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Productivity of Boran cattle maintained by chemoprophylaxis under trypanosomiasis risk

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ABSTRACT

The productivity of grade Boran cattle maintained by chemoprophylaxis under severe trypanosomiasis risk was evaluated at Mkwaja Ranch, Tanzania. Twenty thousand calving records collected over a period of 10 years were analysed. It was established in an area of high tsetse challenge that, using a chemoprophylactic drug (Samorin) strategy, acceptable levels of productivity could be obtained. On average, the productivity level achieved at Mkwaja, expressed per unit of metabolic weight of cow maintained, was approximately 80% of that of Boran reared in a tsetse-free ranching environment in Kenya and was 35% greater than trypanotolerant N'Dama kept in tsetse-infested areas of West and central Africa without trypanocidal drugs.

KEY WORDS

/Tanzania//Mkwaja//trypanosomiasis//disease control//productivity data//chemoprophylaxis//trypanocidal drugs//Boran cattle//N'Dama cattle/

RESUME

La productivité du bétail de race Boran améliorée, entretenue par la chimioprophylaxie dans des conditions de grave risque de trypanosomiase, a été évaluée au ranch de Mkwaja, en Tanzanie. 20 000 recensements de vêlage couvrant une période de 10 ans ont été analysés. Il a été constaté dans une région à forte incidence de tsé-tsé que la mise en oeuvre d'une stratégie utilisant un produit chimioprophylactique (Samorin) permettait d'obtenir des niveaux de productivité acceptables. En moyenne, le niveau de productivité réalisé à Mkwaja, exprimé en unité de poids métabolique par vache, était approximativement 80% de celui des Boran élevées dans un environnement de ranching exempt de tsé-tsé et était de 35% plus grand que celui des N'Dama trypanotolérantes élevées dans des zones infestées de tsé-tsé en Afrique occidentale et centrale sans médication trypanocide.

MOTS CLES

/Tanzanie//Mkwaja//trypanosomiase//lutte anti-maladie//données de productivité//chimioprophylaxie/ /médicaments trypanocides//bovins Boran//bovins N'Dama/

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PREFACE

The major constraint to livestock development in Africa is tsetse-transmitted trypanosomiasis. Direct and indirect losses due to trypanosomiasis have been estimated to be many billions of dollars annually, and the situation appears to be deteriorating, with major tsetse advances occurring throughout the continent. Currently, efforts to control tsetse are limited by the high cost and complex logistics required; no field vaccine is available; and the increased use of trypanotolerant livestock is limited by the fact that only small numbers are available. Thus, African producers must lean heavily on the trypanocidal drugs available and must learn to use them more effectively if any significant improvements into the control of trypanosomiasis are to be made in the immediate future.

Published reports on livestock productivity under chemoprophylaxis are few in number, deal only with very small samples of animals, and usually evaluate only growth and mortality as indicators of performance. It has, however, been noted that the Mkwaja Ranch in Tanzania has over many years built up a collection of records on animal productivity and disease, probably unique in Africa.

In early 1982, discussions were held at Mkwaja between representatives of May and Baker Ltd., the International Livestock Centre for Africa (ILCA), the International Laboratory for Research on Animal Diseases (ILRAD), and staff of Amboni Ltd. It was concluded that a major, well designed study of matching productivity and health data, linked with earlier ecological and tsetse control work, would be of outstanding value. Such a study would provide the opportunity to evaluate, on a much larger scale than ever before, the effectiveness of the use of Samorin (isometamidium chloride) as a chemoprophylactic on East African cattle exposed to a severe tsetse challenge.

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SUMMARY

Chemoprophylaxis against bovine trypanosomiasis has been in widespread use in Africa for more than 30 years. However, there have been few attempts to assess its effectiveness in terms of animal performance achieved. Studies undertaken to date have usually considered only viability and growth and have tended to be on a small scale and of short duration. However, records kept at Mkwaja Ranch, Tanzania, by virtue of their completeness and volume, represented a unique and previously untapped source of information for an evaluation of the long-term effectiveness of chemoprophylaxis.

Thus, ILCA and ILRAD in collaboration with Amboni Ltd. (the owners of Mkwaja Ranch) and May and Baker Ltd., carried out an analysis of matching animal health, animal productivity and trypanocidal treatment data based on more than 20 000 calving records over the 10-year period from 1973 to 1982.

The level of tsetse challenge at Mkwaja Ranch is such that cattle cannot survive unless protected by trypanocidal drugs. Since 1964 a chemoprophylactic regime based on the use of Samorin (May and Baker Ltd., England) has been used. From 1973 to June 1980, all animals from weaning onwards were maintained under Samorin prophylaxis on a herd basis; Samorin was used at 0.5 mg/kg. Trypanosome infection was monitored by thick blood smears. One month after the last herd prophylaxis, 30 to 40 animals per herd, (herds averaged 225 to 300 animals) were tested every 1 or 2 weeks depending on a subjective assessment of the level of challenge. When approximately 20% of the sample tested was positive for trypanosomes the entire herd was treated with Samorin. In addition, individual animals that appeared sick when entering or leaving night paddocks were tested. If positive for trypanosomes and the next Samorin treatment of the herd was not yet due, that animal would be treated with Berenil (Hoechst, West Germany) at 3.5 mg/kg. All pre-weaning calves were treated at monthly intervals with Berenil. In June 1980, the criteria for herd treatment and the drug regime employed were changed. Beginning 2 months after the last prophylaxis, as soon as routine examination revealed the first positive case, all animals in a herd were treated with Berenil and then 1 week later with Samorin at 1.0 mg/kg. However, in late 1981 and 1982, only Samorin was used as Berenil was not available. The only other control measure tested was that of sterile male release of *Glossina morsitans morsitans* in a trial carried out during 1978.

Age at first calving was 47 ± 0.1 months and calving interval 15.9 ± 0.1 months. Average weaning weight at 8 months was 134 ± 0.2 kg and calf pre-weaning mortality was 8.0 ± 0.2%. The mean weight of cows, weighed approximately 10 months after their previous calf had been weaned, was 286 ± 0.1 kg while the average annual cow mortality was 5.8%. Cow productivity was 101.9 ± 0.5 kg of weaner calf per cow per year.

In order to achieve this level of productivity, an average of 4.6 Samorin and 0.7 Berenil treatments were required per animal per year. The number of treatments varied from year to year and was greater in the south of the ranch where the tsetse challenge was higher. However, age and season of calving had no effect on the number of treatments required. Despite such extensive use of trypanocidal drugs there was no indication from productivity levels of the development of drug resistance. In the same way, there was no evidence that the multiple inoculations of Samorin each animal received over the years had affected its productivity.

Infectious diseases (anaplasmosis and salmonellosis) and predators (mainly lion) were the most important causes of death. Trypanosomiasis was diagnosed in only 1% of calves necropsied,

and 3% of adults, indicating that the trypanocidal drug strategy was highly effective.

The reduction in the density of the principal vector, *G. m. morsitans* Westwood, in part of the ranch during 1978, achieved by a combined programme of insecticide application and sterile male release, had little effect on the numbers of positive blood smears or drug treatments required, but had a small beneficial effect on productivity.

Comparison of the pre-weaning growth of calves born at two locations within Mkwaja and sired by either ranch-bred bulls or selected Kenya Boran bulls through artificial insemination, allowed genotype-environment interaction effects to be examined. The use of the Kenyan sires was beneficial in the location where the overall level of performance was high, but of no advantage in the harsher location where the overall level of performance was low. This suggests that the superiority of the Kenya Boran could not be expressed in the harsher environment.

Thus, in an area where cattle if left untreated rapidly succumb to trypanosomiasis, the strategic use of the prophylactic drug Samorin every 80 days on average, allowed the cattle to survive and be productive, without the development of any drug resistance or other side effects from the use of the drug. Productivity indices built up from the important performance traits allowed not only an evaluation of the productivity at Mkwaja Ranch but permitted comparison with other livestock situations in Africa. Herd productivity was approximately 80% of that of Kenya Boran reared on trypanosomiasis-free ranches considered among the best in Africa. A similar comparison with trypanotolerant N'Dama reared in West and central Africa showed the herd productivity of the Mkwaja Boran to be 35% superior.

In conclusion, the study of the records at Mkwaja Ranch covering a 10-year period shows that with good management and an efficient trypanosomiasis monitoring programme, chemoprophylaxis is highly effective in maintaining beef cattle in areas of high tsetse challenge. The fact that this result is based on one of the largest data sets ever analysed offers immediate hope for increased exploitation of tsetse-infested areas by encouraging more widespread rational use of chemoprophylaxis as an integral part of management. These findings should also provide encouragement to pharmaceutical companies and international agencies to develop new and improved trypanocidal drugs.

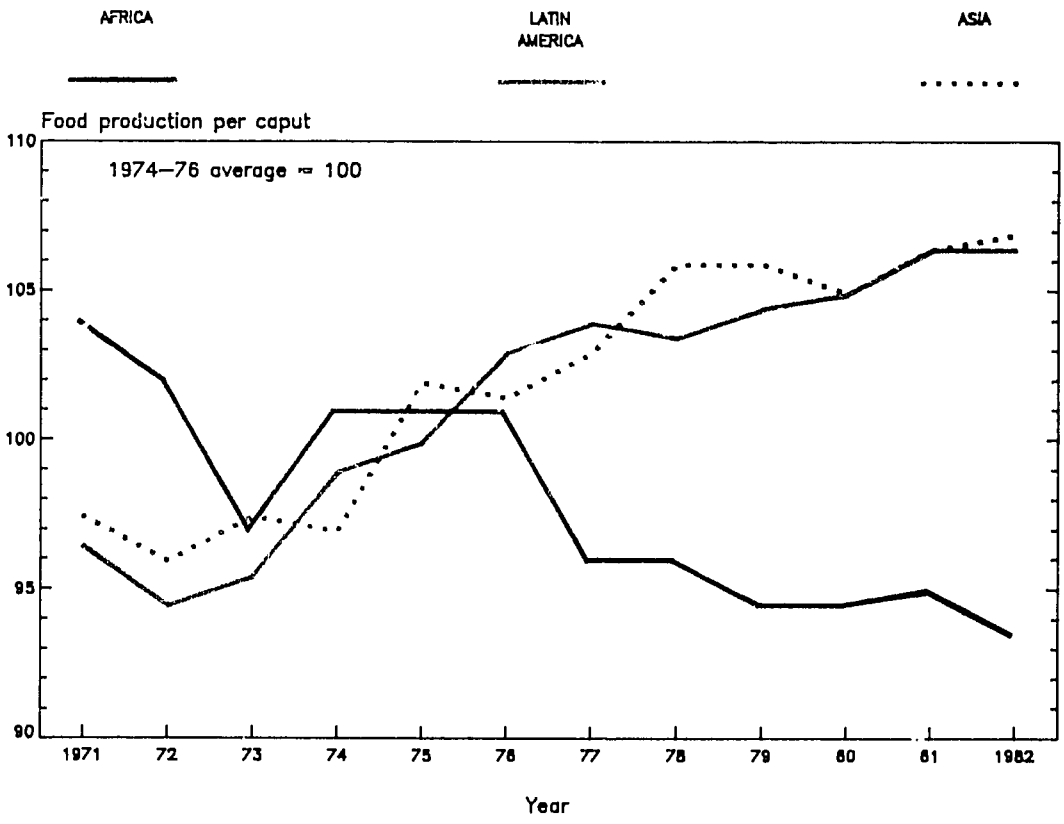
1. AFRICAN TRYPANOSOMIASIS AND APPROACHES TO ITS CONTROL

EXTENT OF THE PROBLEM

The current world human population is estimated to be 4.2 billion and is expanding by about 2% or 70 to 80 million people each year (Gavora, 1982). To deal with this increase, an additional 30 million tonnes of staple foods will be needed annually. A major way in which livestock production can be increased, and thus help meet this need, is the reduction of livestock losses due to disease. It is estimated that a 2% reduction in livestock losses due to disease would provide food for an additional 80 million people (Gavora, 1982).

The situation is most serious in developing countries where 75% of the world's population lives. It is estimated that 65 to 70% of the world's livestock resources exist in these regions, yet they account for only 30% of the world's meat output (FAO, 1975). Over the last 5 years, Africa's population has increased at twice the rate of food production and by the year 2000 will have risen

Figure 1. *The decline in food production per caput in Africa.*

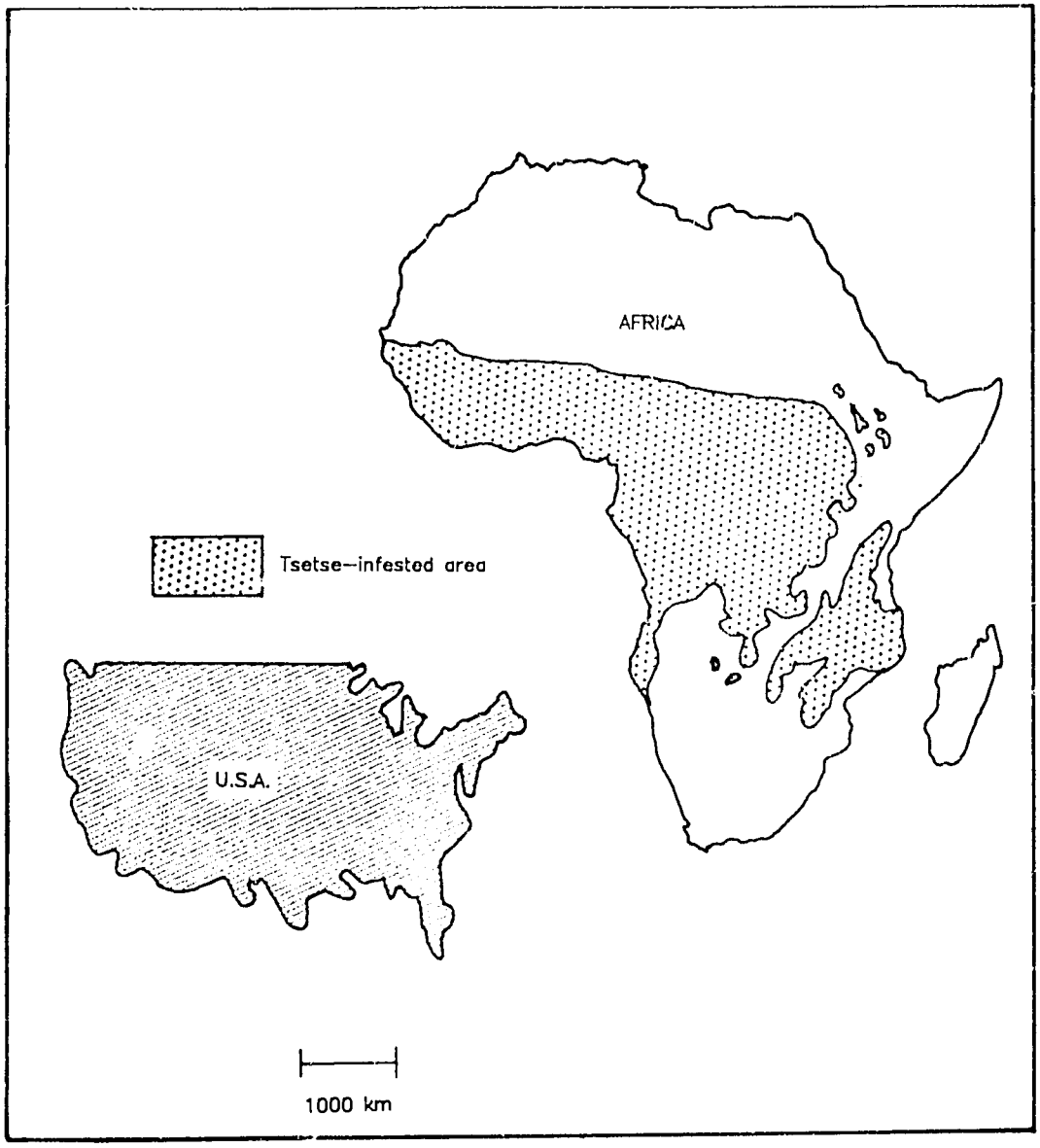


from the current estimated 470 million to 877 million (Anon, 1984). In fact food production per capita in the continent is falling compared with an overall increase in Asia and Latin America (Figure 1).

