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Immunization of Cattle against Heartwater and the Control of the Tick-Borne Diseases, Redwater, Gallsickness and Heartwater.

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In a preliminary report Neitz and Alexander (1941) gave a short account of the immunization of calves against heartwater under laboratory and field conditions. The conclusions drawn from those experiments may be summarized briefly as follows:—

1. Calves up to the age of four weeks possess a marked resistance to heartwater. This resistance is independent of the susceptibility or immunity of the dams and must not be confused with a passive transmitted or colostral immunity.
2. A mortality of approximately 2·5 per cent. may be expected in calves as a direct result of artificial infection. This mortality may be reduced by sulphonamide treatment during the incubation period or during the clinical reaction. (Neitz, 1941.)
3. Immunized calves develop a durable immunity in approximately 93 per cent. of cases.
4. There was some evidence that purebred individuals of the exotic breeds (Aberdeen Angus and Hereford) are more susceptible to heartwater than grades.
5. Practical difficulties of diverse nature prevented the application of this method to mass immunization in the field.

The results of this preliminary work were so encouraging that it was decided to extend the scope of the experiments to an investigation of the incidence of and mortality from the tick-borne diseases redwater (*Piroplasma bigeminum* infection), gallsickness (*Anaplasma marginale*) and heartwater (*Rickettsia ruminantium*) in a tick-infested area such as the Northern Transvaal, the ultimate object being to devise a simple routine method for their control within economic limits. The observations which form the basis of this report extended over a period of five years, when it was decided that sufficient information had been obtained to justify the conclusion of the work. It is hoped that the methods evolved will serve as a practical guide to methods to be adapted to the control of the tick-borne diseases in this country.

A detailed consideration of the somewhat scanty literature dealing with this aspect of the control of tick-borne diseases is included under the discussion of the results of the entire series of experiments.

Methods.

The major portion of the data cited were collected from a ranch in the Northern Transvaal.* On this ranch there are running three separate and distinct herds of cattle: (1) The main herd comprising grade Aberdeen Angus cattle, being bred for the production of high-grade beef for local consumption and for export. The vast majority of these animals are at least threequarter bred Angus. (2) A pure-bred Aberdeen Angus stud herd primarily for the production of bulls to be used in the main herd. (3) A pure-bred Hereford stud herd.

Without going into details of the organization of the ranch, it may be stated that the land is divided into a large number of camps of adequate size to facilitate rotational grazing; an adequate number of dipping tanks have been constructed to ensure regular dipping with a minimum interference with grazing; 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 diseases, to furnish detailed progress reports and to carry out all recommendations was faithfully honoured through their most able Superintendent, Mr. Thos. Grierson. We take this opportunity of expressing our appreciation of this ready co-operation without which the work would have lost much of its value.

Dipping.

This investigation was commenced when the Company directed our attention to the fact that after several years of regular, conscientious five-day dipping they had been unable to confine the mortality from tick-borne diseases within the limits of profitable breeding for the production of beef. Moreover, the harmful effect of this short interval dipping, ascribed not to the direct effects of repeated immersion in the arsenical solution, but primarily to loss of condition of the animals due to interference with grazing, far outweighed any benefits that might accrue. This harmful effect was accentuated in times of scarcity of grazing and was not overcome by building additional tanks at selected convenient sites.

During the course of this investigation changes in the dipping programme have been made from time to time, the changes being governed mainly by weather conditions and degree of tick infestation. The present arrangement is to dip at fortnightly intervals in 7-day strength throughout the summer months; all dipping is suspended during the winter months. Calves were not dipped before weaning at the age of approximately eight months, after which they were submitted to the same treatment as the adult stock. Animals in the pure bred herds are hand dressed in addition every week throughout the year. The strength of the dipping fluid is checked by means of the Government Dip Testing outfit; this was controlled by the submission of samples to Onderstepoort at irregular intervals. The result of this practice is that body ticks are seldom or never seen but a few ticks will usually be found on the majority of animals on the sites favoured by the different genera of ticks.

Breeding.

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.

* Roodekuil Estate of The African and European Investment Company Limited, situated about eight miles south of Warmbaths.

Diagnosis of Diseases.

The purebred herds are under the immediate supervision of an experienced stockman whose duty it is to report any deviation from normal to the Superintendent with the least possible delay. Trusted native herd boys are attached to the other herds with instructions to report immediately any sick or dead animal. Sick animals are examined and a diagnosis attempted from the clinical symptoms. Before any treatment is undertaken a blood smear is taken for submission to Onderstepoort and full particulars are forwarded with the smear. If redwater is suspected an appropriate dose of Pirevan or Acaprin is given; heartwater is treated by the intravenous injection of Uleron, the dose being 1 gram of Uleron per 100 lb. body weight, given as a 10 per cent. solution, half the dose being repeated at 12-hourly intervals as long as is indicated. When in doubt the general principle is to treat for a mixed infection of redwater and heartwater pending the receipt of the microscopic diagnosis. Since all animals are immunized against gallsickness this condition is automatically excluded from a clinical diagnosis. At this stage it is necessary to state that the Superintendent in charge, after several years of experience in the diagnosis of tick-borne diseases controlled by careful examination of beautifully prepared blood smears has attained an almost uncanny accuracy in diagnosis. In spite of this, however, many errors have been made, particularly during the early stage of the two diseases.

All dead animals are submitted to detailed post-mortem examination. As a routine procedure smears are taken from the ear and from the intima of the jugular veins and these, together with a full description, are forwarded to Onderstepoort. Formerly the brain was removed and a portion of the hippocampus forwarded in formalin for histological examination, but the work involved, and shortage of staff necessitated, abandoning this procedure. It is emphasized that without microscopic examination of properly prepared specimens it is quite impossible to make a correct diagnosis in a large percentage of cases. In addition, accurate diagnosis of heartwater from intima smears is frequently exceedingly difficult. In subacute and chronic cases groups of *Rickettsias*, particularly those unmistakable large intracellular colonies of elementary bodies, are rare and the scarcity of demonstrable forms of the organism is accentuated by specific chemotherapy with Uleron. However, recent experience gained from detailed investigation of a presumed cyclical development of *R. ruminantium* has made it possible to arrive at a certain diagnosis of heartwater in many cases which would previously have escaped detection. It is hoped to publish a detailed description of this aspect of the aetiology of heartwater in the near future.

Methods of Immunization.

Gallsickness.

From the beginning of 1940 all calves received an injection of Onderstepoort Gallsickness Vaccine (*Anaplasma centrale* infected bovine blood) when they reached the age of from 2 to 3 months. The routine procedure is to collect the whole of one batch of calves when the oldest had reached the age of about 3 months and, to minimize handling, a simultaneous injection of gallsickness and quarter evil vaccine is given. There were no severe reactions and only one death out of many thousands of animals treated has been ascribed tentatively to the effect of the vaccine. Usually no reaction at all is noticed. Immunization against redwater (*P. bigeminum* infection) was not undertaken.

