progeny will in the course of time include a higher percentage of animals possessing tick-repellent characteristics than would be the case in a random sample of animals where no selection took place in this direction.

TABLE IV A: Thin-skinned group: (3 Hereford cows) (A).

	Brisket mm	Front Rib Below mm	Front Rib Above mm	13th Rib mm	Flank mm	Escutcheon mm
	4,50	5,20	7,55	7,45	9,00	6,70
	4,50	5,10	10,30	9,90	8,70	6,60
	5,90	5,35	10,70	8,15	9,15	6,40
Total	14,90	15,65	28,55	26,50	26,85	19,70
Averages..	4,96	5,22	9,51	8,83	8,95	6,60

Thick-skinned group: (3 Hereford cows) (B).

	mm	mm	mm	mm	mm	mm
	6,85	6,55	11,05	10,45	8,95	8,00
	8,75	7,55	12,65	10,35	12,10	8,90
	7,35	8,05	12,50	8,70	10,50	7,25
Total	22,95	22,15	36,20	29,50	31,55	24,15
Averages..	7,65	7,38	12,06	9,83	10,52	8,05
	7,65	7,38	12,06	9,83	10,52	8,05
Differences in Averages between A and B.....	4,96	5,22	9,51	8,83	8,95	6,60
	2,69	2,16	2,55	1,00	1,57	1,45

All differences greater than 0,65 are statistically highly significant, $P < 0,01$.

As had already been indicated, ticks apparently do not like to attach themselves to parts of the animal's body where they are exposed to the direct rays of the sun. That the coat affords protection for ticks can be seen from Figure XIII , which shows that during the winter months when the total tick population in the Bushveld is smaller than during the summer months, the Afrikaner and Afrikaner cross-bred animals carry more ticks than in summer.

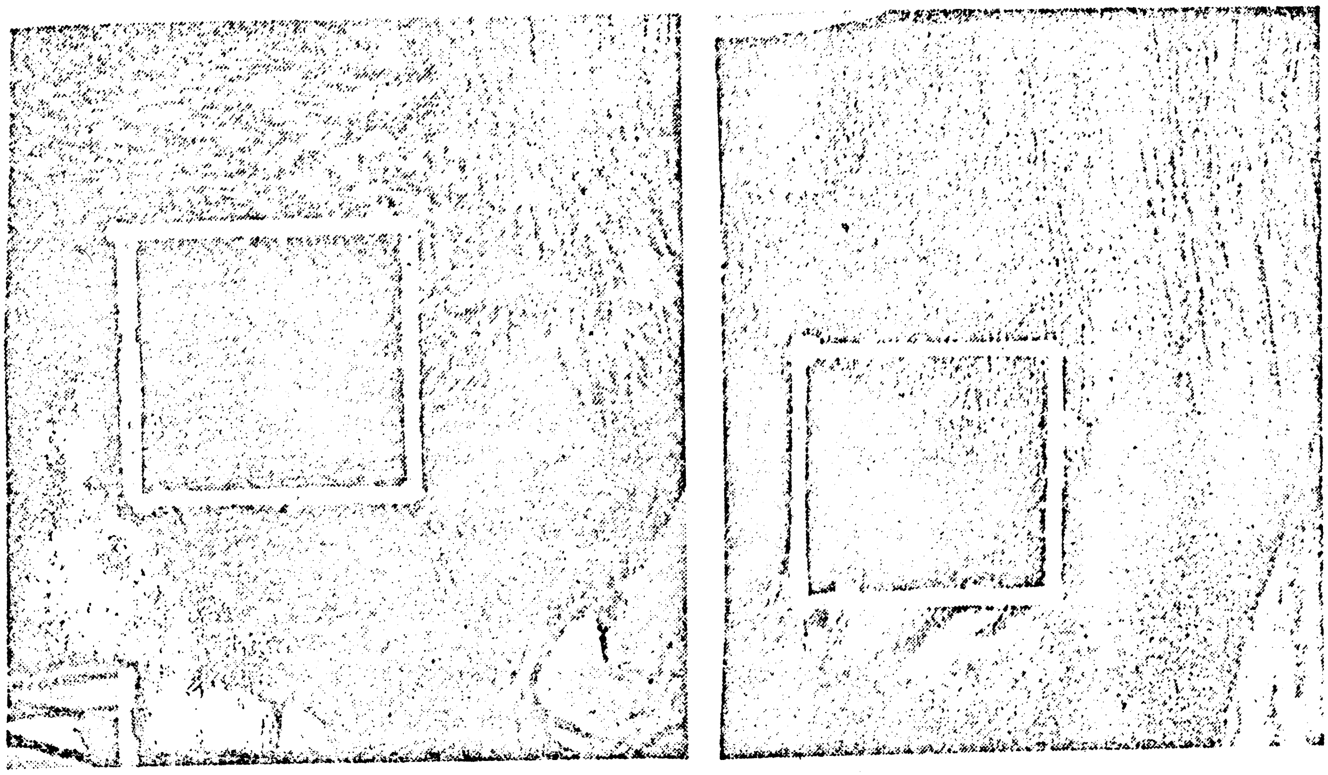
The reason for this is that the animal's coat becomes longer during the winter months and consequently, offers more protection for the ticks. In the case of cross-bred and Afrikaner cattle their coat becomes much longer during the winter months, whereas during the summer months the coats of *Bos taurus* cattle are still longer than the winter coats of *Bos indicus* and cross-bred cattle.