The production per unit area of animal protein is lower in Africa than in any other continent. For Africa, the estimated production of animal protein from livestock farming per 1000 hectares is 542 kg, for Latin America 4113 kg and for Europe 38 083 kg (FAO, 1975). However, Africa has vast agricultural resources which are at present underdeveloped and untapped.

The causes of this serious deteriorating situation are complex, but probably the single most significant factor is the animal African trypanosomiasis group of diseases transmitted by tsetse flies. Currently, vast humid and subhumid areas of Africa are held captive by tsetse flies and the trypanosomes which they transmit. Tsetse flies infest 10 million km^2 of Africa (Figure 2), representing 37% of the continent or about half the habitable land, and affect 37 countries (FAO/WHO/OIE, 1982). It is considered that 7 million km^2 of this area would otherwise be suitable for livestock and mixed agriculture. It is conservatively estimated that this area could support another 140 million cattle plus at least equivalent numbers of sheep and goats. Much of the best watered and most fertile land is infested with tsetse,

Figure 2. *Tsetse flies infest an area of Africa larger than the USA.*



while large areas of good grazing, most notably in the subhumid zone, could be immediately used by pastoralists if trypanosomiasis could be controlled (MacLennan, 1980).

Currently, about 30% of the 147 million cattle in countries affected by tsetse are exposed to infection (FAO/WHO/OIE, 1982). The situation for sheep, goats, pigs, horses, donkeys and camels is probably similar but is less well documented (Table 1). The presence of tsetse flies not only excludes domestic livestock from a considerable area of Africa but also causes severe losses in livestock production due to poor growth, weight loss, low milk yield, reduced capacity for work, infertility and abortion. The annual loss due to tsetse in meat production alone is estimated at US$ 5 billion (FAO/WHO/OIE, 1963). Further losses occur in milk production and in mixed agriculture where draught power and manure play a vital role. In Africa, only 20% of tractive power is mechanised (McDowell, 1977). It has been estimated that a draught ox can increase the agricultural output of a family unit six-fold (McDowell, 1977). Furthermore, the manure provided by livestock is essential for the production of both food crops and cash crops and is a source of energy in the form of biogas (McDowell, 1977). If all these factors are taken into consideration, it is estimated that the development of livestock and agriculture in tsetse-infested Africa could generate a further US$ 50 billion annually.

and goats, i.e. approximately five times as many animals could be maintained. The situation in southern and East Africa is no better, with up to 70% of the land in some countries being infested by tsetse (e.g. Tanzania). It should be emphasised that approximately 50% of the domestic livestock in the 37 countries infested by tsetse are confined to six countries in East Africa (Table 2) and that this is only possible because a large proportion of these animals exist in highland areas, above the limits of tsetse infestation.

Available data indicate that the overall situation with regard to African trypanosomiasis in domestic livestock is deteriorating. MacLennan (1980) states that since the 1950s territorial expansions of tsetse infestation in savanna areas have been prodigious and are continuing, despite regression in some areas as a result of insecticide control programmes and increased cultivation and hunting by expanding human communities. Some of the more recent advances include an area of 26 000 km^2 in Nigeria, while in Central Cameroon an advance of *Glossina morsitans* has occupied about 21 000 km^2 and, unless halted, will proceed to occupy a further 9 000 km^2 of land which at present is extensively used for agriculture. In Zambia, tsetse has extended over 11 700 km^2 in the southwest. The full extent of tsetse spread is not known but other significant advances have been observed in Botswana, Zimbabwe, Malawi, Uganda, Tanzania, Sudan,

Table 1. *Livestock populations in the 37 countries of Africa infested with tsetse fly.*

No. of animals in tsetse-infested Africa (millions)						
Cattle	Sheep	Goats	Pigs	Horses	Mules	Camels
147	104	125	8	3	9	11

Source: FAO/WHO/OIE (1982).

Countries in West and central Africa especially are severely affected by trypanosomiasis. Twenty six per cent of Africa's human population live in the 18 countries from Senegal across to Zaire, but this vast area maintains only 9% of Africa's cattle, sheep and goats (ILCA, 1979). As a result, the average livestock biomass per inhabitant in West and central Africa is only 26 kg in contrast to 136 kg for the remainder of Africa south of the Sahara and 79 kg for the continent as a whole. FAO (1974) estimates the average potential carrying capacity in this region to be 20 cattle/km^2 as compared with the current 3.4 cattle/km^2. Equivalent increases would also be possible for sheep

Ethiopia, eastern Senegal and western Mali. The greatest and most active advance of modern times is probably proceeding in southern Angola (FAO, 1979; MacLennan, 1980).

This situation is resulting in increasing pressure on tsetse-free pastures and is bound to lead to pasture degradation, a fall in output and increased production costs. Thus, the argument that the tsetse conserves Africa is not valid, and it is becoming imperative to make fuller use of tsetse-infested areas to alleviate the pressure on tsetse-free regions.

Table 2. *Populations of domestic ruminants in the East Africa region.*

Country	No. of domestic ruminants (millions)		
	Cattle	Sheep	Goats
Kenya	11.5	4.7	4.6
Tanzania	12.7	3.9	5.8
Uganda	5.0	1.8	2.2
Somalia	4.0	10.2	16.5
Ethiopia	26.1	23.3	17.2
Sudan	18.8	18.1	12.8
Total	78.1 (147)[a]	62.0 (103)	59.1 (125)
Percentage of African total	53%	60%	47%

[a] Figures in brackets give the total number of animals in the 37 countries in Africa infested with tsetse.
Source: FAO/WHO/OIE (1982).

COMPLEXITY OF THE PROBLEM

There is probably no other continent dominated by one disease to the same extent as is Africa by tsetse-transmitted trypanosomiasis. Many factors contribute to the magnitude of the problem, one of the major ones being the complexity of the disease itself. In cattle, three species of trypanosome, *Trypanosoma congolense, T. vivax* and *T. brucei* (Figure 3), cause the disease, either individually or jointly. These trypanosomes are transmitted cyclically by several different species of tsetse (genus *Glossina*) (Figure 4), each of which is adapted to different climatic and ecological conditions (Ford, 1971). While tsetse are not the only vectors of African trypanosomes, cyclical transmission of infection represents the most important problem, because once the tsetse fly becomes infected it remains infective for a long period, in contrast to the ephemeral nature of non-cyclical transmission. At the same time, trypanosomes infect a wide range of hosts including wild and domestic animals. The former, particularly the wild Bovidae and Suidae, do not suffer severe clinical disease but become carriers and constitute an important reservoir of infection (Murray et al, 1982). The success of the trypanosome as a parasite is to a large extent due to its ability to undergo antigenic variation, i.e. to change a single glycoprotein (Cross, 1975) which covers the pellicular surface, thereby enabling evasion of host immune responses and the establishment of persistent infections. Added to the complexity of multiple variable antigen types expressed during a single infection, each trypanosome species comprises an unknown number of different strains, all capable of elaborating a different repertoire of variable antigen types (Van Meirvenne et al, 1977).

For these reasons, no vaccine is available for use in the field, and the current control measures, which involve tsetse control or the use of trypanocidal drugs, have been limited in their efficacy.

Figure 3. *African trypanosomes.*

Figure 4. *Tsetse fly.*

However, recent developments in the understanding of tsetse biology, antigenic variation, host susceptibility and immune responses, and in the strategic use of drugs currently available, means that all these approaches must be re-evaluated with a view to improving the control of trypanosomiasis in domestic livestock.

CONTROL OF THE PROBLEM

Tsetse control

Attempts to control tsetse have been made for over 60 years. Initially, they included eradication of wildlife, clearing of fly barriers to prevent the advance of the vector and widespread bush clearing to destroy breeding habitats. Following the introduction of modern chemicals, the principal method employed to control tsetse populations has been the use of insecticides, alone or in conjunction with traps and screens. Biological control methods are still under development and consideration.

Insecticides. The use of insecticides is the major method currently employed for tsetse control. The insecticides used fall into two categories, residual and non-residual. Residual insecticides (DDT and more recently dieldrin) are usually applied using hand-operated sprays that deliver the insecticide to sites where resting tsetse are known to alight. Ideally, the persistence of the insecticide should be sufficient to make only one application necessary. Non-residual insecticides require several applications; at present, endosulphan is the insecticide most frequently chosen. However, new synthetic pyrethroids which are 50 times more toxic to tsetse than endosulphan are currently being developed and tested. Non-residual treatments are applied mainly by fixed-wing aircraft or helicopters. Recent advances in the techniques of aerial spraying have resulted in better use of sprayed insecticides, by using fixed-wing aircraft against savanna species of tsetse and helicopters against tsetse inhabiting gallery forests and riverine areas. There has been significant success where insecticide control measures are properly implemented. For example, using residual sprays applied by hand-spraying machines nearly 200 000 km^2 of Nigeria have been cleared of *Glossina morsitans*. Control of tsetse by insecticides has also achieved notable success in Zimbabwe, Botswana and Zambia.

Despite the proven efficacy of tsetse control by insecticides, major tsetse advances are occurring in West, central, East and southern Africa. This is due to the severe limitations of this approach on practical, economic and environmental grounds. Currently in Africa, there is a lack of trained personnel, both at the leadership and field levels, to implement insecticide control programmes. The costs of insecticide control programmes are high, being approximately US$ 800, US$ 400, and US$ 2000/km^2 for ground, fixed-wing aircraft and helicopter spraying respectively. Natural or man-made barriers are required to defend sprayed areas and prevent reinvasion, and constant surveillance for early detection of reinvasion is essential. Finally there are increasing demands to limit the use of insecticides because of their detrimental effect on naturally occurring fauna and flora.

Current research on insecticides involves the development of new potent chemicals with low toxic environmental effects e.g. synthetic pyrethroids such as permethrin, cypermethrin and decamethrin. In addition, the techniques of aerial spraying are being improved through studies of droplet size, rate of delivery and extent of dispersion.

Use of traps and screens. Traps and screens have been used for many years as means of sampling tsetse populations. However, with recent developments in the design and colour of traps and with the identification of tsetse attractants, increasing interest is being given to the use of traps as a possible method of tsetse control. It has been found that bovine breath acts as a powerful attractant for tsetse, with carbon dioxide and acetone being its major components (Vale, 1980). Colour is also an important attractant with responses of tsetse to yellow, green and blue being in the ratio of 1 to 10 to 150 respectively. Insecticide-impregnated traps have produced good results on a limited scale in Burkina Faso and Ivory Coast as a means of tsetse control in areas where human sleeping sickness is common. In Zimbabwe, it has been shown that the use of traps in combination with attractants leads to the capture of large numbers of *G. m. morsitans* and *G. pallidipes*. The use of improved traps impregnated with insecticide could develop into a simple and relatively cheap method of control, although it must be emphasised that this approach has yet to be proved effective in the field or with species of tsetse other than *G. m. morsitans* and *G. pallidipes*.

Biological methods. The concept of 'sterile male release' is based on the fact that tsetse females copulate only once, and if the male of a copulating pair is sterile the female will not produce during her lifetime. Thus, a series of field trials were carried out to evaluate the impact of the release of γ-irradiated male tsetse on tsetse

populations. Trial work was carried out at Mkwaja Ranch in Tanzania and in Zimbabwe, Burkina Faso, Nigeria and Zambia. Although under field conditions it has been demonstrated that this approach can significantly reduce tsetse populations, the majority opinion is that sterile male release is not a practical proposition because it is too sophisticated and too expensive. It is also estimated that ten sterile males are required per female. In order to reduce the number of sterile males required it is necessary to carry out two to three insecticide sprays and then to release 12 000 sterile males per km^2, even in areas where the tsetse density is low. The cost of this method is estimated to be US$ 3000 to US$ 4000 per km^2. As the effect is tsetse-species specific, the cost increases with the number of species to be controlled.

Variation in susceptibility to trypanosome infection has been reported with certain strains of tsetse and consideration is being given to the development of tsetse which are refractory to infection. Research is also being carried out on the isolation of pheromones (sex hormones) and their characterisation for use as attractants in traps. Insect growth regulators have been identified with a view to their use as biological insecticides which would have no undesirable side-effects on humans or their environment. Enzymes in tsetse saliva and gut are also being identified with a view to using them as immunogens to vaccinate the host against tsetse. A further approach is the search for predators, parasites or pathogens which might serve to control tsetse populations. All these investigations are at a very early stage of development and much has to be done before they can be considered as possible methods of control.

Future prospects for vaccination

There is no evidence that immune responses against antigens common to trypanosomes contribute to host protection. Thus, the major constraint to the development of a commercially applicable vaccine against trypanosomiasis is the phenomenon of antigenic variation, as it is now well established that host protective responses are effected by antibodies directed against surface coat antigens of the trypanosome (Murray and Urquhart, 1977). The repertoire of these antigens generated by bloodstream forms of the parasite is large, with the result that the development of a field vaccine has been considered an impossibility.