Anthrax.

All animals on the ranch are immunized against anthrax in October of each year with Onderstepoort spore vaccine.

Heartwater.

The method of immunization has been described previously (Neitz and Alexander, 1941). Essentially it consists of using the natural resistance of young calves to control the disease set up by the intravenous injection of heartwater infected sheep blood. In the case of purebred stock and animals over the age of three weeks Uleron is given on the seventh day after injection, i.e., during the incubative stage of the disease to control the reaction and in all cases of severe reactions appropriate treatment with Uleron is immediately commenced. Previous experience has indicated that a mortality of approximately 2·5 per cent. may be anticipated as a direct result of immunization and a durable immunity can be expected to persist in 93 per cent. of the animals which recover.

It must be appreciated that immunity production is entirely dependent upon the initiation of infection in the animals. The infective titre of sheep blood tapped at the height of the febrile reaction is not high since approximately 2 per cent. of fully susceptible adult sheep may escape infection from as large a dose as 10 c.c. administered within a few minutes of tapping from the donor (Alexander, 1931). As the viability of the *Rickettsia* outside the animal body is strictly limited and possibly does not exceed 24 hours, it will be seen that the greatest care must be taken to complete all injections as soon after tapping the blood as possible. In the experiments to be reported all injections were completed within 16 hours. From 1943 onwards the ranching company has maintained its own strain of heartwater in sheep, thus enabling injections to be carried out within an hour of bleeding. It was anticipated that this procedure would result in the production of a better general immunity to be ascribed simply to the fact that the calves would receive a certain infecting dose of blood. An examination of the tabulated results will show that this forecast was correct.

Results.

The observations and results will be described under four separate headings:—

A. The occurrence of tick-borne diseases amongst:—

1. Adult stock born and bred on the ranch.
2. A control group of 195 grade Aberdeen Angus calves.

B. The effect of immunization and the subsequent incidence of tick-borne disease amongst:—

1. Grade Aberdeen Angus calves.
2. Purebred Aberdeen Angus and Hereford calves.

C. The immunization of purebred Aberdeen Angus cattle varying in age from 7 months to 5 years and 9 months.

D. The immunization of a mixed group of purebred Afrikaner cattle.

A. 1. *The Occurrence of Tick-borne Diseases amongst Adult Stock Born and Bred on the Ranch.*

This group comprised the adult animals on the ranch numbering 1,200 at the time when the work commenced. They had been immunized only against anthrax and quarter evil and had received no prophylactic treatment against any of the tick-borne diseases. The incidence of disease and the results from the beginning of 1940 are given *in extenso* in Table 1.

TABLE 1.

The Occurrence of Tick-borne Diseases in non-immunized Adult Cattle.

No. in Herd.	Year.	Disease.	Number which contracted Tick-Borne Diseases. No.	Appr. Age. Years.	Recovered. Treated.	Recovered. Not Treated.	Recovered. Total	Died. Treated.	Died. Not Treated.	Died. Total
1200	1940	Heartwater.....	6 (2, 1, 3)	? (?, 5, 3)	3 (0, 1, 2)	0 (0, 0, 0)	3 (0, 1, 2)	3 (2, 0, 1)	0 (0, 0, 0)	3 (2, 0, 1)
		Redwater.....	1	?	0	0	0	0	1	1
		Gallsickness.....	1	?	0	0	0	0	1	1
1160	1941	Heartwater.....	27 (7, 1, 2, 6, 11)	? (?, 7, 6, 5, 4)	11 (2, 0, 2, 1, 6)	0 (0, 0, 0, 0, 0)	11 (2, 0, 2, 1, 6)	10 (2, 0, 0, 3, 5)	6 (3, 1, 0, 2, 0)	16 (5, 1, 0, 5, 5)
		Redwater.....	2	?	2	0	2	0	0	0
		Gallsickness.....	2	5	0	2	2	0	0	0
850	1942	Heartwater.....	37 (15*, 1, 3, 2, 16)	? (?, 10, 7, 6, 5)	15 (7, 0, 0, 1, 7)	0 (0, 0, 0, 0, 0)	15 (7, 0, 0, 1, 7)	12 (4, 0, 1, 1, 6)	10 (4*, 1, 2, 0, 3)	22 (8*, 1, 3, 1, 9)
		Redwater.....	5 (1, 3, 1)	10 (10, 5, 4)	1 (0, 1, 0)	2 (0, 1, 1)	3 (0, 2, 1)	1 (0, 1, 0)	1 (1, 0, 0)	2 (1, 1, 0)
		Gallsickness.....	4 (2, 1, 1)	? (?, 7, 4)	0 (0, 0, 0)	3 (1, 1, 1)	3 (1, 1, 1)	0 (0, 0, 0)	1 (0, 1, 0)	1 (1, 0, 0)
600	1943	Heartwater.....	9 (4, 2, 3)	? (?, 6, 5)	6 (3, 1, 2)	0 (0, 0, 0)	6 (3, 1, 2)	2 (1, 0, 1)	1 (0, 1, 0)	3 (1, 1, 1)
		Redwater.....	1	?	1	0	1	0	0	0
		Gallsickness.....	1	5	0	0	0	0	1	1
	4 years 1940 to 1943	Heartwater.....	79*	Up to 10 years	35	0	35	27	17*	44*
		Redwater.....	9		4	2	6	1	1	2
		Gallsickness.....	8		0	5	5	0	3	3

* One animal showed a mixed infection of heartwater and gallsickness.

Results.—A survey of the observations recorded in Table 1 indicates a number of points of the greatest interest:—

(i) By far the highest mortality was due to heartwater. It is not possible to give the figures as percentages since this particular group of cattle was being depleted irregularly by sales. A total of 79 cases of heartwater was diagnosed; in live animals, from unmistakable clinical symptoms and the exclusion of redwater and gallsickness by microscopic examination of blood smears; in dead animals from intima smears of the jugular veins. Of this number 62 received treatment with Uleron; 35 recovered and 27 died, i.e., the treatment was successful in slightly more than half of the cases. In this connection it should be noticed that there was not a single recovery amongst the 17 animals in which a diagnosis of heartwater was made but which for various reasons could not be treated. This apparent poor response to sulphonamide therapy is due entirely to the fact that under ranching conditions a diagnosis of heartwater is only possible so late in the course of the disease that any hope of a cure is slight.