The fact that Afrikaner cattle carry more ticks in winter than in summer, makes one doubt the wisdom of the customary method of moving Afrikaner cattle from the Highveld to the Bushveld during the winter months.

A factor which might also tend to make Afrikaner cattle and crosses of this breed less susceptible to tick infestation, is that they are not so prone to lie in the shade of trees as cattle belonging to the exotic beef breeds. In the shade of trees the grass is usually rank and the ground moist with the result that more ticks are generally present there.

In the selection of cattle which are regarded as tick-repellent it should be noted that these animals also possess the characteristics desired to give them a high degree of hardiness to tropical and sub-tropical conditions.

Figure XIII   Note the numerous large fully-engorged ticks on the woolly-coated animal while the few ticks on the smooth-coated animal are small.



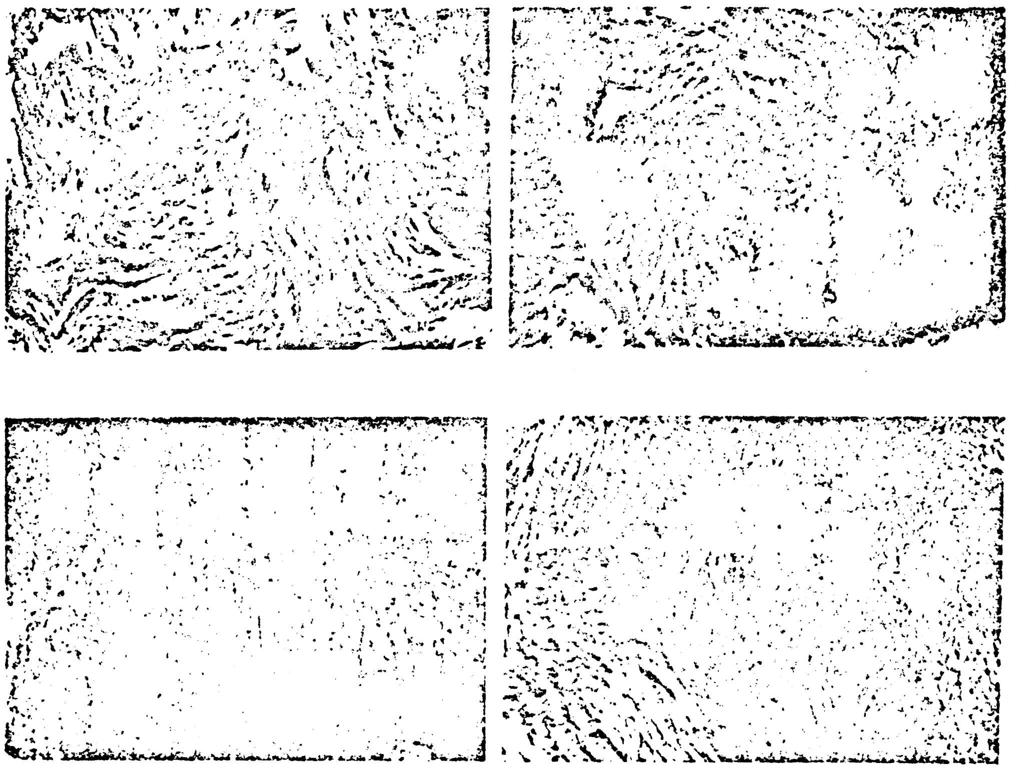
These photos were taken on July 21st 1941, i.e. in winter. On the woolly-coated animals 203 ticks were counted in the 100 sq.cm demarcated area while only 14 small ticks were counted in the area on the smooth-coated animal. It is apparent that from the unadapted animal many more fully-engorged female ticks drop which lay many-many more eggs than the few ticks that drop from the adaptable animal.