However, there is now evidence to indicate that the repertoire of antigens produced by metacyclic parasites following transmission through the tsetse is much more limited (Crowe et al, 1983). Thus, it has been possible to immunise cattle against tsetse-transmitted homologous (but not heterologous) strains by prior exposure to metacyclic parasites which have been propagated in tissue culture, or by prior infection via tsetse flies followed by trypanocidal drug treatment (Morrison et al, in press). The immunity produced has been shown to last for as long as 5 months. Nevertheless, the feasibility of production and the efficacy of a vaccine against metacyclic trypanosomes will depend on the relative stability of the metacyclic antigen repertoire for each species of trypanosome and on the number of strains which occur in the field. Current research is directed towards these objectives. It is thought, however, that the number of strains of *T. congolense, T. vivax* and *T. brucei* is likely to be prohibitively large for the production of a 'cocktail' vaccine containing the appropriate metacyclic antigens. As a result the development of a conventional vaccine against African trypanosomiasis is unlikely in the foreseeable future.

Trypanotolerance

It has long been recognised that certain breeds of cattle in West and central Africa, mainly the N'Dama and West African Shorthorn, along with their sheep (Djallonke) and goat (Dwarf West African) counterparts, possess the ability to survive and be productive in tsetse-infested areas where other breeds rapidly succumb to trypanosomiasis (ILCA, 1979; Murray et al, 1982). However, it was only recently that the potential of these breeds was fully appreciated when it was established that they are much more productive than originally thought (ILCA, 1979) and that their trypanotolerance is an innate and not merely an acquired characteristic (Murray et al, 1982). As a result, increasing attention is being paid to the more widespread use of trypanotolerant breeds, especially in the tsetse-infested humid and subhumid areas of West and central Africa.

One of the major constraints to the more widespread use of trypanotolerant breeds of cattle is the limited number of animals available. At present, there are about 3.4 million N'Dama and 1.8 million West African Shorthorn, with the result that the current demand for N'Dama heifers and bulls greatly exceeds the number available for distribution. Furthermore, the cost of transport over great distances, along with the period of acclimatisation required for adaptation to different environmental conditions, means that a long-term investment is needed before any significant

development and economic returns can be expected.

It must also be emphasised that the degree of trypanotolerance can be influenced by a number of factors, one of the most important being the level of tsetse challenge. It has been shown that as the level of challenge increases, productivity falls (Table 3) and that when tsetse challenge is high N'Dama can suffer severely from trypanosomiasis as judged by stunting, wasting, abortion, extreme lethargy leading to reduce ability to work and even death.

Thus, trypanotolerance is not a refractory state and it is essential in tsetse-infested areas to consider the strategic use of trypanocidal drugs in order to realise the full potential even of trypanotolerant breeds.

Table 3. *Influence of level of tsetse challenge on productivity of trypanotolerant cattle, West and central Africa, 1977–78.*

Level of tsetse challenge	No. of herds	Productivity index[a] (kg)
Zero	3	40.1
Low	13	31.9
Medium	10	23.2
High	4	18.8

[a] Total weight of 1-year-old calf and liveweight equivalent of milk produced per 100 kg of cow per year.

Source: ILCA (1979).

Trypanocidal drugs

Escalating costs and other problems (discussed above) of initiating and maintaining tsetse control campaigns, together with the non-availability of a vaccine, have led to the livestock industries in the vast tsetse-infested areas of Africa being almost completely reliant on the use of trypanocidal drugs to both treat and prevent the disease. Without these drugs, the situation would be disastrous. However, despite the need and demand for effective trypanocides, no new drug has been produced for commercial use in the last 25 years[1]. As far as the treatment of cattle is concerned, only "Samorin" (isometamidium chloride – prophylactic), "Berenil" (diminazene aceturate – therapeutic) and "Novidium" or "Ethidium" (homidium chloride or bromide – therapeutic) are commercially available and there would appear to be no immediate prospects for new compounds for commercial use. None of the new compounds which have been identified in recent years has been found to be as effective in practice as those currently available. In fact over the last 10 years there have been increasing reports of the successful use of Samorin as a prophylactic, in combination with Berenil as a therapeutic.

Samorin has been successfully employed to control trypanosomiasis in exotic cattle in Kenya (Mwongela et al, 1981) and Zebu cattle in Kenya (Wilson et al, 1975), Tanzania (Blaser et al, 1979; Wiesenhutter et al, 1968), Ethiopia (Bourn and Scott, 1978) and Mali (Logan et al, 1984). In Mali, it was concluded that the economic losses caused by death and decreased weight gain in cattle treated with Berenil indicated that even in areas where the tsetse challenge was marginal and the incidence of trypanosomiasis relatively low, it paid to use a prophylactic programme with isometamidium chloride. Despite this considerable body of experimental evidence, the amount of trypanocidal drugs used in Africa is small in relation to the number of animals at risk. Currently, the number of doses employed is around 25 million (Le Roux, pers. comm.). This is despite the fact that a possible 50 million cattle, 30 million sheep and 40 million goats are estimated to be exposed. Even if animals were treated only twice a year, 240 million doses would be required, ten times the number currently used. The reasons for failure to make better use of the trypanocidal drugs available are complex but include:

a. Lack of precise information on the importance of the impact of trypanosomiasis on livestock production. Too often, widespread morbidity and mortality due to trypanosomiasis are attributed to poor nutrition. As a result, insufficient funds are allocated by governments for the purchase of trypanocidal drugs.

b. The belief that the cost of trypanocidal drugs and of their use is high. This is a reasonable but probably unfounded assumption as there is little published information on the economics of use of trypanocidal drugs on livestock production.

c. The belief that repeated use of the same trypanocidal drugs must lead to drug resistance. This conclusion is supported by several field reports of the development of parasitaemia within a few weeks of treatment, an observation usually taken as evidence of drug resistance. While this may be true, it is equally

[1] Recently quinapyramine sulphate and prosalt have been reintroduced; however the special advantage of quinapyramine salts is against infections due to *T. evansi*.

likely to be the result of a relapse from a privileged site in the host to which the drug has no access, or to reinfection, or to underdosing. Weigh scales, and even weighbands, are frequently not available to allow accurate dose computation. Undoubtedly, true drug resistance does occur in terms of reduced parasite sensitivity to the drug (Pinder and Authie, 1984) and it must be given serious consideration where extensive use of trypanocidal drugs is being made or considered. However, to date there is little evidence that drug resistance is a problem in situations where management of the drug regime is good, even when the drug has been used over long periods of time.

In conclusion, the cost of tsetse control, the lack of a field vaccine and the limited prospects of new families of trypanocidal drugs appearing in the next 5 years make reliance on the trypanocidal drugs currently available an unavoidable necessity. It is therefore essential, firstly that their effectiveness be clearly demonstrated under different systems of management and various levels of tsetse challenge, and secondly that the risk of drug resistance be reduced.

It has been noted by a number of authors that the Mkwaja Ranch in Tanzania has over many years built up a collection of records on animal productivity and disease, probably unique in Africa. In early 1982, discussions were held at Mkwaja between representatives of May and Baker Ltd., the International Livestock Centre for Africa (ILCA), the International Laboratory for Research on Animal Diseases (ILRAD), and staff of Amboni Ltd. It was concluded that a major, well designed study of matching productivity and health data, linked to previous ecological and tsetse control work, would be of outstanding value. This would provide the opportunity to evaluate on a large scale the effectiveness of the use of Samorin (isometamidium chloride) as a prophylactic on grade Boran cattle exposed to a severe tsetse challenge.

2. MKWAJA RANCH

HISTORY

Mkwaja Ranch was established in 1954 by Amboni Ltd. with the intention of supplying the labour force on their sisal estates with meat. Prior to Amboni acquiring the lease, the land had been more or less untouched bush for many years. Local female East African Zebu (Figure 5) were purchased from the Central Province and Boran bulls were imported from Kenya. Since this time ranch-bred bulls, together with semen obtained from Boran bulls at Kabete Artificial Insemination Centre, Kenya, have been used and therefore the herd can now be considered as grade Boran (Figure 6).

A major factor in the establishment of the ranch was the availability of the prophylactic drug Antrycide prosalt (a mixture of quinapyramine chloride and sulphate, Imperial Chemical Industries Ltd.) which, for the first time, allowed susceptible cattle to be maintained in tsetse-infested areas of East Africa. The original objective was to rely on a chemoprophylactic regime only in the short term. It was envisaged that the profit realised during this period could be used to offset the costs of tsetse, and hence trypanosomiasis, elimination. This was to be achieved by a combined programme of establishing a barrier of cleared vegetation around the ranch, erecting

Figure 5. *Small East African Zebu cattle.*

Reproduced with permission from *Advances in Parasitology*, Academic Press.

Figure 6. *Grade Boran cattle at Mkwaja Ranch.*

game fencing, and eliminating the vector within the barrier by use of insecticides, game shooting, selective clearing and controlled burning.

Thus, a barrier 1 km wide was established around the northern area of the ranch and tsetse control programmes were implemented. However, the results achieved were not the positive ones expected. The two main problems were the unexpected speed with which the vegetation in the cleared barrier regenerated, and the difficulty of identifying tsetse foci which prevented effective action being taken against them. Goats were introduced into the barrier in an attempt to control regeneration of bush, but with very little effect.

By 1957, the tsetse-trypanosomiasis policy had already been modified, when it was decided that, with the use of prophylaxis, it was possible to have a viable operation with a reduced fly population. The selective clearing operations were discontinued but insecticidal spraying around handling facilities and along the Msangasi River was undertaken intermittently in an effort to limit the fly challenge. In 1959, efforts to maintain the barrier ceased and it was opened up for grazing. Thus the goal of tsetse eradication was, at least temporarily, abandoned and a shift to a policy reliant upon a combination of the prophylactic Antrycide, complemented by limited efforts to control the tsetse population, took place.

Concern over the possibility of drug resistance led to a switch from a prophylactic to a curative regime using Berenil during the period 1962 to 1964. By 1964 the combined approach of controlling the tsetse population by spraying and of controlling trypanosomiasis by the use of Berenil was abandoned and a new prophylactic regime, backed up by Berenil, was adopted. This came about partly because the costly spraying programme was thought to be having a negligible effect, but mainly because a field experiment with the newly available Samorin had proved successful.

A chemoprophylactic regime based on Samorin has now been in operation at Mkwaja for nearly 20 years, and apart from the sterile male field trial described below, no efforts have been made to control the vector.

Ford and Blaser (1971) discuss at some length the ecological impact of stocking the ranch on its vegetation. The stable equilibrium of flora and fauna that had previously existed in the area was destroyed by the introduction of a large biomass of primarily grass-eating cattle. This resulted in less grass being available to fuel the fires which were an important factor in restricting the spread of woody vegetation and maintaining open grassland. The result at Mkwaja was therefore a reduction in the grazing area as doum palms (*Hyphaene* sp.) and *Acacia zanzibarica* prolifer-

ated. This led to 'overstocking' and the accompanying decline in productivity discussed below. The ranch management realised by 1964/65 that bush encroachment was a major problem, possibly a greater one than that of disease.

In 1967 an extensive programme of bush clearing was started in the northern area of the ranch, and between 1967 and 1975 more than 6500 ha of primary bush was cleared. This was achieved using D7 caterpillars and Fleco brushcutters. Regeneration of cleared areas was tackled with small D4 caterpillars and Marden brushcutters for heavy regrowths, or by hand slashing followed by application of arboricide for lighter regrowths. Doum palms were killed by the application of diesel fuel into their hearts. This intensive period of bush clearing ended when all available effort was directed to the construction of a fly-barrier prior to a sterile male tsetse field trial. On completion of this project, major mechanical bush clearing was again undertaken and between 1978/79 and 1980/81 a further 2900 ha were cleared. By 1981 approximately 50% of the 19 500-ha northern area had been cleared of its original vegetation, and it is envisaged that this effort will continue as resources become available. Table 4 shows the area of primary bush cleared by year. No bush clearance has been attempted in the southern area.

As part of a pasture improvement trial undertaken by the Swiss Federal Institute of Technology, goats were imported into the ranch in 1975, with the objective of using them to control regeneration of woody vegetation. The authors of the report of this trial were enthusiastic about the use of goats in controlling regrowth, but the ranch management does not believe they were really effective (Kloetzli et al, 1981). Although goats are believed to be less susceptible to trypanosomiasis than cattle they were maintained on a drug regime similar to that adopted for the cattle on the ranch, with the twin objectives of minimising losses due to trypanosomiasis and of preventing the goats from acting as a trypanosome reservoir.

Table 4 *Primary bush cleared in the northern area of Mkwaja Ranch, 1967–81.*

Year[a]	Area cleared (ha)
1967/68	260
1968/69	759
1969/70	503
1970/71	1244
1971/72	1186
1972/73	117
1973/74	773
1974/75	1937
1978/79	1210
1979/80	485
1980/81	1184
Total	9658

[a] Financial year i.e. April to March.

Although originally steers were fattened at Mkwaja, the ranch is now effectively a breeding unit, calves being transferred at weaning to better grazing elsewhere. This approach was adopted because of two factors. Firstly, the final weight that ranch-fattened steers achieved began to decline in the mid-1960s. Ford and Blaser (1971) attributed this to 'overstocking', although they argued that the situation was more complex than simply having too many cattle on the ranch. "If the ranch was overstocked", they said, "it was overstocked with trees, shrubs and wildlife and not with cattle". If all woody vegetation except that required for timber, shade or windbreaks could have been removed and prevented from regeneration they estimated that the ranch could support 20–40% more than the peak cattle population reached in 1965/66 i.e. as many as 20 000 animals. The problems of eliminating bush however are considerable and the decision was made to transfer calves at weaning to Amboni's sisal estates. Secondly, in parts of Amboni's sisal estates where sisal growth was unsatisfactory, its cultivation had been discontinued and good quality pasture developed instead. Although tsetse are present on the estates, the challenge is less than that known to exist on the ranch.