(ii) The incidence of redwater and gallsickness (only 17 cases over a period of 4 years) is surprisingly low and the value of treatment (Pirevan and Acaprin for redwater and intravenous mercurochrome and nursing for gallsickness) is indicated by the single death, even though 7 cases recovered and only 4 died when treatment was not administered. At first sight the low incidence of redwater and gallsickness may be considered to indicate either that dipping had controlled the tick population or alternately that infection was almost absent from the ticks. That ticks had not been eliminated is obvious. That a heavy infection is present amongst the ticks is illustrated by two observations:—

(*a*) A number of adult cows (27) were introduced from two farms in East Griqualand and Natal which are reputed to be remarkably free from tick-borne diseases. On arrival in the Transvaal these cows were drafted into an immunization experiment and were kept under close daily observation. Within 20 days 8 had reacted to virulent redwater which could only have been contracted naturally (cf. Table 6).

(*b*) Within a few days of arrival 5 of these cows calved. By the time the first born calf had reached the age of 23 days *P. bigeminum* infection had been diagnosed in all five calves and one died before an injection of Acaprin could be given.

These observations indicate that the vectors are infective, and that is substantiated by the high incidence of almost subclinical infections occurring amongst purebred calves undergoing heartwater immunization and, therefore, being left under the closest possible observation. The most feasible explanation appears to be that young calves are highly resistant but not immune to *P. bigeminum* and *A. marginale* infection.

This resistance favours the development of premunition at an early age and this naturally-developed immunity either persists or is maintained by constant reinfection. A detailed investigation of the degree of premunition amongst say year old animals could not be undertaken since it would involve blood subinoculations into susceptible animals under tick-free conditions. A sufficient number of these animals were not available to furnish results of statistical significance.

(iii) The incidence of tick-borne diseases not merely in adult but even in aged animals that had been exposed to a variable degree of tick infestation practically from birth is somewhat difficult to explain. For instance, it is hardly reasonable to assume that two 10 year old and several 7, 6, and 5 year old animals had been sufficiently fortunate to escape the attention of infective ticks for that length of time. Possibly some other abnormality caused a recrudescence of disease in premune animals; an occurrence of this nature is somewhat negatived by the observation that only in one instance was a mixed infection of redwater and heartwater encountered. It is more likely that loss of immunity resulted from auto-sterilization, a phenomenon which is known to occur in the case of redwater and heartwater but has not been demonstrated with gallsickness. At least the observation indicates quite clearly that a life-long immunity is not the invariable result of a previous non-fatal attack of any of the tick-borne conditions under consideration.

A. 2. *The Occurrence of Tick-borne Diseases in a Control Group of Grade Aberdeen Angus Calves.*

In 1939 the immunization of calves against heartwater was started as a routine control measure. A total of 284 calves were available for the experiment. Of these 89 selected at rondam were immunized (cf. Table 3) and the remaining 195 were left untreated in accordance with our usual practice of endeavouring to have twice as many controls as experimental animals in any critical investigation. Full details of this control group are given in Table 2.

Results.—From Table 2 it is apparent that the value of this group as an adequate control of the incidence of a mortality from tick-borne diseases was reduced materially by the sale of 125 oxen in 1942. The decision to sell was made when the Company examined the record of mortality in June. Up to that time 48 cases of heartwater (24·6 per cent.) had been diagnosed, 8 in the first year, 2 in the second, 13 in the third, and 25 in the first half of the fourth year. Of these 48 cases, treatment could be administered to only 23 of which 12 died, the course of the disease being so rapid in the others that the carcasses were simply found in the veld. These figures compared so unfavourably with the record of the immunized groups (see Table 3) that additional heavy mortality was anticipated, and the oxen were transferred to the fattening pens where they would not be exposed to tick infestation. Only 32 heifers were retained. The following year 10 of the 32 contracted heartwater and 7 died.

The sale of the 125 oxen was a striking tribute to the estimate of the value of immunization but was an unfortunate necessity from the experimental point of view since it has prevented a statistical analysis of the results. However, the role of heartwater as the major cause of mortality is clearly indicated. On the other hand the incidence of redwater and gallsickness in a form which attracted attention and permitted diagnosis is exceedingly low. During the first 3½ years only 4 cases were diagnosed and only 1 death from anaplasmosis occurred; during the fifth year of observation 2 cases of redwater and 2 cases of gallsickness were encountered all of which recovered. These figures closely parallel those recorded in Table 1 from observations on adult stock and the same explanations are pertinent.

TABLE 2.

Incidence of Tick-borne Diseases in a Control Group of 195 Grade Aberdeen Angus Calves.

Year.	Disease.	Animals which contracted Tick-borne Diseases.						
		No.	Recovered.			Died.		
			Treated.	Not Treated.	Total.	Treated.	Not Treated.	Total.
1939	Heartwater.....	8	—	—	—	—	8	8
	Redwater.....	—	—	—	—	—	—	—
	Gallsickness.....	—	—	—	—	—	—	—
1940	Heartwater.....	2	—	—	—	—	2	2
	Redwater.....	—	—	—	—	—	—	—
	Gallsickness.....	—	—	—	—	—	—	—
1941	Heartwater.....	13	6	—	6	4	3	7
	Redwater.....	1	—	1	1	—	—	—
	Gallsickness.....	1	—	—	—	—	1	1
1942*	Heartwater.....	25	5	—	5	8	12	20
	Redwater.....	1	—	1	1	—	—	—
	Gallsickness.....	1	—	1	1	—	—	—
1943†	Heartwater.....	10	3	—	3	3	4	7
	Redwater.....	2	2	—	2	—	—	—
	Gallsickness.....	2	—	2	2	—	—	—
1939 to 1943	Heartwater.....	58	14	—	14	17	27	44
	Redwater.....	4	2	2	4	—	—	—
	Gallsickness.....	4	—	3	3	—	1	1

* Between June and December, 125 young oxen were stall fed, fattened and sold.
† The year commenced with the surviving 32 heifers.

B. 1. *The Effect of Immunization and the subsequent Incidence of Tick-borne Diseases amongst Grade Aberdeen Angus Calves.*

In 1939 a start was made with the mass immunization of the calves on the ranch against heartwater. In that year 89 calves were treated. The results were so encouraging that, in 1940, 243 were treated and in addition routine annual immunization against anaplasmosis was instituted. From 1941 all calves on the ranch were immunized against both gallsickness and heartwater. The gallsickness vaccine was obtained from Onderstepoort through the usual channels; the heartwater infected sheep blood was forwarded by passenger train about every 14 days when it became available. From 1943 onward the ranch has maintained its own strain of heartwater by serial passage through sheep and has taken full responsibility for immunization as a routine duty.

The results are given in detail in Tables 3 and 4. Each year's batch of calves are distinctly earmarked so that it is possible to give the history of each group separately.

TABLE 3.

Mortality from Heartwater in Immunized Grade Aberdeen Angus Calves.