It also appears that greasiness of the hair coat of adaptable cattle develops much less static electricity when stroked and does not matt so that penetration by parasites to the skin surface is more difficult.

The thick vascular hide of adaptable cattle freely admits exudation and clotting at the site of insect and tick bites. This further reduces the ability of parasites to attack the skin effectively. This is also the reason why so very few adaptable cattle develop abscesses and blowfly strikes.

It is also easy to select livestock for smooth-coatedness, even within the British breeds of livestock. The calves born with straight, long, medullated hair containing a low percentage of non-medullated inner coat will become smooth-coated the first spring after birth. These cattle are usually early hair shedders in spring.

Figure XIV



The illustration on the left is that of a three day old Hereford calf born with long straight hair. This hair does not possess felting qualities. The bottom left illustration is of the hide and hair of the same animal at maturity. She is smooth-coated. The top right illustration is of a three day old Hereford calf, the hair is fairly short and non-medullated and felts. The bottom right illustration is the coat of the same animal when full-grown; the animal is woolly-coated, and very much more vulnerable to tick infestation.

It was on these principles that the author bred his smooth-coated Hereford herd at Mara. As a result of this exercise the mortality rate of the Herefords from all causes was reduced from 34% in the late forties to 14% in the late fifties.

The woolly-coated animal readily becomes hyperthermic on hot days and as a result of stress stands or lies in the shade were the incidence of ticks is very much higher than in the open.

The author reviewed very many papers on ticks and livestock, but unfortunately not one of the South African or Australian papers written from 1944 until 1980 have added a single selection criterion on how to breed tick-repellent cattle. Since the tick-count work at Mara research station was done during the period 1940-43 all the cattle in our breed creation work which ultimately resulted in the fixing of the Bonsmara breed of cattle was done on selection criteria which make cattle tick-repellent. This lowers the mortality rate under ranching conditions.

In "Tegnikon, Jaargang 28, September 1980, No. 3" in an article by Dr. T W Naudé on the use of chemicals in animal production there appears a sentence under the section on the control of ticks. ((1) "Control of Ticks") ("Beheer van Bosluise") that cannot be passed over without further comment:

"A further interesting finding[2] that fits in with this system of tick control is that it has now (1980) been proven that certain breeds of cattle of *Bos indicus* origin have a greater natural resistance against tick infestation than cattle of *Bos taurus* origin and that selection on these grounds could bring about a tremendous saving in dipping costs."

([2]Utech K.B.W. R.H. Wharton and J.D. Kerr:
Australian Journal Agric. Res 29, 885 (1978))

It is essential to point out here that the author advocated the breeding of tick-repellent cattle since the very early forties. All the bulls of the British beef breeds, (*Bos taurus* origin) especially those that were used in the Bonsmara breed creation work were selected to be smooth-coated and thick-hided.

As early as August 1949 Bonsma lectured at Brisbane University, Queensland, Australia, on animal climatology, livestock ecology and breeding for adaptability.