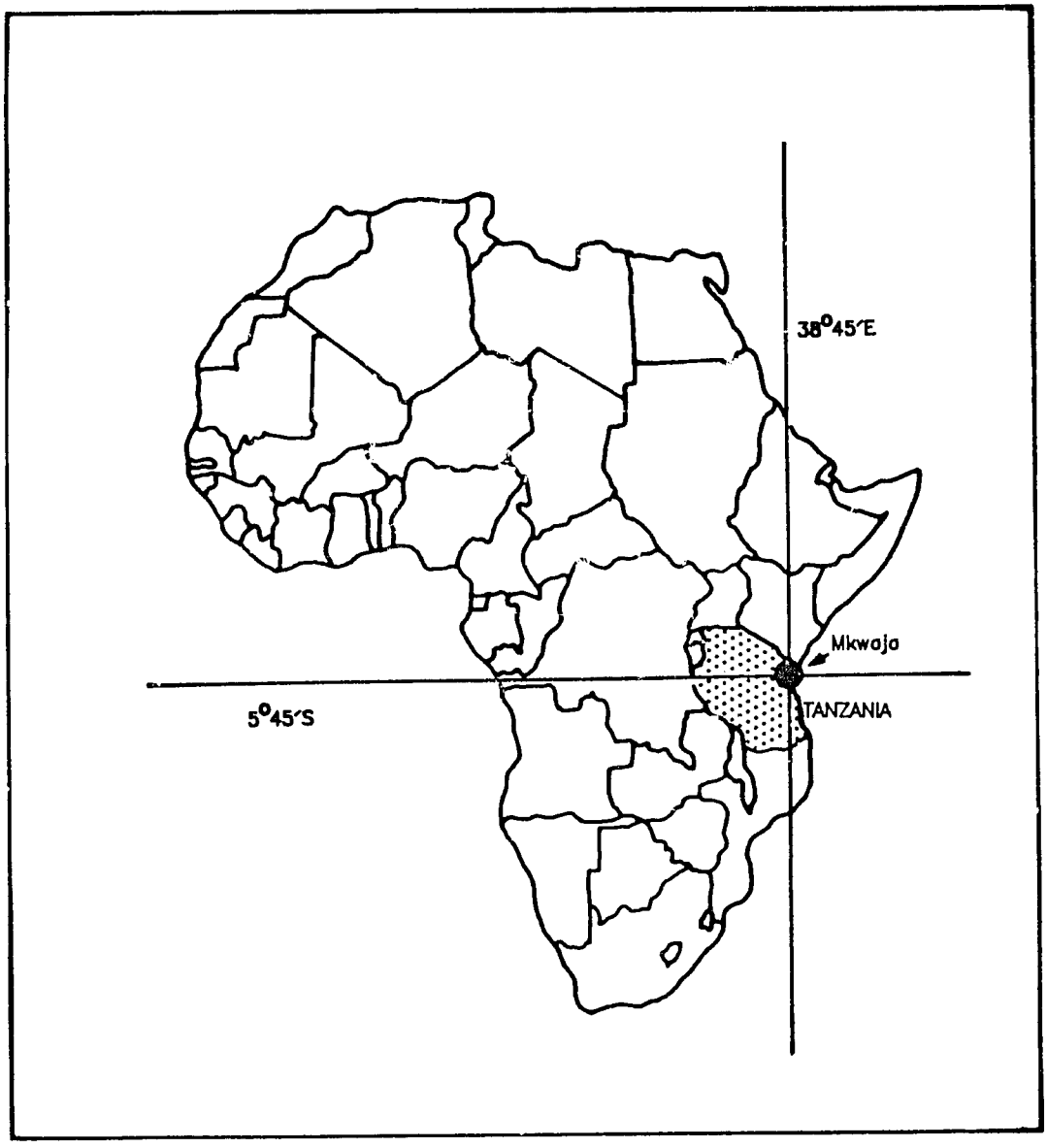
ENVIRONMENTAL FEATURES

Mkwaja Ranch is located on the Tanzanian coast in Pangani District about 100 km south of Tanga (Figure 7). The ranch covers an area of approximately 47 250 ha. Its southern boundary follows the Mligaji River, the eastern boundary lies up to 8 km from the coast and the western boundary follows the line of the Ruvu-Mnyusi railway.

Climate

Mean annual rainfall measured at the ranch headquarters for the period 1972 to 1982 was 1055.8 mm with a range of 613.8 to 1444.5 mm (Table 5) and for the 20-year period of 1964 to 1983 was 997.6 mm. Rainfall is bimodal with the long rains normally occurring from March to May and the short rains from October to December.

Figure 7. *Location of Mkwaja Ranch, Tanzania.*



The latter failed in 3 consecutive years (1974 to 1976) during the study period.

Mean monthly maximum and minimum temperatures for the period 1972 to 1982 measured at the ranch headquarters are shown in Figure 8. Monthly maximum temperatures ranged from 32.1°C in March to 28.7°C in July, while corresponding minimum temperatures ranged from 24.5 to 20.9°C.

Soils and vegetation

Soils on the ranch are mainly sandy loams of low nutrient content and exchange capacity, overlying coral rag, with heavy alluvial blackcotton clays in the valleys and flood plains. The vegetation at Mkwaja has been extensively described (Skovlin and Williamson, 1978; Kioetzli et al, 1981), but in summary can be characterised as coastal forest-savanna mosaic (Figure 9). Although substantial areas of the northern area have been cleared of primary vegetation, all parts of the ranch have adjacent gallery forest, scrubby areas or wooded pastures. There are large areas of wooded grassland with vigorous growths of doum palm and *Acacia zanzibarica*. The ranch manager estimates that 75% of the ranch is available for grazing, the remainder either having too dense vegetation or consisting of steep-sided ravines.

Table 5. *Total annual rainfall, total and mean monthly rainfall, and number of rain days by season at Mkwaja Ranch headquarters, 1972–82.*

Year	Total annual rainfall (mm)	Season 1 (January to February)			Season 2 (March to May)			Season 3 (June to September)			Season 4 (October to December)		
		Total rainfall (mm)	Mean monthly rainfall (mm)	No. of rain days	Total rainfall (mm)	Mean monthly rainfall (mm)	No. of rain days	Total rainfall (mm)	Mean monthly rainfall (mm)	No. of rain days	Total rainfall (mm)	Mean monthly rainfall (mm)	No. of rain days
1972	1002.5	86.6	43.3	4	577.2	193.7	37	77.3	19.3	10	261.4	87.1	12
1973	1018.4	59.5	29.8	7	561.4	187.1	23	69.2	17.3	12	328.3	109.4	10
1974	668.1	27.0	13.5	3	384.8	128.3	26	165.6	41.4	22	90.7	30.2	13
1975	826.1	29.9	15.0	5	441.7	147.2	35	186.6	46.7	22	167.9	56.0	17
1976	613.8	22.4	11.2	4	428.6	109.5	25	175.7	43.9	24	87.1	29.0	11
1977	1305.9	137.8	68.9	11	245.2	81.7	26	402.1	100.5	20	520.8	173.6	25
1978	1377.3	172.0	86.0	12	556.5	185.5	36	138.0	34.5	16	510.8	170.3	33
1979	1288.6	312.8	156.4	15	568.8	189.6	33	162.3	40.6	17	244.7	81.6	18
1980	928.3	138.1	69.1	5	263.5	87.8	18	82.8	20.7	15	443.9	148.0	23
1981	1140.4	20.7	10.4	4	620.8	206.9	41	124.5	31.1	14	374.4	124.8	20
1982	1444.5	0.0	0.0	0	524.6	174.9	32	279.8	70.0	37	640.1	213.4	27
Mean	1055.8	91.5	45.8	6.4	461.2	153.8	30.2	169.4	42.4	19.0	333.6	111.2	19.0
Season category		Dry			Long rains			Dry			Short rains		

Figure 8. *Mean monthly maximum and minimum temperatures at Mkwaja Ranch headquarters, 1972-82.*

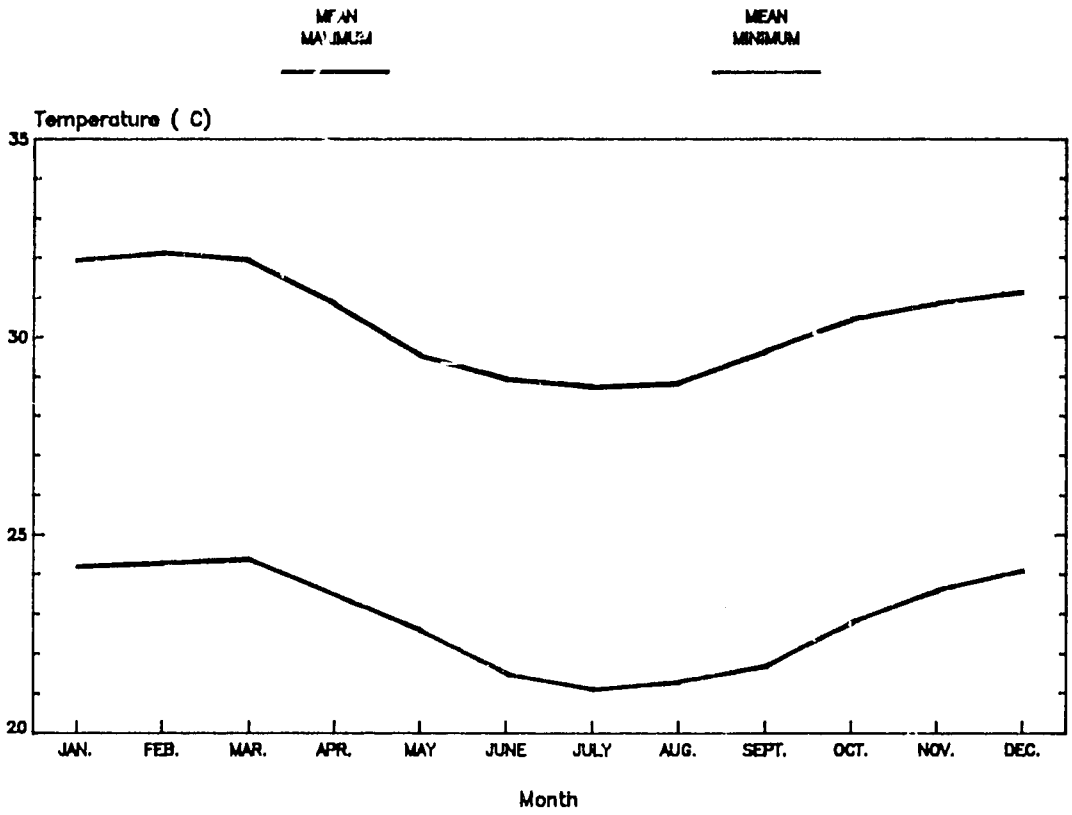


Figure 9. *General view of the Mkwaja Ranch environment.*

Wild fauna

The range of wild mammals present is extensive, particularly in the southern area, including, in order of probable abundance, warthog, waterbuck, bushpig, reedbuck, bushbuck, baboon, buffalo, duiker, dik dik, sable antelope, hartebeest, giraffe, hippopotamus, kudu and porcupine (Gates et al, 1983). Predators include lion (Figure 10) and hyena and very occasionally wild dog. Leopards were previously present but have been eliminated by trapping. It is estimated that wildlife represents about 25% of the animal biomass on the ranch (Skovlin and Williamson, 1978).

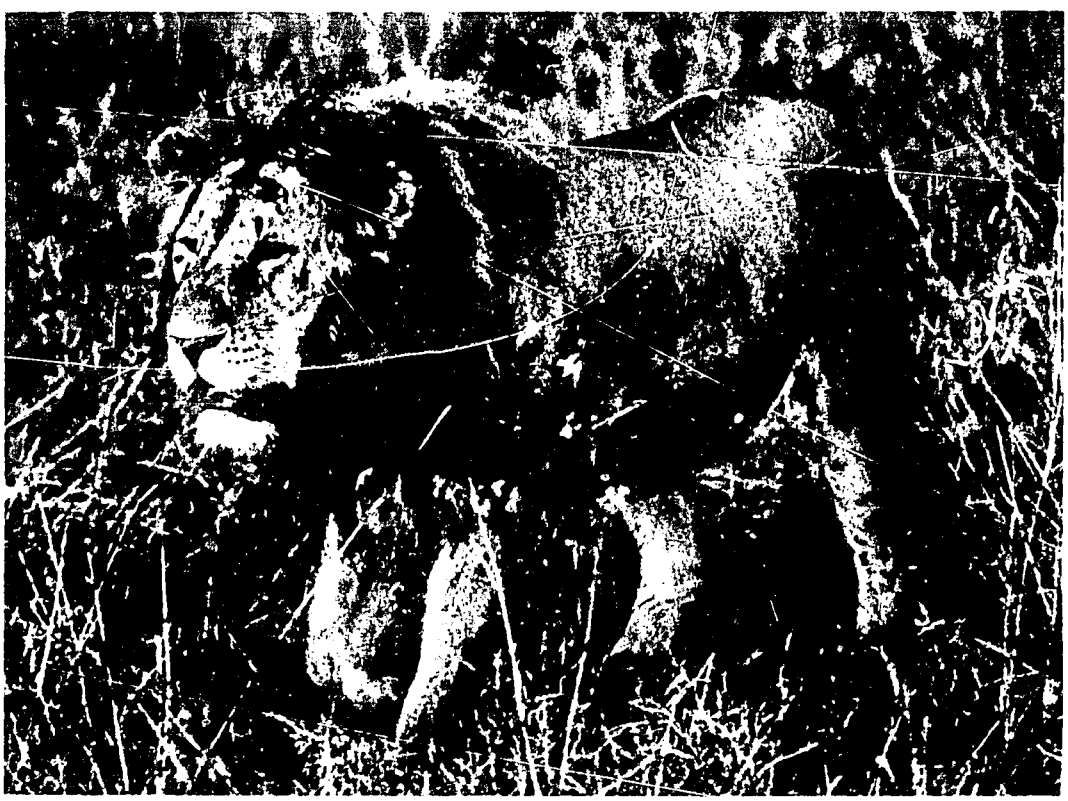
VECTORS AND TRYPANOSOMES

Three species of tsetse flies were identified by the extensive survey carried out in 1976/77. These were *G. m. morsitans* Westwood, *G. pallidipes* Austen and *G. brevipalpis* Newstead (Gates et al, 1983). Previous unpublished surveys conducted in 1957/58 did not detect *G. m. morsitans* but did encounter *G. austeni*. It is possible that *G. austeni* is still present, but the species was not detected in the recent survey, possibly because of the fly collection technique used – a moving black screen rather than bait oxen. *G. m. morsitans* has almost certainly invaded Mkwaja since the early 1960s.

The distribution of the three species varies throughout the ranch. In the 1976/77 survey *G. m. morsitans* and *G. pallidipes* were most commonly found in the same location, but in some habitats only one species was present. Areas of relatively open woodland characterised by a predominance of medium to large isolated trees and only small (50–100 m^2) thickets, were favoured by *G. m. morsitans*. Interiors of large (25 ha and more), dense thickets contained only *G. pallidipes*. More frequently both species have been found in the same location, typically where a flyround passed through open woodland within 20–30 m of the larger thickets.