Year of Birth of Calves in Group.	Number Immunized.	Mortality Due to Immunization.	Number that Contracted Heartwater, 4 Weeks or more after Immunization.							
			Year.	Number.	Recovered.			Died.		
					Treated.	Not Treated.	Total.	Treated.	Not Treated.	Total.
1939	89	4 = 4·5%	1939	1	—	—	—	—	1	1
			1940	—	—	—	—	—	—	—
			1941	2	—	—	—	1	1	2
			1942	18	11	—	11	2	5	7
			1943	3	2	—	2	0	1	1
			1941–43	24 = 26·9%	13 = 14·6%	—	13 = 14·6%	3 = 3·4%	8 = 9·0%	11 = 12·3%
1940	243	7 = 2·9%	1940	7	2	—	2	4	1	5
			1941	7	5	—	5	2	—	2
			1942	12	3	—	3	3	6	9
			1943	6	2	—	2	2	2	4
			1940–43	32 = 13·1%	12 = 4·9%	—	12 = 4·9%	11 = 4·5%	9 = 3·7%	20 = 8·2%
1941	359	18 = 5·0%	1941	8	5	—	5	2	1	3
			1942	14	7	—	7	4	3	7
			1943	12	4	—	4	5	3	8
			1941–43	34 = 9·5%	16 = 4·5%	—	16 = 4·5%	11 = 3·1%	7 = 2·2%	18 = 5·0%
1942	325	19 = 5·9%	1942	17	10	—	10	6	1	7
			1943	8	4	—	4	4	—	4
				25 = 7·8%	14 = 4·3%	—	14 = 4·3%	10 = 3·1%	1 = 0·3%	11 = 3·4%
1943	358	5 = 1·4%	1943	6* = 1·7%	—	—	—	—	6 = 1·7%	6 = 1·7%
1939–43	1374	53 = 3·9%		121 = 8·8%	55 = 4·0%	—	55 = 4·0%	35 = 2·6%	31 = 3·2%	66 = 4·8%

* Includes 4 animals found dead. Carcasses were unsuitable for collection of material and death is presumed to have been due to heartwater.

TABLE 4.

Incidence of Redwater and Gallsickness in Grade Aberdeen Angus Calves for a Period of 5 Years (1939-43).

Year of Birth.	No.	Disease.	Animals which contracted Redwater and Gallsickness.						
			Number.	Recovered.			Died.		
				Treated.	Not Treated.	Total.	Treated.	Not Treated.	Total.
1939	89	Redwater	—	—	—	—	—	—	— } 1
		Gallsickness	1 (1)	—	—	—	—	1	1 }
1940	243	Redwater	4 (1, 1, 3, 3)	2 (3, 3)	—	2 } 3	1 (1)	1 (1)	2 } 2
		Gallsickness	1 (3)	—	1	1 }	—	—	— }
1941	359	Redwater	6 (*c*, *c*, 1, 1, 1, 2)	4 (1, 1, 1, 2)	2 (*c*, *c*)	6 } 15	—	—	— } 0
		Gallsickness	9 (3 × *c*, 5 × 1)	—	9	9 }	—	—	— }
1942	325	Redwater	13 (5 × *c*, 8 × 1)	6 (3 × *c*, 3 × 1)	1 (*c*)	7	2 (2 × 1)	4 (*c*, 3 × 1)	6 } 7
		Gallsickness	7 (4 × *c*, 3 × 1)	—	6	6	—	1 (*c*)	1 }
1943	358	Redwater	7	—	—	—	—	7	7
		Gallsickness	—	—	—	—	—	—	—
1939–1943	1,374	Redwater	30 (2·2%)	12 (0·9%)	3 (0·2%)	15 (1·1%)	3 (0·2%)	12 (0·9%)	15 (1·1%)
		Gallsickness	18 (1·3%)	—	16 (1·2%)	16 (1·2%)	—	2 (0·2%)	2 (0·2%)
		TOTAL	48 (3·5%)	12 (0·9%)	19 (2·3%)	31 (2·3%)	3 (0·2%)	14 (1·1%)	17 (1·3%)

4 (*c*, *c*, 1, 3) signifies four animals 2 being ves, 1 a year old, and one 3 years old.
5 × *c* signifies 5 animals, all calves.

Results.—Consideration of the results summarized in Tables 3 and 4 serves to focus attention on a number of interesting points.

In the first place the incidence of redwater and gallsickness was surprisingly low (c.f. Table 4). During the five years under review only 18 cases of anaplasmosis were diagnosed, of which 16 recovered without treatment and two died, one being a calf and one a yearling which had not been immunized. Redwater was diagnosed in only a slightly larger number of cases, viz., 30; of these 15 recovered, 3 without treatment, and 15 died, 3 of which in spite of treatment.

Heartwater was the cause of by far the heaviest mortality (c.f. Table 3). Out of a total of 1,374 calves immunized 53 (3·9 per cent.) died as a direct result of the injection of infective blood. This figure was slightly higher than had been anticipated, and it should be noted that no controlling injection of Uleron was given during the incubation period and all deaths from heartwater that occurred within four weeks of injection were ascribed to the treatment. When the 53 deaths due to immunization are added to the 121 cases diagnosed in the immunized animals it is seen that the total incidence of heartwater was 174 (12·7 per cent.). Of the 121 cases which represent those animals which failed to develop an adequate immunity or whose immunity failed to afford complete protection, 55 recovered as a result of treatment and 66 died, 35 in spite of treatment.

At first sight this incidence of heartwater may seem rather high when compared with the record of the disease in the group of adults averaging rather less than 1,000 over a period of 4 years, viz., 79 cases, of which 44 died (c.f. Table 1), but it must be remembered that an undetermined number of those adults must have developed an active immunity as a result of recovery from the naturally contracted disease during calfhood. A more correct conception of the beneficial effect of immunization would be obtained from a comparison of the mortality in the 1939 immunized and non-immunized groups. Unfortunately, for the reasons given above, such a direct comparison is not possible but it is quite apparent that a significant difference between the two groups does exist. In the immunized group of 89 animals 4 (4·5 per cent.) died as a direct result of immunization, 24 subsequently contracted heartwater and 11 died making the total mortality 15 (16·8 per cent.). In the control group of 195 animals over a period of 3½ years 48 cases of heartwater (24·6 per cent.) were diagnosed and 37 deaths (19·0 per cent.) occurred, but 125 oxen during the worst heartwater season under review were removed. From the fact that 10 of the 33 remaining animals contracted the disease the following year and 7 died it is a reasonable supposition that a considerable percentage of the oxen would have died.

B. 2. *The effect of Immunization and the subsequent Incidence of Tick-borne Diseases amongst Purebred Aberdeen Angus and Hereford Calves.*

At the end of 1940 the result of immunization of the grade animals appeared to be sufficiently encouraging to warrant the extension of the method to the purebred studs. The greater value of the animals rather than fear of disaster owing to possible greater susceptibility of purebred individuals of exogenous breeds was the factor which prompted the use of Uleron during the incubation period of the artificially induced disease according to the method described by Neitz (1941). Accordingly all the calves (287) were given an intravenous injection of 10 c.c. of a 10 per cent. solution of Uleron on the seventh day after the heartwater sheep blood. The results are tabulated in Table 5.