The first Australian research worker who did research work on breeding livestock to be tick-repellent was Dr G W Seifert who was an animal science student in Bonsma's livestock ecology and animal breeding classes at the University of Pretoria during the late fifties and early sixties.

The concept of breeding cattle to be tick-repellent did not emanate from Australia but very definitely in South Africa and was regularly advocated in animal science lectures at the University of Pretoria since 1941.

To summarize, the following criteria were adopted:

(1) Breed for adaptability with regard to tropical and sub-tropical climates where heat-tolerance is important. The adaptable animal is not in a state of stress on hot days, hence it will not lie or stand in the shade. All animals in a state of stress are full of ticks and the ticks aggravate the stressfull state. Dr A D Thomas' work proved that cattle that carry very many ticks often die as a result of tick toxicosis.

(2) Select cattle that have thick hides with high vascularity. Bonsma's work 1953 - "The improvement of Indigenous Breeds in Sub-tropical environments" proved beyond doubt that the thick-haired, smooth-coated animal has a much more vascular hide than the animal with a thin hide and dull hair. The injuries on a thick-hided animal bleed freely and a fibrin plug forms immediately and the injury heals in a few days time; not so in the case of the thin-hided, woolly-coated animal, that is why these animals so often develop tick-bite abscesses.

It also costs appreciably more to dip woolly-coated cattle. In the Mara tick research work (1940-43) it was found that woolly-coated cattle carried 5,69 litres of dip out of the plunge dip as compared to the 3,4 litres carried out by straight, short-haired, smooth-coated cattle.

The treatment of wounds and abscesses is also less costly in the case of adapted cattle.

(3) Coat colour is also of importance in breeding livestock to be tick- and fly-repellent.. The black colour in cattle is a distinct disadvantage in areas of the humid sub-tropics where ura-flies (Hypoderma spp.) prevail. These ura-flies are very similar to the warble flies of cold temperate zones, but much more ferocious. The ura-flies lay their eggs singly on hairs, chiefly about the mid-rib region. The larvae hatch in 4 to 5 days. Infestations of cattle with larvae of Hypoderma spp., cause serious damage to hides, occasional deaths due to anaphylactic shock and damage to the central nervous system. The migrating larvae cause severe damage to the most valuable portion of the hide. Ticks also give preference to attaching themselves on the black portion of the hide in the case of Friesland cattle.

Figure XV

The cause why ticks and stinging flies give preference to attaching themselves to or stinging black cattle is probably because the hide temperature is higher and perhaps also due to difference in light reflection.

(4) A very interesting observation that emanated from taking fourteen body measurements on approximately a thousand head of cattle every three months, was that the *Bos indicus* types of cattle flick their tails much faster and with more force at a much lower intensity impulse, than do the *Bos taurus* types of cattle.

The tail switch of adapted animals is much fuller and in the case of the *Bos indicus* cattle the tip of the tail switch hair is much sharper than that of the *Bos taurus* cattle. It smarts when struck by a fast flick of the tail by a *Bos indicus* animal especially a n'Guni, while measuring cattle.

The lower twenty to twenty-five centimetres (8-12 inches) of the tail in the case of *Bos indicus* cattle, especially in the case of the lighter coloured ones, is devoid of the small, thin, lower caudal vertebrae, this makes the tail much more flexible, which is important in flicking off insects in the region of the thigh.

Much research work needs still to be done on the function of the tails of different breeds and types of cattle.

Prof Peter Wright, Dept. of General Physiology, Dental School, University of the Witwatersrand, has shown that there are arteriovenous anastomosis related to every caudal vertebrae. His conclusion is that the tail acts as a thermoregulator.

The tail's reaction in cattle is a very complex process and a speculative assumption is that certain animals lack myelination of the lower caudal nerves and that the tail then works automatically; this means that they do not have full voluntary control over the tail, such animals are energetic tail waggers. Myelin, the lecithin sheath around nerves cause a fast reaction of the muscles upon an impulse. This is probably the reason why *Bos indicus* and *Bos indicus* cross-bred cattle can strike so fast and intensely with their tails.