The years 1969 to 1976 had below average rainfall and by the end of this dry period *G. brevipalpis* was confined to riverine gallery forest where there were permanent pools of water. Both 1977 and 1978 were years of above average rainfall and in mid-1978 the first *G. brevipalpis* found away from the riverine habitat were caught in dense forest 4 km from the nearest permanent water. Fly numbers gradually increased and within 2 years of the onset of the heavy rains, *G. brevipalpis* was being found in addition to *G. m.*

Figure 10. *The main predator at Mkwaja Ranch.*



morsitans and *G. pallidipes* in semi-open woodland up to 300 m from forest.

At the end of 1977, estimated densities (males per km^2) of *G. m. morsitans* were 630 and 1080 and of *G. pallidipes* 255 and 265 in the northern and southern areas respectively. Bush clearing at Mkwaja has concentrated on more open woodland in the northern part of the ranch. The habitat of *G. m. morsitans* has therefore been considerably reduced in this area, accounting for its lower apparent density compared to the southern area. The habitat of *G. pallidipes* has remained virtually untouched throughout the ranch and the apparent densities of this species are similar in the northern and southern areas.

Between February and May 1976 engorged *G. m. morsitans* and *G. pallidipes* were captured for an analysis of their food sources. Although the 12 000 head of cattle on the ranch were estimated to represent 75% of the 'animal biomass', they accounted for only 5.6% of the total blood meals. The host species are shown in Table 6, reproduced from Tarimo et al (1983).

Trypanosomiasis is endemic and more than 37 000 blood slides examined over a 10-year period have shown that *T. congolense* is the most commonly detected species (93%) followed by *T. vivax* (6%) and *T. brucei* (1%). No data are available concerning fly infection rates. Biting flies other than tsetse, including Tabanids and *Stomoxys* are also present and mechanical transmission of trypanosomiasis cannot be ruled out.

RANCH MANAGEMENT AND PRODUCTION METHODS

Internal organization

The ranch is divided into two blocks of roughly equal area (Figure 11). The northern area is surrounded by the remnants of the fly barrier and contains the ranch's administrative and workshop facilities. Approximately 50% of the northern area has been cleared of its primary vegetation, while the southern area is still in its natural state, modified only by grazing pressure. For administrative purposes the ranch is divided into nine sections, six in the northern area and three in the southern area. Each section is equipped with water dams, dips and spray-races for the control of tick-borne diseases, and handling facilities. A veterinary guard supervises health procedures of all the herds in each section.

At the ranch headquarters are based a veterinary surgeon who also acts as ranch manager, a microscopist, and personnel engaged in record keeping, administration and maintenance. Facilities include offices, stores for drugs, chemicals and fuel, a workshop, a diesel generator, a radio link with Amboni Ltd. at Tanga, a weighcrate, handling facilities and a slaughterhouse. The ranch has its own station, with cattle-loading facilities, on the Ruvu-Mnyusi railway, which is a link line between the Tanga-Moshi and Dar-es-Salaam-Kigoma mainlines, and therefore transport of animals by rail is relatively easy.

Herding

Heifers and breeding cows are kept in about 20 herds ranging in size from 225 to 300 head. Each herd is given a name and records show the location of herds within the ranch on a month-by-month basis. When the number of animals in a herd drops below 200, due to culling and natural mortality, herds are amalgamated to bring the number back up to between 225 and 300. Each herd has its own night paddock and herdsmen keep watch at night to deter predators. During the study period the breeding herd averaged 4800 cows and 180 bulls. Except when health or other routine procedures require animals to be handled, herds are turned out to graze at 06.00 hours and return to their night paddocks at about 18.00 hours. No supplementary feed is supplied to any animals. Mineral licks were used until 1979. All animals are watered once a day prior to returning to their night paddocks. Rain water is collected and stored in around 30 earth dams that have been constructed throughout the ranch. The possibility of using bore holes has been investigated, but both near-surface and deep bore holes are saline.

Registration of calves

All calves are registered, weighed and tagged within 7 days of birth. Each herd is allocated to three herdsmen who are able to identify cow/calf pairs. Calves are weighed using a portable weighcrate and at the same time are tagged in both ears with a metal tag bearing their unique identification number. Regular checks are carried out and missing tags replaced as necessary. In addition, the ears are clipped to provide a permanent means of establishing the age of an animal. The identification number of calf and dam, date of registration, sex, weight, herd and description of colour are recorded in the field record book, and later this information is transferred to the cow's record card and a new card is started for the calf.

Weaning

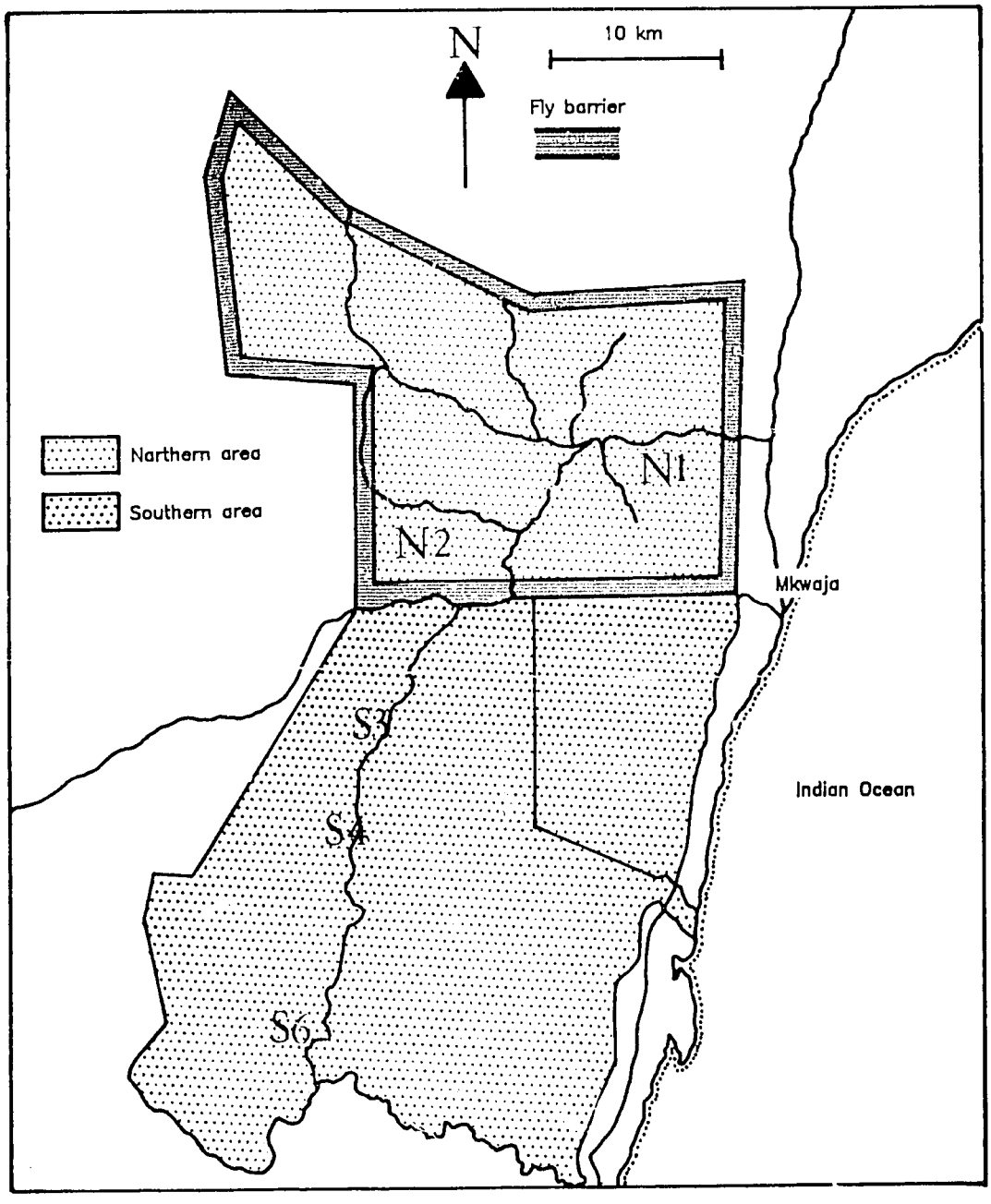
Calves are weaned at approximately 8 months of age after weighing. Their weaning weights and

Table 6. *Identification of blood meals in Glossina captured by vehicle trapping at Mkwaja Ranch, 1976.*

Host	Feeding activity of *Glossina*									
	G. morsitans				*G. pallidipes*				Total for both species	
	Males		Females		Males		Females			
	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage	Number	Percentage
Warthog	143	57.2	36	50.0	27	56.2	87	40.1	293	49.9
Bushpig	49	19.6	21	29.2	10	20.8	66	30.4	146	24.9
Bushbuck	27	10.8	12	16.7	3	6.3	34	15.6	76	12.9
Ox	9	3.6	3	4.1	7	14.6	14	6.5	33	5.6
Goat	10	4.0			1	2.1	2	0.9	13	2.2
Buffalo	7	2.8					11	5.1	18	3.1
Reedbuck	2	0.8					2	0.9	4	0.7
Rodent	1	0.8					1	0.5	3	0.5
Man	1	0.4							1	0.2
Total	250		72		48		217		587	

Reproduced by permission of OAU/STRC.
Source: Tarimo et al (1983)

Figure 11. *Positions of the northern and southern areas and five locations at Mkwaja Ranch.*



weaning dates are entered into a field record book. Later this information is transferred to both the cow's and calf's record cards. After weaning, all calves, except males from A.I.-sired herds, are divided into male and female herds and transferred from the ranch to neighbouring sisal estates. Heifers return to the ranch for bulling at approximately 36 months. Prior to bulling they are weighed and according to their weights are either culled (less than 200 kg), assigned to either natural service breeding herds (200–280 kg) or to A.I. herds (280 kg and greater). Surplus heifers are sold to other ranches when available, but usually all suitable heifers are required to maintain Mkwaja's breeding herds.

Male calves from natural service herds are all castrated between 8 and 18 months of age. All male calves from A.I.-sired herds are left entire and remain on the ranch until an initial selection is made at 18 months of age for breeding bulls. Selection criteria are bodyweight and conformation. Animals not selected are castrated and

moved to the sisal estates for finishing. A second selection is made at 30 months, again based on weight and conformation; rejected animals are castrated. Animals selected at 30 months are first used for breeding at 45 months of age. Steers return to the ranch for weighing prior to marketing, at an average age of 45 months.

Breeding

Heifers with the highest (greater than 280 kg) pre-bulling weights are assigned to herds in which A.I. is used. When oestrus is detected heifers and breeding cows are inseminated once with semen obtained from the A.I. centre at Kabete, Kenya. Cows and heifers are pregnancy-tested at around 5 months by rectal examination and empty animals (approximately 30%) are sent for natural service.

For natural service herds a bull to cow ratio of 1:20 is used. Bulls are left in the breeding herds for 3 months. Fresh bulls are sometimes introduced towards the end of the mating season when the original bulls are observed to be inactive. For the duration of the study period two breeding seasons have been used. For most herds, bulls are kept in the breeding herds from August to October, but for a few herds the mating season is December to February.

Culling

From 1954 the official culling policy of the ranch has been to remove from the breeding herd cows which failed to produce a live calf each year. From 1960 to 1982 this policy was followed less strictly than previously. Culling was also carried out in the case of diseased or injured animals. Heifers are culled, prior to entering the breeding herd, on the basis of weight, any animal weighing less than 200 kg being rejected. Animals showing anatomical defects or which suffer certain diseases, e.g. parasitic otitis, are also culled. Bulls are not culled at any particular age, but continue to be used until their mating activity is observed to decline. Very small and defective calves are culled at or before weaning.

Marketing

Originally Mkwaja was established to supply meat to the workforce on Amboni's sisal estates. The ranch management realised, however, that it would be more profitable to market their Mkwaja-bred beef to buyers who paid a premium for quality. Therefore they adopted a policy of buying from Tanganyika Packers Ltd., or when this source of supply failed, from up-country cattle markets, mature steers, which they finished and sold to the sisal workforce, reserving a proportion of ranch-bred steers for the quality fresh meat market in Dar-es-Salaam. This policy was started during the 1973/74 financial year and by 1977/78 only bought-in stock were sold to the estates. Bought-in steers invariably arrive in poor condition and require treatment for internal parasites (especially liver fluke, *Fasciola gigantica*) and trypano-somiasis. Halofuginone is used to control East Coast Fever and when supplies of this drug are not available the buying-in policy is stopped. Since these animals originate from foot-and-mouth disease endemic areas they represent a risk of infection and are consequently kept away from the ranch, going directly to the estates. Emergency slaughters, which are not condemned as unfit for consumption, are sold mainly to the ranch workforce, although there is a limited local trade to outsiders.

Disease control

Trypanosomiasis control measures are detailed in Chapter 7. All animals are vaccinated against rinderpest and annually against anthrax, blackquarter and pasteurellosis. In addition, breeding stock are vaccinated against foot-and-mouth disease and campylobacteriosis *(Campylobacter fetus)* and heifers against *Brucella abortus*.

Tick-borne diseases are controlled by a strict programme of dipping or spraying; twice weekly using an organo-phosphorus acaricide in the wet season, and once a week using toxaphene in the dry season. This is augmented by hand-dressing with an organo-phosphorous acaricide in used engine oil (2% v/v) which is applied to tick predilection sites e.g. under the tail. Hand dressing is interposed between routine dipping/spraying with the need being assessed by observation of tick infestation. East Coast Fever has been successfully controlled and there have been no cases for more than 20 years. Anaplasmosis is treated with oxytetracycline.

Salmonellosis epizootics have occurred sporadically, e.g. in 1977/78, affecting calves in particular. No treatment is employed, but large night paddocks are used in an attempt to reduce the risk of infection caused by crowding.

The principal internal parasite is *Haemonchus* sp. and animals below the age of 24 months are treated approximately every 3 months with an anthelmintic. Liver fluke is not present on the ranch. There was an outbreak of foot-and-mouth disease in 1977/78 in spite of the vaccination programme.

An ear infection caused by the worm *Rhabditis bovis*, which can lead to damage of the cen-

tral nervous system and death, was responsible for a number of emergency slaughters.

Wild predators

Wild predators are a significant cause of mortality particularly in calves. Lions and hyenas are the most important but leopards and wild dogs have also killed animals. Leopards have now been virtually eliminated from the ranch by a programme of trapping. Wild dogs are rare visitors, but in spite of shooting, trapping and poisoning of carcasses, lions and hyenas are still a problem.

In conclusion, Mkwaja Ranch has been developed and maintained by good management and disease control measures in an area of heavily infested tsetse savanna, an ecological situation representative of vast areas of Africa.