TABLE 5.

The effect of Immunization and the subsequent Incidence of Tick-borne Diseases amongst Purebred Aberdeen Angus and Hereford Calves.

Year of Birth of Calves in Group.	No. Immunized against Heartwater.	Mortality Due to Immunization.	Animals which contracted Redwater, Gallsickness and Heartwater.								
			Year.	Disease.	No.	Recovered.			Died.		
						Treated.	Not Treated.	Total.	Treated.	Not Treated.	Total.
1941	106	3	1941	Redwater	7	4	1	5	—	2	2
				Gallsickness	1	—	1	1	—	—	—
				Heartwater	7	2	—	2	4	1	5
			1942	Redwater	2	1	—	1	—	1	1
				Gallsickness	1	—	1	1	—	—	—
				Heartwater	2	2	—	2	—	—	—
			1943	Redwater	—	—	—	—	—	—	—
				Gallsickness	—	—	—	—	—	—	—
				Heartwater	5	4	—	4	—	1	1
			1941 to 1943	Redwater	9	5	1	6	—	3	3
				Gallsickness	2	—	2	2	—	—	—
				Heartwater	14	8	—	8	4	2	6
1942	97	1*	1942	Redwater	7	5	—	5	—	2	2
				Gallsickness	1	—	1	1	—	—	—
				Heartwater	6	5	—	5	1	—	1
			1943	Redwater	—	—	—	—	—	—	—
				Gallsickness	—	—	—	—	—	—	—
				Heartwater	3	1	—	1	—	2	2
			1941 to 1943	Redwater	7	5	—	5	—	2	2
				Gallsickness	1	—	1	1	—	—	—
				Heartwater	9	6	—	6	1	2	3
1943	84	2†	1943	Redwater	1	—	—	—	—	1	1
				Gallsickness	1‡	—	—	—	—	1	1
				Heartwater	1	—	—	—	1	—	1
1941 to 1943	287	6†	1941 to 1943	Redwater	17	10	1	11	—	6	6
				Gallsickness	4‡	—	3	3	—	1	1
				Heartwater	24	14	—	14	6	4	10

* Two calves died before the age of 4 weeks from Redwater and are shown under heading Redwater.
† 1 Calf died from shock as the injection of Uleron was being given.
‡ Death apparently due to *Anaplasma centrale*, i.e., caused by gallsickness vaccine.

Results.—In reviewing the results in the purebred Aberdeen Angus and Hereford studs, it must be appreciated that these animals are maintained under conditions of much closer supervision than the grade herds. This probably accounts for the larger number of cases of redwater and gallsickness that were diagnosed since smears were taken as soon as an animal was noticed to be off colour at either the morning or evening inspection. There were four cases af anaplasmosis, none of which were given any medicinal treatment and the only death has been attributed to the reaction produced by the gallsickness vaccine; it is possible that there may have been some complicating factor. Redwater was diagnosed in 17 animals and of the six deaths none had been treated simply because a clinical diagnosis had not been made and the microscopic diagnosis was made too late for treatment to be initiated. Incidentally it should be noted that five of the six deaths occurred in animals less than one year old.

The incidence of heartwater was surprisingly low. Only six deaths (2·1 per cent.) as a direct result of immunization were recorded and of these one animal dropped dead presumably as a result of shock as it was being treated with Uleron. This low mortality must be ascribed to the beneficial effect of the controlling Uleron injection administered on the 7th day after the infective blood. Subsequent to immunization 24 cases of heartwater were diagnosed; 14 responded to treatment and six of the ten deaths occurred amongst animals undergoing treatment.

These figures afford a striking contrast to the incidence of tick-borne diseases amongst the control group of non-immunized animals (Table 2) but do not permit of direct comparison with the immunized grade groups since the period of exposure to natural infection was two years less. However, 1942 was undoubtedly the worst heartwater year during the period under review, yet the mortality amongst the stud animals was low.

C. *The Immunization of Purebred Aberdeen Angus Cattle varying in Age from 7 months to 5 years and 9 months.*

In view of the shortage of purebred Angus bulls and also in order to introduce new blood into the existing stud the owners of the ranch decided to import a number of animals (27) from two farms in Natal and East Griqualand, which were certainly free from heartwater and reputedly free from redwater and gallsickness. The risk of mortality from tick-borne diseases was fully appreciated but it was decided to immunize against anaplasmosis with the ordinary routine vaccine, to rely upon early clinical diagnosis and specific chemotherapy for the control of redwater and to immunize against heartwater.

The general scheme of heartwater immunization finally decided upon was to give an injection of Uleron on the seventh day after the injection of infective sheep blood, to keep a daily record of temperatures from the twelfth day and to commence specific Uleron therapy as soon as a definite febrile reaction became apparent.

The results, which were highly satisfactory, are given in tabulated form in Table 6.

TABLE 6.

Immunization of Imported Purebred Aberdeen Angus Cattle: September, 1942.

Origin.	Age.	Reaction.	Treatment.	Result.
Local.....	3 days	Redwater, day 9.....	Pirevan, day 9.....	Recovered.
	7 days	Redwater, day 8.....	Pirevan, day 8.....	,,
	12 days	Redwater, day 8.....	Pirevan, day 8.....	,,
	15 days	Redwater, day 8.....	Pirevan, day 8.....	Died Redwater.
	18 days	Redwater, day 8.....	Pirevan, day 8.....	Recovered.
East Griqualand	7 months	No reaction.....	Nil.....	No reaction.
	7 months	Heartwater, day 18–23	Uleron, day 18 and 19	Recovered.
	9 months	Heartwater, day 14–21	Uleron, day 14–18....	,,
	9 months	Heartwater, day 17–20	Uleron, day 17–19....	,,
	9 months	Heartwater, day 14–21	Uleron, day 14–16....	,,
	2 years 6 mths.	Heartwater, day 21–26	Uleron, day 21–24....	,,
Natal.....	2 years 6 mths.	Heartwater, day 21–25	Uleron, day 21–23....	,,
	2 years 6 mths.	Heartwater, day 19–24	Uleron, day 19–23....	,,
	2 years 6 mths.	Heartwater, day 21–25	Uleron, day 21–23....	,,
	2 years 6 mths.	Heartwater, day 24–30	Uleron, day 24–28. ..	,,
	2 years 6 mths.	Heartwater, day 19–24	Uleron, day 19–22....	,,
	2 years 6 mths.	Redwater, day 12... Heartwater? 12–15.	Pirevan, day 12..... Uleron, day 12–14...	,, ,,
East Griqualand	2 years 6 mths.	Redwater, day 9.... Heartwater, day 14–19	Pirevan, day 9..... Uleron, day 13–17...	— Recovered.
Natal.....	2 years 6 mths.	No reaction.....	Nil.....	No reaction.
	2 years 6 mths.*	No reaction.....	Nil.....	,,
East Griqualand	2 years 8 mths.	Heartwater, day 25–30	Uleron, day 25–27....	Recovered.
	2 years 8 mths.	Heartwater, day 20–25	Uleron, day 20–23....	,,
Natal.....	2 years 9 mths.	Redwater, day 10 .. Heartwater, day 13–16	Pirevan, day 10..... Uleron, day 13–14...	,, Recovered.
	2 years 9 mths.	Redwater, and heartwater, day 13–20	Pirevan, day 13 and 14, Uleron, day 13–20	,,
	2 years 9 mths.	No reaction.....	Nil.....	No reaction
	3 years	Heartwater, day 17–25	Uleron day, 17–22....	Recovered.
East Griqualand	3 years 9 mths.	Redwater, day 11, no heartwater	Pirevan, day 11.....	,,
	3 years 9 mths.	Redwater and heartwater? together	Pirevan, day 17..... Uleron, day 17–20....	,, ,,
	3 years 9 mths.	Redwater, day 10... Heartwater, day 17–20	Pirevan, day 10..... Uleron, day 17–19...	,, ,,
	3 years 9 mths.	No. reaction.....	Nil.....	No reaction.
	3 years 10 mths.	Heartwater, day 18–20	Uleron, day 18–20....	Recovered.
	5 years 9 mths.	No reaction.....	Nil.....	No reaction.