Another observation with regards to insect-repellency on cattle is the way some cattle stamp their feet on the slightest impulse on the leg, so much so, that the author could not use a pedometer attached to the front legs of n'Guni and some Afrikaner cattle, to measure the distance they walk daily. The stamp of the feet in the case of those cattle is so intense that it often records three steps, with one single stamp.

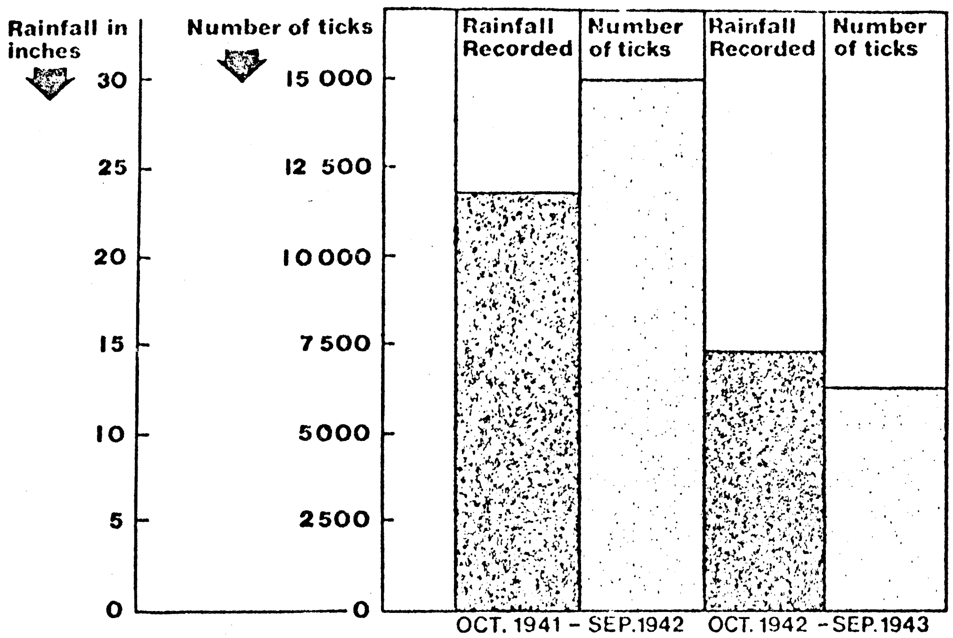
CONCLUSIONS

There is only one efficient way to reduce the tick populations in the tick infested areas of South Africa and that is to breed tick-repellent cattle and to dip these cattle regularly, that is weekly during the periods of intense tick infestations, that is usually two to three weeks after good rains in summer See Figure XVI.

The Australian way of measuring tick-repellency by putting collars containing 20 000 tick larvae round the neck of the animal and then counting the number of ticks on the animal after a certain lapse of time, is not an accurate index of an animal's tick-repellency under natural conditions. It puts the tick-repellent animal at a disadvantage.

Ticks under natural conditions do not attach themselves at the start of their life cycles on cattle to the neck of an animal. The sub-cutaneous muscles on the neck are not well developed, hence very little flickering of the neck muscles takes place upon irritation. By this method of determining tick-repellency the naturally tick-repellent animal is at a disadvantage with regards to determining natural resistance to ticks, because the resistant animal is very seldom in a state of stress due to high atmospheric temperature,

FIGURE XVI



THE RATIO BETWEEN THE AMOUNT OF RAINFALL RECORDED AND THE NUMBER OF TICKS COUNTED ON 24 HEAD OF CATTLE. (12 Afrikaner- and 12 Exotic beef cattle)

Rainfall and temperature have a direct influence on the number of ticks in any environment.

hence it does not readily lie in the shade where the tick counts are very high.

Furthermore, the efficient flickering of the thick vascular hide, the fast flicking of the tail and the stamping of the legs upon the slightest impulse make it so much more difficult for ticks to attach themselves to the highly adaptable, tick-repellent animal.