3. THE NEED FOR TRYPANOCIDAL DRUGS AT MKWAJA

Over the 30 years that Mkwaja Ranch has been in existence the rearing of cattle has depended on the use of trypanocidal drugs. During the 10-year study period covered by this report, two trypanocidal drugs were employed. These were Samorin, used as a prophylactic, and Berenil, used as a therapeutic. It is important to consider the background of both these drugs.

SAMORIN

Samorin, isometamidium chloride, is manufactured by May and Baker Ltd. (Dagenham, England); the same drug is sold in francophone countries of Africa as Trypamidium by Specia Ltd. (Paris, France). Isometamidium chloride (Berg, 1960) is a stable, dark purple/red powder with a solubility in water of 6% w/v at 20°C. Prophylactic activity against trypanosomes can last for several months depending on the level of tsetse challenge, species of trypanosome, pathogenicity of different strains of trypanosomes, and possibly the condition of the animal. The chemical's prophylactic action is thought to be a result of its relatively slow rate of resorption. Hill and McFadzean (1963) concluded from experiments with mice that the deposit of isometamidium chloride at the site of injection was of prime importance for prophylaxis and that deposits in the liver and kidneys were of secondary importance.

Samorin is generally prepared as a 2% w/v solution in distilled or cooled, boiled water. It is given by deep intramuscular injection at the dose rate 0.5 – 1.0 mg/kg bodyweight. Care must be taken with the site and method of inoculation if severe local reactions, caused by leakage from intramuscular sites to subcutaneous tissue, are to be avoided.

Samorin has been in widespread use for over two decades and the question of the existence of drug resistance must be considered. Folkers (1966) failed to induce drug resistance in cattle despite repeated low dosage (0.25 mg/kg) given to cattle over a 15-month period. More recently, Wilson et al (1975) found no isometamidium-resistant strains in their cattle studies in Kenya. Nevertheless, there are now reports from several countries of the development of drug resistance (reviewed by Leach and Roberts, 1981). However, the extent to which true drug resistance occurs awaits and requires investigation (cf. Chapter 1), as most reports have been made solely on the basis of the development of parasitaemia within a few weeks of treatment. Formal proof in the form of a bovine- or mouse-screening test has rarely been obtained. Bourn and Scott (1978) in their study of working oxen in Ethiopia suspected that isometamidium-resistant strains had developed and demonstrated in mice that *T. congolense* isolates in the area under study were resistant to homidium bromide, a phenanthridium drug related to isometamidium. In spite of this, oxen remained in good condition while on isometamidium prophylaxis. Using test cattle, stocks of *T. congolense* with reduced susceptibility to Samorin have been demonstrated in Zimbabwe (Lewis and Thomson, 1974) and in Kenya (Gitatha, 1981), while Pinder and Authie (1984), using a mouse-screening system, found that certain stocks of *T. congolense* isolated from cattle in Burkina Faso also exhibited reduced susceptibility.

BERENIL

Berenil, diminazene aceturate, is manufactured by Farbwerke Hoechst (Frankfurt, West Germany). It is a diamidine and is a stable, yellow, odourless powder. Diminazene aceturate is a fast-acting drug with an immediate curative effect but little prophylactic action against bovine trypanosomiasis. Thus, Wellde and Chumo (1983), using

steers treated with Berenil 1 hour to 39 days prior to infection with a Berenil-sensitive strain of *T. congolense*, were unable to demonstrate any significant prophylactic activity after 6 days following treatment. Berenil is normally prepared as a 7% solution in distilled water or cooled, boiled water and is given at a dose of 3.5 – 7.0 mg/kg body weight by deep intramuscular injection. Local reactions to subcutaneous or intramuscular injections are negligible. Well documented evidence of Berenil resistance is limited although Berenil-resistant strains of *T. vivax* have been reported in West Africa (Jones-Davies, 1967) and in East Africa (Mwambu and Mayende, 1971). No cross-resistance between isometamidium chloride and diminazene aceturate has been reported (Leach and Roberts, 1981).

At Mkwaja Ranch, a number of experiments have been conducted to compare the efficacy of trypanocidal drugs and their strategic use. Between 1975 and 1977, two major experiments were carried out with Samorin and Berenil on cattle before and after weaning. This chapter describes the outcome of these studies, the preliminary results of which were reported by Blaser et al (1979). In addition to allowing an evaluation of the different drugs, these experiments, by including untreated control animals, demonstrated the level of tsetse fly challenge and trypanosomiasis risk to which cattle on Mkwaja Ranch were exposed. In the first experiment, the study was carried out on weaned animals. In the second, both the pre-weaning and post-weaning stages were included.

EXPERIMENT 1

Materials and methods

Cattle. In December 1974, 100 calves (50 males and 50 females) with an average age of 6 months were selected. During February 1975, the animals were weaned and transferred to the Msangazi Valley area where the tsetse fly challenge is higher than in the breeding areas. Throughout the period of study, the animals were kept with several hundred cattle of the same age.

Drug strategy. Prior to weaning, all calves were treated monthly with Berenil at 3.5 mg/kg. On 17th March 1975, when aged approximately 9 months, the experimental animals were divided into three groups and treated with the appropriate trypanocidal drug for their groups. As a result of five deaths prior to weaning, 95 animals were used as follows:

Group 1: 37 calves (18 males, 19 females) were treated with Samorin.

Group 2: 40 calves (20 males, 20 females) were treated with Berenil.

Group 3: 18 calves served as untreated controls.

Samorin was administered at 0.5 mg/kg by deep intramuscular injection into the neck. Berenil was given at 3.5 mg/kg also by deep intramuscular injection. The timing of treatment was as described in Chapter 7 for the herd as a whole. Thus, starting from March 1975, all animals in Groups 1 and 2 were treated with Samorin or Berenil respectively every 2 to 3 months until the experiment was terminated in October 1977, month 31 of the study, when the cattle were approximately 40 months of age. In all other aspects of management and disease control the experimental animals were treated in the same way as the rest of the herd.

Parameters assessed. The parameters assessed included survival, anaemia as estimated by measurement of packed red cell volume per cent (PCV), parasitaemia by thick blood smear, cause of death by post-mortem examination and weight changes in kg.

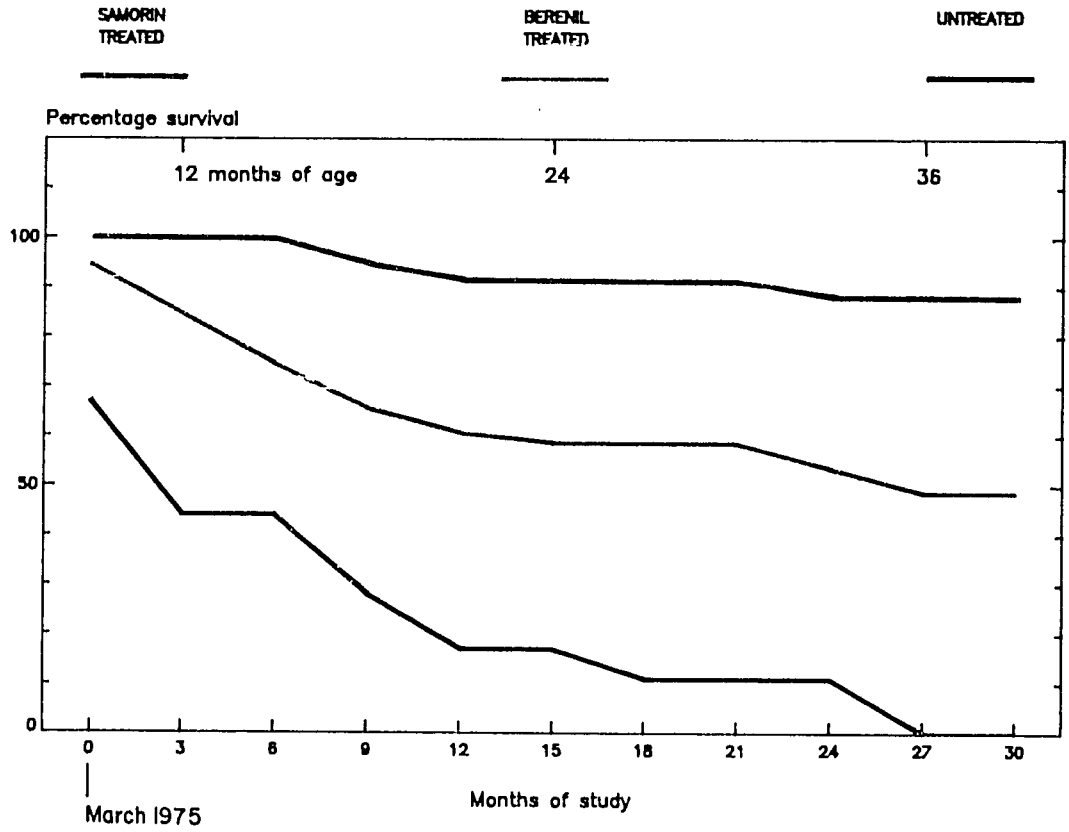
Results and discussion

Survival. Major differences in survival emerged among the three groups of cattle (Figure 12). The massive tsetse fly challenge that exists on Mkwaja Ranch was confirmed by the fact that none of the untreated cattle survived beyond 30 months of the study. By 3 months after the start of the experiment, 6 untreated cattle were dead and by 12 months, 13 of the 18 (over 70%) had succumbed. The fact that 5 animals were able to survive beyond this time, 2 for over 2 years, probably reflects innate differences in susceptibility to trypanosomiasis in cattle at Mkwaja, as there is little doubt that all animals exposed must have become infected.

On the other hand, in the group of cattle treated with Samorin, only 4 out of 37 animals (11%) died during the 31 months of study; no animal died during the first 9 months and only one died in the last 15 months of the experiment. The use of Berenil was not nearly as effective as Samorin. Thus, 21 of the 40 animals (52%) in the Berenil-treated group died. However, it was of interest that 14 deaths occurred during the first 12 months while the remaining 7 animals succumbed during the next 21 months. This result might suggest that the Berenil regime was leading to acquired resistance to trypanosomiasis.

Disease progress. As systematic examination of blood smears for trypanosomes was not carried out, it was not possible to evaluate the overall pre-

Figure 12. *Percentage survival of cattle calculated at 3-monthly intervals, Mkwaja Ranch, 1975-77 (Experiment 1).*



After 31 months of tsetse challenge at Mkwaja Ranch 33 of the 37 cattle (89%) treated with Samorin were alive but only 19 of the 40 animals (48%) treated with Berenil had survived. All of the 18 untreated cattle died.

valance of trypanosomes. However, during the last 3 to 4 months of the study the tsetse challenge was reported to be very high. On the few occasions when cattle were bled at this time, up to 20% of the Samorin-treated animals and nearly 50% of the Berenil-treated group were infected, while the two surviving untreated controls were consistently infected. *T. congolense* was the most common trypanosome species identified on thin blood smears (approximately 90%) and *T. vivax* was found in the remainder.

In the same way, PCV estimations were not carried out on a regular basis and the group means gave little indication of the actual situation within each group. Thus, after animals died, usually with a low PCV, the group mean rose. Nevertheless, the Samorin-treated group showed no evidence of anaemia until the end of the study (Table 7).

Towards the end of the study, the surviving Berenil-treated cattle had developed severe anaemia. It was during this period that the tsetse challenge was reported to be high and a large number of trypanosome-positive cases were found. In the untreated cattle, all developed marked anaemia. The large standard deviations observed in this group (Table 7) reflected the marked heterogeneity in susceptibility in these cattle, with some animals developing severe anaemia more quickly than others.

Cause of death. Under the conditions prevailing on this large ranch, it was not possible to carry out post-mortem examinations on all the animals that died. However, in those cases where the carcass was available it would appear that trypanosomiasis and predation by lions were the main causes of death (Table 8).

Thus, in the untreated group, trypanosomiasis was confirmed in six of the nine cases necropsied; lions accounted for the other three. Of the five Berenil-treated animals necropsied, trypanosomiasis was diagnosed in two, snake-bite in one and lions accounted for the remaining two. On the other hand, in the Samorin-treated cattle, trypanosomiasis was not diagnosed and lion ac-

Table 7. *Packed red cell volume estimations in three groups of cattle, Mkwaja Ranch, 1975–77.*

Group	Packed red cell volume (PCV) (%)					
Month of study[a]:	0	9	12	24	27	31
1. Samorin						
Mean	36	33	32	33	33	28
SD	4	5	6	4	4	4
Number	37	37	35	34	33	33
2. Berenil						
Mean	34	30	30	31	30	21
SD	3	5	6	4	5	4
Number	40	30	26	23	21	19
3. Control						
Mean	32	27	28	30	24	–
SD	3	8	7	4	6	–
Number	18	8	5	2	2	0

[a] At month 0 (March 1975) the animals had just been weaned and were approximately 9 months of age. At month 31 (October 1977) they were approximately 40 months of age.

counted for the death of the only two carcasses found for examination. Although it was not possible to confirm the cause of death in the majority of cattle, as the only differences in the management of the three groups of cattle was the use of trypanocidal drugs, we conclude that the cause of death in the cases not necropsied was most likely trypanosomiasis.

Weight changes. Marked differences among the groups in the total liveweight mass produced were evident (Table 9). Thus, at the start of the experiment the total liveweight of the 37 cattle in the Samorin-treated group was 5032 kg and 31 months later was 9042 kg in the 33 survivors, an increase of 80% (Figure 13). In contrast, the starting total liveweight mass of the 40 Berenil-treated cattle of 4920 kg had dropped by 8% to 4598 kg in the 19 surviving animals by 31 months. The untreated group did not survive.

Conclusion. The level of tsetse challenge at Mkwaja Ranch is such that cattle cannot survive without the use of trypanocidal drugs. Even the regular use of the highly effective therapeutic drug Berenil was not enough to keep significant numbers of animals alive and productive. Only with Samorin was it possible to maintain productive animals at Mkwaja.

Table 8. *Cause of death among three groups of cattle, Mkwaja Ranch, 1975–77.*

Diagnosis of cause of death	Samorin group	Berenil group	Control group
	(No. of animals)		
No necropsy	2	16	9
Lion	2	2	3
Snake bite	0	1	0
Trypanosomiasis	0	2	6
Total	4	21	18
No. of cattle at risk	37	40	18

EXPERIMENT 2

Because of the success of Samorin in post-weaned cattle, it was decided to explore the use of Samorin in pre-weaned calves from an early age and compare it with different Berenil strategies.