* Had contracted natural heartwater six weeks previously and recovered under treatment.

Results.—Before considering the results it must be pointed out that the animals were introduced in two batches at an interval of several months. This enabled the Superintendent in charge to give each individual animal his personal attention and to carry out the requisite treatment. As soon as a definite febrile reaction was noticed a blood smear was taken and immediately posted to the laboratory for examination. In each case a diagnosis was returned by telephone within 24 hours; if negative for redwater Uleron treatment was recommended, if positive for redwater Pirevan was injected and subsequent treatment was left to the discretion of the Superintendent. No case of anaplasmosis was diagnosed.

There were no deaths from heartwater as a result of the immunization and there was no mortality from tick-borne diseases amongst this group of 31 animals during the ensuing three and a half years.

The incidence of redwater was comparatively high. Amongst the 27 adults 7 cases were encountered and all responded to specific treatment. It must be particularly noted that all of the five calves born after arrival of the dams on the ranch developed redwater. In four of the five calves smears were taken and the parasites detected on the first day the calves were put on temperature; in the case of the fifth calf a diagnosis was made on the second day of taking temperatures, i.e., when the animal was only fourteen days old.

D. *The Immunization of a mixed group of Purebred Afrikaner Cattle.*

Up to this stage all the experimental work had been carried out on two exogenous breeds of beef cattle, viz., purebred and grade (at least ¾ bred) Aberdeen Angus and Herefords. An opportunity was, therefore, sought of collecting analogous data from a purebred Afrikaner herd. An owner, who wishes to remain anonymous, generously offered his animals for the experiment, which was carried out under the supervision of Mr. M. de Lange, veterinary officer in charge of the Nooitgedacht Laboratory, Ermelo. The dams of the calves were running on badly infected heartwater veld, and originally it was planned to move them to Ermelo so that the calves would be available for treatment before they attained the age of three weeks. A set of unforeseen circumstances, however, interfered with this arrangement and the calves received their injection of infective blood when only nine were under three weeks of age and the remaining 45 ranged from four to ten weeks (4 weeks—4, 5 weeks—2, 6 weeks—19, 7 weeks—10, 8 weeks—1, 10 weeks—9). In addition a 12-months-old bull was included in the group.

The heartwater blood was obtained from a sheep reacting to the " Mara " strain of heartwater virus at the Ermelo experimental station and all injections were completed within 3 hours of tapping the blood.

As no reliable data were available as to the relative susceptibility of Afrikaner and other breeds of cattle it was decided to administer a protecting dose of Uleron on the seventh day after injection. As the animals had been born and bred under ranching conditions any attempt to obtain a daily temperature record, even if such a procedure were possible, could only be misleading so the veterinary officer in charge carried out a careful daily inspection in the hope of picking out reactors which should be treated.

On the 10th day after injection it was noticed that a few calves were " off colour ". On the 14th day one six-weeks-old calf died from heartwater; on the following day a seven-weeks-old calf died, followed by two more deaths the next day (both seven-weeks-old calves). As it was quite apparent that the mortality would be heavy all the calves were given a second injection of Uleron on the 16th day. As in the previous experiments the dose was the standard dose of 1 gram per 100 lb. body weight, and in addition it was decided to repeat treatment daily to those animals where such a course appeared to be indicated. Only two more calves died (one 5 weeks old and one 3 weeks old), but eight reacted very severely and in some cases three additional injections were given before recovery was assured. In addition one calf (six weeks old) reacted severely and recovered but subsequently developed pneumonia which proved fatal. The diagnosis in each case was confirmed by the clinical symptoms, post-mortem examination and the demonstration of *Rickettsias* in intima smears.

Results.—Out of a group of 54 purebred Afrikaner calves ranging from three weeks to ten weeks of age at the time of the immunizing injection, six died (11 per cent.) from heartwater and eight reacted very severely but recovered. The remainder showed either slight or no clinical reaction. The severe reactions and deaths occurred in spite of two prophylactic injections of Uleron on the 7th and 16th days, and the six deaths were recorded in spite of repeated Uleron treatment during the period of easily detectable clinical symptoms. All the severe reactions and four of the six deaths occurred amongst calves that were six weeks or older at the time of the commencement of immunization, but a five weeks and a three weeks old calf also died.

The twelve-months-old bull showed no clinical reaction but as it had been running for one season on heartwater veld it may have been immune when drafted into the trial.

It must be noted that in this experiment on purebred calves the method finally adopted closely resembled that applied to the treatment of purebred adult animals of an exogenous breed and the precautions taken were more rigorous than those applied to the routine immunization of purebred Aberdeen Angus and Hereford calves under the age of three weeks. Consequently the results should be read in conjunction with those cited in Tables 5 and 6. Such a comparison clearly emphasizes the conclusion that it may be dangerous to attempt to immunize calves over the age of three weeks by this method, that the resistance of baby calves is independent of the resistance or susceptibility of the dams, that additional prophylactic and therapeutic precautions must be taken in the case of adult stock and finally that there is no difference in susceptibility to heartwater between the Afrikaner breed and the two exogenous breeds of cattle available for this experimental study.

No mortality from tick-borne diseases amongst the 47 calves which recovered from heartwater, and which had also been immunized against both redwater and gallsickness occurred during the ensuing three years.