The tick-repellency work done by the Australians indicates that there is a difference in the number of ticks that are attached on cattle after being infected with 20 000 larvae. It varies from 85%-98%. There is therefore a difference of 13% in favour of the tick-repellent cattle with regard to tick-repellency. This however is a very small difference if expressed in terms of repellency, because the animal that has 15% of the 20 000 ticks on it after a lapse of time has 3 000 ticks attached to it, while the one with a 98% repellency, only has 400 ticks on it, hence a difference of 750 percent.

If one assumes that the percentage of female ticks on the animals is approximately 20% of the total count, then in the first case there are 600 fully engorged females on the non-repellent animal. How many more eggs will the 600 large female ticks lay in comparison to the 120 relatively small female ticks on the tick-repellent animal. In the light of Dr R.A.I. Norval's work on the number of eggs the different types of females lay, it is deducted that the 600 fully engorged ticks will probably lay approximately ten million eggs.

Every aspect of the breeding of Bonsmara cattle was based on the concept "MAN MUST MEASURE." The measurement of adaptability was based on all the available data recorded on the foundation animals in terms of body temperatures, respiration- and pulse-rates, TICK COUNTS, hide thickness, hair counts per square centimetre and the most composite measurement for adaptability, namely Average Daily Gain (A.D.G.), fertility, milk production, low mortality and ultimately longevity. This breeding policy has been adopted since the early forties and to this day every Bonsmara breeder is encouraged to do tick counts on his stud bulls. Unfortunately so many of them feel it is too time consuming to do tick counts on 2x100 sq.cm areas, one on the escutcheon and one on the dewlap.

If these breeders do not do tick counts on their cattle, the author's advice to them is, inspect your cattle carefully on dipping days and cull the ten percent of animals that carry the most ticks. These cattle usually carry more than half the total number of ticks in the herd.

By adopting this selection method it will be possible for the breeders in South Africa's ranching areas to greatly reduce the numbers of ticks on their adaptable cattle. It is also the only logical method of reducing the tick population cheaply and effectively in time to come, especially the three-host ticks like the heartwater tick (*Amblyomma hebraeum*).

The heartwater immunization work and the tremendous publicity it was given has retarded a proper breeding policy for the semi-arid sub-tropical ranching areas by many-many years. It is also a great pity that the extension service of the Department of Agriculture never propagated the concept of breeding tick-repellent cattle - A concept that had been clearly formulated and adopted at Mara and Messina research stations by Bonsma in the early 1940's.

The only breeders that really endeavoured to breed adaptable tick-repellent cattle under the guidance of Bonsma were the Bonsmara breeders. As a result of adopting this breeding policy the mortality rate of Bonsmara cattle in the ranching areas has constantly been lowered and is now even lower than that of the purebred Afrikaners.

It must be remembered that heartwater immunization of cattle may make them immune to heartwater, but it certainly does not make these cattle adaptable to the sub-tropics and tropics of the ranching areas of South Africa. The result of this immunization campaign was that many ranchers persisted in breeding *Bos taurus* cattle in areas where they were not adapted, with the deleterious results of Roodekuil Estates, see table on page 22.

This immunization also does not prevent cattle from dying as a result of tick toxicosis as Dr A D Thomas' work at Louis Trichardt clearly illustrated.

Adaptable cattle that are tick-repellent will not only reduce the tick population in an area because so many fewer fully engorged females which lay so many fewer viable eggs drop from them, but they are also a much better economic proposition than the heartwater immunized cattle, because they grow better, have a higher calving percentage, are bred for functional efficiency and finally they carry much less dip out of the dipping tank.

It must be stressed that the immunization of an unadapted animal or the saving of the life of such an animal by therapeutic treatment, does not make such an animal a productive functionally efficient, adaptable animal to the tropics and sub-tropics.

Unfortunately all the climatological, ecological and breeding for adaptability research work that was done with such meticulous care by Bonsma and his associates during the period 1937-1960 was abandoned when Bonsma finally bid farewell to Mara and Messina research stations in 1960.

No single concept with regards to what makes animals adaptable and tick-repellent has emanated from those research stations since that time.

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