Materials and methods

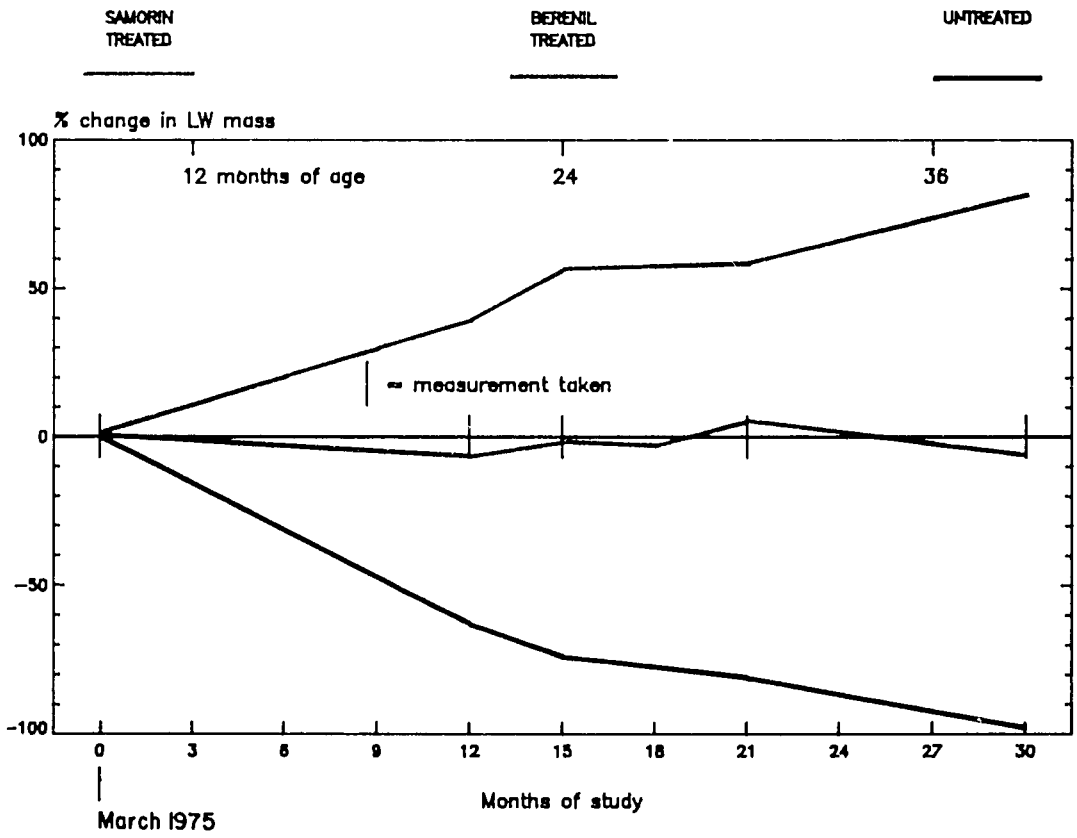
Cattle. Eighty female calves were selected from the Vuga and Umba herds in November 1975 at the age of 4 to 6 weeks. They were maintained at the Ruande section along with several hundred other suckling animals of the same age. The animals were weaned during July 1976 at around 9 months of age.

Table 9. *Mean weight changes among three groups of cattle, Mkwaja Ranch, 1975–77.*

Group	Month of study:	0	12	15	21	32
1. Samorin						
Mean weight change (kg)		136	196	229	231	274
SD		28	25	N	N	40
Number of animals		37	35	34	34	33
2. Berenil						
Mean weight change (kg)		123	177	202	224	242
SD		15	21	N	N	29
Number of animals		40	26	24	23	19
3. Control						
Mean weight change (kg)		123	165	192	200	0
SD		40	15	N	N	0
Number of animals		18	5	3	2	0

N = not known.

Figure 13. *Percentage change in total liveweight mass of cattle, Mkwaja Ranch, 1975-77 (Experiment 1).*



After 31 months of tsetse challenge at Mkwaja Ranch, the total liveweight mass of the Samorin-treated cattle had increased by 80%, while that of the Berenil-treated group had dropped by 8%. The untreated group produced nothing.

Drug strategy. Starting at 4 to 6 weeks of age, the 80 calves were divided into 4 groups of 20 animals each and treated as follows:

Group 1: Animals were given Samorin at 0.5 mg/kg at 2-monthly intervals.

Group 2: Animals were given Berenil at 3.5 mg/kg at 2-monthly intervals.

Group 3: Animals were given Berenil at 3.5 mg/kg every month (the ranch policy for calves).

Group 4: Animals were maintained as untreated controls.

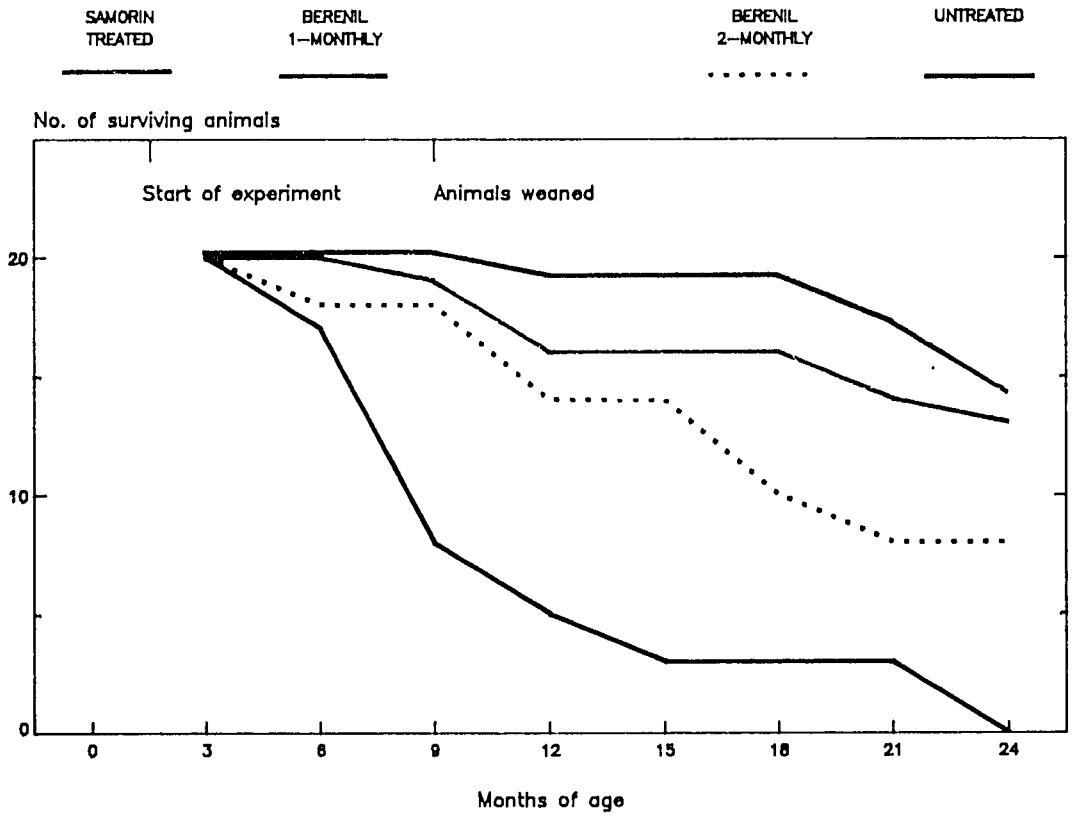
The experiment was continued until October 1977, when the cattle were approximately 2 years old.

Parameters assessed. The same parameters as in Experiment 1 were measured.

Results and discussion

Survival. As in the previous experiment, major differences in survival were found among all four groups (Figure 14). By weaning, only 8 of the 20 untreated calves (40%) were alive, whereas all 20 of the calves under Samorin prophylaxis were alive. Only one of 20 calves treated once a month with Berenil and two of 20 treated with Berenil every second month were dead by 9 months of age. After weaning, all groups suffered severely. Of the remaining eight untreated cattle, all were dead by 21 months of age, although the variation in survival (despite the fact that all animals were likely to have been infected) probably reflects, as in the previous experiment, the existence of innate differences in susceptibility to trypanosomiasis in cattle at Mkwaja. At this time, three of the Samorin group had died and a further three died during the subsequent 3 months leaving 14 survivors out of 20 (70%) at the termination of the study in October 1977. The group treated with Berenil once a month performed nearly as well as the Samorin-treated animals in terms of survival, with 13 animals (66%) alive at the end of the ex-

Figure 14. *Survival of cattle calculated at 3-monthly intervals, Mkwaja Ranch, 1975-77 (Experiment 2).*



The experiment started when the animals were 4 to 6 weeks old. By weaning all 20 of the Samorin-treated calves were alive, one calf of the Berenil once per month group had died, 2 calves of the group that received Berenil every 2 months had died, while 12 of the untreated group of 20 calves had succumbed. After weaning all groups suffered severely: 6 of the Samorin-treated group, 6 of the Berenil once per month group, 10 of the Berenil every 2 months group and the remaining 8 animals in the untreated group died.

periment. The animals treated with Berenil every second month suffered most severely of the treated groups and there were only eight survivors (40%) by October 1977.

Disease progress. Routine examination of blood smears was not carried out in this study. Nevertheless, in June 1977 the incidence of trypanosome infection in Groups 1, 2 and 3 was 22%, 58% and 33% respectively, reflecting the high tsetse challenge which was reported to be occurring around this period. At this time, the three surviving untreated controls were all parasitaemic. As in the previous experiment, *T. congolense* accounted for 90% of the infection and *T. vivax* for 10%.

In this study, PCV levels were not measured in any systematic way. What was obvious from the limited data available was that the animals which died usually exhibited low PCV levels (15% or less) and that the mean average PCV was higher in the Samorin-treated animals and in the cattle given Berenil once a month.

Cause of death. When necropsies were possible, trypanosomiasis was found to be the major cause of death (Table 10).

In the untreated control cattle, trypanosomisis accounted for ten deaths, lion for one, plant poisoning for one and the remaining eight carcasses were not available for necropsy. In Group 2 (Berenil every second month), 6 of the 12 animals necropsied died of trypanosomiasis and one animal of salmonellosis. In only one of the seven cases necropsied in Group 3 (Berenil once a month) was a diagnosis possible and this was confirmed as trypanosomiasis. In the Samorin-treated animals, trypanosomiasis was not diagnosed in any of the six animals that died. The number of deaths in this group was much higher than in the equivalent group in Experiment 1 over the same time period. It was concluded that some unidentified factor other than trypanosomiasis accounted for this difference and, as a result, the poorer performance of this group when compared to Experiment 1.

Weight changes. The four groups of cattle showed marked differences in total liveweight mass produced (Table 11, Figure 15).

In the Samorin-treated cattle (Group 1) the total liveweight increase from birth (20 animals) to 24 months (14 animals) was from 500 kg to 2464 kg. The corresponding increase in Group 3 (Berenil once a month) was from 500 kg (20 animals) to 2132 kg (13 animals). In the animals treated with Berenil every second month the gain was much less and was from 480 kg (20 animals) to 1264 kg (8 animals). No control cattle survived.

Once again in this second experiment, the Samorin-treated group produced the greatest liveweight mass. It should be noted that because of the deaths which occurred in the Samorin group after weaning, there was no change in total liveweight mass between weaning at 9 months and 24 months of age. Furthermore the average weight of Samorin-treated animals at 24 months was 53 kg less in the second experiment (176 kg) than in the first (229 kg).

Conclusion. As in Experiment 1, untreated cattle could not survive at Mkwaja Ranch. Confirming the previous result, the Samorin-treated group performed best in terms of survival and liveweight mass produced. What was of further interest was that Samorin was the most effective drug in protecting calves prior to weaning. Of the two Berenil strategies tested, Berenil once a

Table 10. *Cause of death among four groups of cattle, Mkwaja Ranch, 1975–77.*

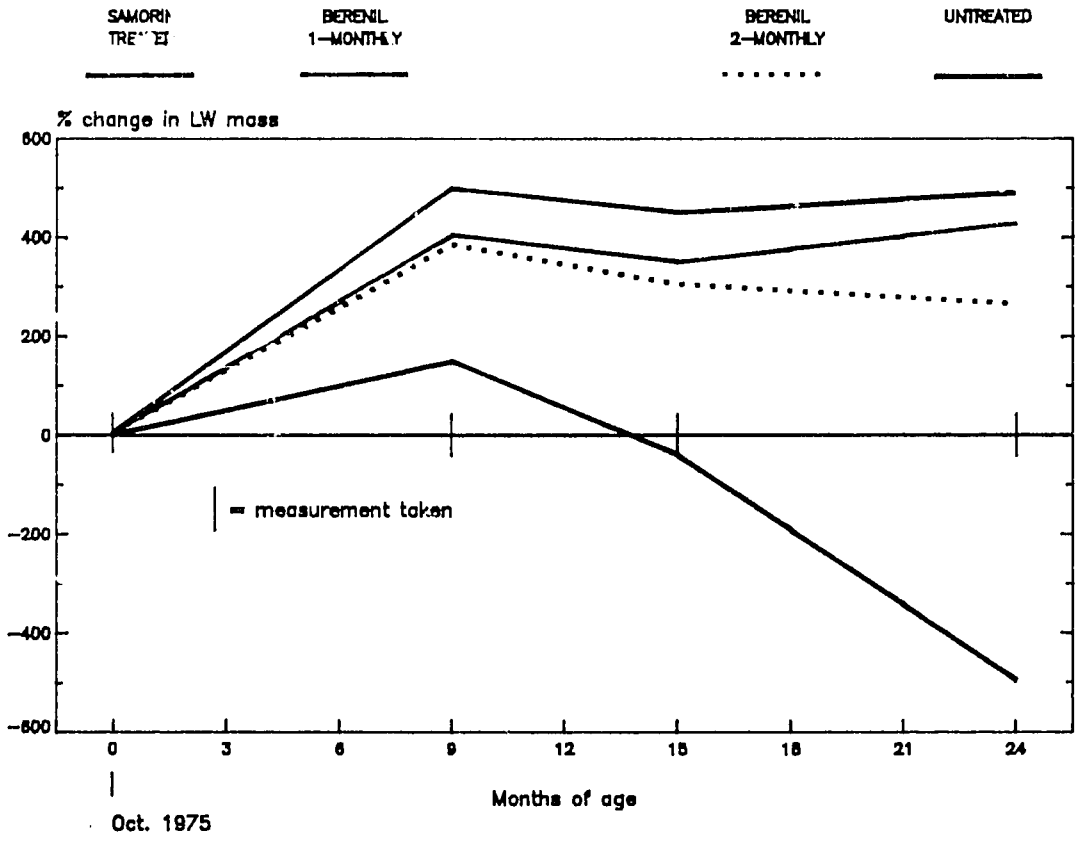
Diagnosis of cause of death	Group 1 (Samorin bimonthly)	Group 2 (Berenil bimonthly)	Group 3 (Berenil monthly)	Group 4 (Control)
	(Number of animals)			
No necropsy	6	5	6	8
Lion	0	0	0	1
Plant poisoning	0	0	0	1
Salmonellosis	0	0	0	0
Trypanosomiasis	0	6	1	10
Total	6	12	7	20
No. of cattle at risk	20	20	20	20

Table 11. *Mean weight changes among four groups of cattle, Mkwaja Ranch, 1975–77.*

Group	Month of age[a]:	Birth	9	15	24
1. Samorin (bimonthly)					
Mean weight change (kg)		25	125	119	176
SD		N	N	N	38
Number of animals		20	20	19	14
2. Berenil (bimonthly)					
Mean weight change (kg)		24	101	102	158
SD		N	N	N	28
Number of animals		20	18	14	8
3. Berenil (monthly)					
Mean weight change (kg)		25	106	108	164
SD		N	N	N	39
Number of animals		20	19	16	13
4. Control					
Mean weight change (kg)		24	89	93	0
SD		N	N	N	0
Number of animals		20	8	3	0

[a] The calves were born in October 1975. N = not known.