Discussion.

The results of this series of experiments furnish data of considerable value on the mortality from the major tick-borne diseases of cattle on the so-called heartwater veld of the Northern Transvaal and indicate that the measures employed for their control have been highly successful.

At the outset it must be emphasized that complete control of these diseases is dependent upon permanent rupture of at least one link in the chain of cyclical development of the disease, i.e., elimination of the arthropod vectors, elimination of the reservoir of infection of those vectors, or replacement of the susceptible host by a resistant or immune host.

1. *Elimination of the vectors.*—At present the only effective weapon for the destruction of ticks is regular systematic dipping combined with careful handdressing. It is not the intention to enter into any discussion on dipping but it must be realized that this study was initiated when it became apparent that under ranching conditions the ill effects of continued short interval dipping outweighed the benefits and that ticks were not eliminated. Whether complete control would be achieved by enforced dipping of all stock in the area is a contentious point on which adequate data are not available. At least on this particular ranch the numbers of ticks were greatly reduced but they were not eliminated.

2. *Elimination of the Reservoirs of Infection.*—All the reservoirs of infection of ticks are not known with certainty though a considerable amount of evidence on the role played by game has been collected by Neitz (1937 and 1944). In the case of redwater and gallsickness the continued presence of a reservoir may be quite unnecessary since the causal parasites are hereditary symbionts of the ticks passed from generation to generation for an undetermined length of time. Moreover, immunity to the piroplasms is of the nature of a labile infection or premunition, so that where immunization either by natural or artificial means is practised as a method of control, adequate reservoirs of infection are automatically maintained. In the case of heartwater the *Rickettsia* is not hereditary in the tick and each batch of larvae which hatch from eggs laid by either infected or non-infected engorged females must pick up infection *de novo*. It is contended that the percentage of infected nymphae and adults cannot be accounted for solely by feeding on cattle or sheep during the febrile stage of heartwater when the infectivity of the blood is known to be at its maximum. There must be other reservoirs and in this connection it is of interest to note that both the springbuck and the blesbuck are known to be susceptible (Neitz, 1937 and 1944) and recently the susceptibility of the ferret has been clearly established (Mason and Alexander, 1940). Therefore, the elimination of the reservoir of heartwater would necessitate the elimination of all game and possibly many species and genera of small carnivores and rodents. Such a goal under present conditions is hardly attainable and may be undesirable from other points of view.

3. *Replacement of the Susceptible Host by a Resistant or Immune Host.*—A possible alternative to this scheme is the development of specific chemotherapeutic treatment to a degree where it can be easily and cheaply applied by the farmer. There is a wealth of literature on the chemotherapy of redwater and gallsickness but it would be out of place to discuss that literature in detail in this article. It will suffice to say that no drug or combination of drugs is known which have a specific effect upon the *Anaplasma* but the use of mercurochrome by intravenous injection has some value in the alleviation of secondary symptoms. That therapy cannot be relied upon to control the mortality from gallsickness in a herd of susceptible adult cattle is instanced by the fact that on another farm in the Northern Transvaal an unexplained outbreak of virulent gallsickness was responsible for a mortality of 9·0 per cent. out of 421 animals in spite of the most painstaking effort to apply treatment. Eventually the outbreak was controlled by mass immunization.

In the case of redwater a number of drugs are known to have a specific action against the piroplasm, e.g., trypan blue, pirevan, acaprin, the flavins, etc. It is possible to reduce the death rate very materially but errors in diagnosis and the peracute course of virulent infections are a source of many failures. As an instance the Somerset Estates in the Northern Transvaal permit us to record the death from redwater of 75 animals constituting approximately 50 per cent. of a particular herd before effective measures could be adopted to bring a virulent outbreak under control.

In the treatment of heartwater the value of sulphonamides has recently been reported (Neitz, 1939). It is pointed out that initiation of treatment at an early stage in the course of the disease is essential, but the very nature of the disease and the difficulty of making an early diagnosis combine to

prevent this, so that, in the hands of the farmer under ranching conditions, the successful treatment of 50 per cent. of cases must be considered satisfactory.

It is apparent, therefore, that treatment of individual animals suffering from tick-borne diseases must be regarded merely as the last line of defence to be brought into action when all else has failed, and, from the discussion above, it is abundantly clear that the only single method of control which holds out hope of success is the replacement of the susceptible host by a resistant or immune host.

It is possible to immunize against redwater (*P. bigeminum*), in fact, a redwater vaccine has been issued for many years, but there are practical difficulties in the way of its successful application, which, combined with the encroachment of the antigenically dissimilar *Babesia bovis* infection (Neitz, 1941) makes immunization not entirely satisfactory. The anaplasmosis vaccine is excellent and a fuller appreciation of the immunity produced is reflected in the steady increase in the demand. However, from the data collected it is quite apparent that by intelligent adaptation of the system of animal husbandry being advocated the losses from these two diseases may be considered negligible.

The chief cause of mortality is heartwater. Up to the present no entirely satisfactory method of immunization has been elaborated but it is claimed that the methods employed in the series of experiments reported above have been attended by considerable success. In a few words the method consists of utilizing the natural resistance of calves under the age of three weeks to overcome the disease produced by the intravenous injection of infective sheep blood and thus to develop a durable active immunity, or alternatively to control the disease by the use of sulphonamides during the incubation period or during the period of detectable clinical symptoms since treatment does not appear to affect the resultant immunity.

Up to this point attention has been paid only to the production of immunity by artificial means and nothing has been said about natural immunity production or the breeding of naturally resistant animals.

From the data presented it is abundantly clear that young calves up to the age of three weeks possess a high degree of resistance to heartwater. This resistance rapidly diminishes and as exemplified by the experiment on the immunization of purebred Afrikaners, has ceased to afford adequate protection at the age of five or six weeks. If a new-born calf happens to pick up infection an inapparent disease will be the result, followed by a durable immunity. But under conditions where the tick population is small either the heartwater vector, *Amblyomma hebraem*, is not partial to engorgement on very young animals or the proportion of infective ticks is so low that young animals are not infected naturally and hence the mortality, when full susceptibility is attained, is high. The consequence is that artificial infection must be resorted to. In the case of redwater and gallsickness not merely the new born calf but young calves up to an undetermined age (unpublished experiments by Neitz) are resistant and consequently permanent immunity as a result of inapparent labile infection is the rule. This is reflected in the low mortality among adult animals born and bred in the area, and the high morbidity and mortality among introduced stock if treatment is not applied.

Brief reference must now be made to a system of animal husbandry which is frequently advocated and has many adherents to-day, i.e., the practice of dipping spasmodically at irregular intervals, if dipping is carried out

at all, to maintain a moderate tick infestation to produce immunity as a result of naturally acquired infection. There is nothing whatever to justify such a procedure which is fraught with so many dangers so readily apparent from the results of the present series of experiments. If profitable beef production over a number of years is the aim of the breeder regular dipping is essential to reduce the tick population to a minimum, because only by that procedure will losses due to heartwater, the chief cause of mortality even in conjunction with calfhood immunization, be brought within economical limits.

Recently there appeared an article by Bonsma (1944) on hereditary heartwater-resistant characters in cattle that merits review, because it appears to present data in support of a number of gross misconceptions and errors which should be corrected before they receive wide publicity. 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 observations. It is a well-known phenomenon that on heavily tick infested veld, individuals in a herd will remain practically tick free while others will be infested with innumerable ticks of all genera and species in all stages of development and in all stages of engorgement. Similarly it is a common observation that animals moved from one area to another may become so heavily tick infested that they are easily recognized in the new herd. Whether these tick repellent or tick attracting properties constitute hereditary characteristics is not known 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 dozens of ticks.

At this stage it is necessary to direct attention to a few of the many inaccuracies, misconceptions and errors in the article by Bonsma. In the first place the author appears to have no clear conception of the fundamental difference between resistance, immunity and premunition (or labile infection). Possibly he is not to be blamed for this lapse, however serious it may be, and however much it may affect the validity of the final conclusions, but no excuse can be offered for misquotation of the literature. For instance, at the end of a review of some literature on hereditary resistance to disease which may or may not be relevant the statement is made that " in the case of cattle the opinion has been held since 1849 that Zebu cattle are immune to redwater (piroplasmosis), though isolated cases of the disease occur "; also that very eminent protozoologist Yakimoff (1937) is referred to as pointing out that he could induce the disease in Zebus experimentally and that calves are more susceptible than adults. Actually Yakimoff is insistent that the mortality amongst adult susceptible Zebus in Madagascar from redwater is very heavy, that calves are relatively resistant and in his final paragraph states: " There is no basis for the conception of zootechnicians that the Zebu is resistant to piroplasms. The Zebu irrespective of the breed or location in the universe has no resistance to piroplasmosis." (Literal translation.) It is irrelevant to state that Yakimoff's point of view is not supported by Kelly (1943) who brings forward experimental evidence to show that the Zebu is more resistant to redwater than the British beef breeds and quotes American ranchers confident belief that resistance to tick fevers is proportional to the percentage of

Zebu blood in a cross. We have no accurate data on the relative susceptibility of the Afrikaner to piroplasmosis or anaplasmosis, but have shown that in a particular area in the Northern Transvaal, the chief cause of mortality is heartwater and confidently state, that the Afrikaner is no more resistant to artificially induced heartwater than the Angus or Hereford. In comparing relative susceptibility to a disease such as heartwater it is necessary to sound a note of warning that there exists a marked difference in the virulence of different strains of the virus. Consequently degrees of resistance can only be based upon records of mortality when a single strain of virus is used. In these studies great care was taken to use only the " Mara " strain. Further, any reference by Bonsma to the incidence of or mortality from redwater, gallsickness or heartwater must be discounted since diagnosis was made from symptoms and post-mortem lesions only and it can be emphasized that without resort to the microscope in skilled hands even approximate accuracy cannot be attained. At least we feel that we can agree with the opinion that there is no difference in susceptibility of calves from immune or susceptible dams and that Afrikaner cattle may show a lesser degree of tick infestation than the exogenous breeds under certain circumstances. This latter point of view is supported by Kelly (1943) who found that under ranching conditions in Northern Australia the Zebus and Zebu crosses are repellent to a degree which protects them from gross tick infestation and consequently they are not subject to the so-called tick worry. He makes no claim, however, that this tick repellence is absolute and again it is necessary to emphasize that a single tick may produce as virulent a disease as a score of ticks. For the rest we disagree with Bonsma's methods, mathematics and many of the conclusions. For instance, he concludes from his record of mortality amongst animals from birth to 27 months that in young animals the resistance to heartwater is lower. We submit that from his own figures and using his own arguments it is equally valid to conclude that the resistance of young animals is higher.

From the above it is clear that in South Africa there is no recognized breed of beef animal which is insusceptible to heartwater and in the control of this disease replacement of a susceptible host by a resistant host can only be attained by artificial immunization. The method prescribed is a practical one which can be applied by large ranching concerns, or by groups of smaller farmers. It is not possible to issue infective blood from a central laboratory for general use until some method of preservation of the virus has been evolved.

Recommendations.

It is fully appreciated that conditions in different districts and on different farms vary so much that no single system of animal management can be advocated for the control of tick-borne diseases. In the Northern Transvaal a system has been developed from the application of which encouraging results have been obtained. Briefly the salient points may be enumerated as follows:—

1. Castrate before the age of one week.
2. Immunize against heartwater before the age of three weeks.
3. Keep immunized calves under careful observation from the 12th to the 28th day so that severe reactions may be controlled by appropriate chemotherapy.

4. Immunize simultaneously against quarter evil and gallsickness at the age of three months.
5. Wean at the age of eight months.
6. Dip all animals regularly including young calves from the age of three months to reduce tick infestation to a minimum.
7. Examine all sick animals carefully in an attempt to make a diagnosis. If in doubt treat simultaneously for redwater and heartwater.

Summary.

1. A record of the number of cases of tick-borne diseases in a herd of adult cattle rather less than 1,000 in number over a period of four years is given, viz., 8 cases of anaplasmosis of which 3 were fatal, 9 of redwater of which 2 were fatal, and 79 of heartwater, of which 44 were fatal.

2. In a control group of 195 grade Angus animals under observation from birth for a period of 3½ years there occurred 48 cases of heartwater (37 fatal), 2 redwater (no deaths) and 2 gallsickness (1 death). The alarming rate at which the animals were contracting heartwater compelled the Company to deplete the herd after 3½ years for economic reasons by the sale of 125 oxen. Of the remaining 32 control animals 10 cases of heartwater (7 deaths), 2 redwater (no deaths) and 2 gallsickness (no deaths) occurred.

3. In a comparable group of 89 animals immunized against heartwater the record shows 1 case of gallsickness which was fatal, no cases of redwater, and 24 cases of heartwater of which only 11 were fatal.

4. In a grade herd 53 calves out of 1,374 = 3·9 per cent. died as a direct result of immunization.

5: In the immunized herd (1,321 grades) there were 30 cases of redwater of which 15 were fatal, 18 cases of gallsickness of which 2 were fatal and 121 cases of heartwater of which 66 were fatal.

7. There was no mortality amongst 27 adult purebred Aberdeen Angus cattle varying from 7 months to 5 years and 9 months in age as a result of immunization against heartwater and there was no subsequent mortality over a period of three years.

8. 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.

9. Heartwater is the chief cause of mortality under ranching conditions in the Northern Transvaal.

10. The control of tick-borne diseases is discussed and a system of animal husbandry suggested.

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