Figure 15. *Percentage change in total liveweight mass of cattle, Mkwaja Ranch, 1975-77 (Experiment 2).*



As in the previous experiment, the Samorin-treated group performed best. The Samorin-treated cattle produced a total liveweight mass of 2464 kg, the group treated with Berenil once per month 2132 kg (14% less) and the group treated with Berenil every 2 months 1264 kg (49% less than the Samorin group). The untreated group produced nothing.

month was markedly superior to Berenil every second month and was almost as effective as Samorin. However, the once-a-month strategy would be twice as costly in terms of manpower and drugs.

GENERAL CONCLUSION

From the results of these two experiments on approximately 180 cattle studied for up to 31 months, it is obvious that ranching is only possible at Mkwaja with the use of trypanocidal drugs. Because of the high persistent tsetse challenge, Samorin with its long prophylactic action was significantly more effective than Berenil. When it is considered that at Mkwaja Ranch the tsetse challenge is recognised as being among the highest in Africa, the findings of these studies have far-reaching implications for the use of Samorin chemoprophylaxis to control trypanosomiasis in cattle throughout the tsetse-infested areas of Africa.

4. APPROACH TO ANALYSIS OF MATCHING PRODUCTIVITY AND HEALTH DATA AT MKWAJA

BACKGROUND

Ford and Blaser (1971) reported that chemoprophylaxis against bovine trypanosomiasis had then been in widespread use in tropical Africa for about 15 years and large quantities of drugs had been dispensed every year. Few attempts, however, had been made to assess the results of intensive treatments in large populations of cattle. They considered that the cattle records maintained at Mkwaja Ranch were probably unique in East Africa and while not attempting any analysis of these records, drew attention to their existence.

Skovlin and Williamson (1978) studied the sequence of plant succession following two decades of grazing and bush clearing at Mkwaja and concluded that the continuous grazing had reduced the fuel that formerly supported frequent fires, this leading to bush encroachment, this in turn encouraging a maintenance or increase in tsetse numbers.

In 1975, the ranch was selected as a test site for a tsetse fly control project by the United States Agency for International Development (USAID) and the Tanzanian Government (Williamson, 1975). The objective of this programme was to determine if a technique involving the application of insecticide and the release of sterilized male tsetse flies could be an effective method of control. As part of this operation, regular estimates of the apparent density of tsetse flies were carried out at Mkwaja from approximately mid-1976 to mid-1979, covering both treated and control areas of the ranch (Gates et al, 1983; Williamson et al, 1983; 1983a).

Two trials at Mkwaja on calf growth and viability reported at a preliminary stage by Blaser et al (1979) and in detail in Chapter 3, show conclusively that ranching is only possibly with the use of trypanocidal drugs.

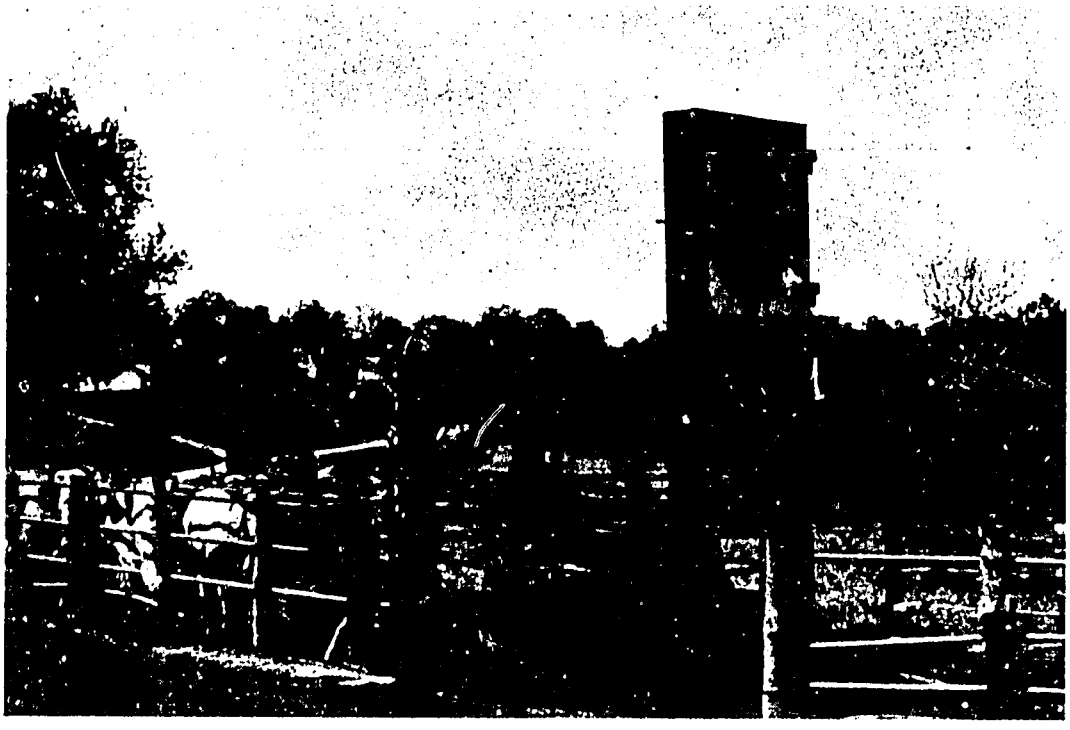
Thus, over many years, considerable amounts of information on individual aspects of tsetse evaluation and control, trypanosomiasis infection, ecological succession and animal performance (Figure 16) have been recorded. There have been virtually no attempts however at linking either individual components of a particular subject (e.g. tying together the important performance traits of reproduction, growth, viability, etc. to determine overall productivity), or at linking vital aspects such as tsetse numbers, cattle trypanosomiasis infection rates, prophylaxis treatments, and subsequent animal productivity levels.

The broad aims of the large-scale study reported here include accurate evaluation of the overall productivity achieved under prophylaxis, followed by comparison both with cattle of similar genetic composition under no trypanosomiasis risk, and with dissimilar cattle genetically resistant to trypanosomiasis, kept under risk conditions without prophylaxis.

Specific aspects of the study are concerned with the influence of environmental effects such as an animal's geographical situation on the ranch, season and year involved, age of the animal or its dam, sex, prophylactic treatment, involvement of any additional therapeutic treatments, and the various interactions between these effects, on reproductive, viability, growth and productivity traits.

In the measurement of prophylactic and therapeutic treatment effects, the influence of geographical area, year, season, cow age etc. and their interactions on the number of treatments required, is investigated. The impact of number of

Figure 16. *Weighing Boran cattle at Mkwaja Ranch.*



treatments and their timing in relation to parturition is evaluated for the major performance traits.

The availability of data on apparent densities of tsetse over a 3-year period allows attempts to link tsetse density, level of trypanosomiasis infection diagnosed, number of prophylactic treatments required and ultimate animal productivity to be made. Any impact on cattle productivity traits of reduction of tsetse by insecticide application and the release of sterilized male tsetse flies, is investigated.

Finally, utilisation, through artificial insemination of semen from Boran bulls in Kenya, enables an evaluation of the influences on growth traits of progressive grading-up to pure Boran, and an examination of genotype-environment interaction effects, to be made.

DATA PREPARATION

It was considered desirable to attempt to cover a 10-year period, and in view of the tsetse recording work that had been carried out from mid-1976 to mid-1979, 3½ years before and after these dates were added. The period chosen was thus 1 January 1973 to 31 December 1982.

Basic records were built up covering all production and health aspects of calvings taking place over the 9 years from 1 January 1973 to 31 December 1981. One record cabinet was found to have been invaded by termites, and all data cards in it reduced to dust. Complete records of 70% of the cows calving over this period were available.

Data extracted for each calving covered cow number, date of calving, dam number, sire number, date of birth, herd number, herd location on ranch at calving, calf number, calf sire number, calf sex, calf registration date and weight, calf weaning date and weight, date of calf pre-weaning death, calf bulling weight and date, or steer selling weight and date, date of cow's last Samorin treatment before calving, date of cow's last Berenil treatment before calving, cow's next calving date, dates of all cow's Samorin treatments between calving date and next calving date, dates of all cow's Berenil treatments between calving date and next calving date, and date of culling or death of cow.

Abortions had not been consistently recorded, therefore could not be included. Many weaning weights for calves weaned in 1980 were missing due to the loss of the relevant field record book.

Performance traits and chemoprophylactic treatments. From these data, the age at first calving, cow age at each calving, calving interval, calf weaning weight adjusted to 240 days, calf death, cow productivity (weight of 240-day calf per cow per year), numbers of Samorin and Berenil treat-

ments over set periods, and intervals between various Samorin and Berenil treatments, were calculated as indicated below.

Seasons. From the monthly rainfall data in Table 5, calving dates were assigned to one of four seasons:

Dry 1: January to February
Long rains: March to May
Dry 2: June to September
Short rains: October to December

Cow age. Cows were assigned to one of four age groups at calving; 3–4 years, 5–6 years, 7–8 years, and 9 years or over.

Area and location of ranch. Animals were assigned to either northern or southern areas and locations N1 or N2 within the northern area and S3, S4 or S6 within the southern area, on the basis of herd geographical situation (Figure 11).

Number of Samorin treatments. Cows were assigned to one of four classes: one, two, three and four or more treatments between parturition and 8 months post-parturition.

Timing of Samorin treatments. Cows were assigned to one of four classes depending on the time of their first Samorin treatment relative to parturition date:

Shortly before parturition:	Between 30 and 11 days prior to parturition
At parturition:	10 days before to 10 days after parturition
Shortly after parturition:	Between 11 and 30 days after parturition
Longer after parturition:	Between 31 and 240 days after parturition.

Berenil treatments. Cows were assigned to two classes depending on whether or not they received any Berenil treatment between parturition and 8 months post-parturition.

DATA ANALYSES

All information on cow reproductive performance, on calf viability, birthweight, weaning weight and pre-weaning growth, on heifer and steer post-weaning growth characters, on numbers of Samorin and Berenil treatments required by breeding cows over specific periods, and on an index of cow productivity, were analysed by least squares procedures (Harvey, 1977), using fixed models. Unequal and disproportionate subclass numbers gave unbalanced factorial designs for which conventional analyses of variance techniques were not applicable. Typical models used included the fixed effects of geographical situation on the ranch, season and year involved, age of cow or calf's dam, sex of the calf, number and timings of Samorin treatments over the relevant period, involvement of any additional Berenil treatment, and the various interactions between these effects. The specific factors included in the model used will be evident when the results are presented for each character analysed. The residual mean square was used as the error term to test the significance of all differences evaluated. Linear contrasts of least squares means were computed to determine the significance of differences between groups. More comparisons were made using the least squares means than there are independent degrees of freedom. Therefore, all of the comparisons are not independent, and the error rate over the entire set of comparisons may be different from that indicated by the level of probability. Tests of significance associated with the linear contrasts, although not independent, can be taken as guides as to whether the observed values could have occurred by chance.

It should be noted that in different sections of the report, productivity indices can refer to those actually achieved by the cattle population maintained on the ranch, or to least squares mean values, or to those calculated from component trait values.

5. CATTLE PRODUCTIVITY AT MKWAJA

The most important cattle performance traits at Mkwaja Ranch are cow reproduction, cow and calf viability, calf growth and cow weight. Aspects of these characters can be combined to build up an index such as total weight of weaner calf produced per cow per year, or per unit weight of cow per year, or per unit metabolic weight of cow per year. The merit of such indices lies in relating all the more important production characters back to the weight of breeding cow that has to be supported, which is closely associated with cow maintenance costs. Management decisions such as culling policy influence annual cow replacement rate and thus herd and lifetime productivity.

Table 12 summarises the overall performance levels achieved by Mkwaja Boran cattle from 1973 to 1982, and indicates the numbers of records available for analysis of each trait. The traits analysed were age at first calving and calving interval, representing reproductive performance; pre-weaning mortality, age at pre-weaning death, annual cow mortality and cow age at death, representing viability; birthweight, weaning weight and daily liveweight gain from birth to weaning, representing pre-weaning growth; weight of weaner calf per cow per year, representing productivity; heifer 36-month weight and daily liveweight gain from weaning to 36 months, and steer 45-month weight and daily liveweight gain from weaning to 45 months, representing post-weaning growth; cow weight at 4 to 15 years on a small available sample, representing mature cow weight; and annual cow culling rate and cow age at culling, representing breeding herd replacement.

RESULTS OF ANALYSES

Reproductive performance

The mean age of first calving for 4460 heifers born from 1971 to 1978 was 47.0 ± 0.1 months, with a coefficient of variation of 14%. The mean calving interval for 11 999 records from 1973 to 1981 was 15.9 ± 0.01 months, with a coefficient of variation of 36%. This mean calving interval was equivalent to an annual calving percentage of 75.3%.

Mortality

The mean pre-weaning mortality based on 18 266 calves born from 1973 to 1981 was 8.0 ± 0.2%, with a coefficient of variation of 333%. The mean age at pre-weaning death, based on 975 calf deaths recorded from 1973 to 1981 was 82 ± 2.6 days with a coefficient of variation of 87.8%. The distribution of calf deaths at 2-weekly intervals from birth to 40 weeks of age is indicated in Figure 17. Fifty percent of calf deaths had occurred by 8 weeks, the majority being during the first 2 weeks of life.

The mean annual cow mortality based on 45 852 records from 1973 to 1981 was 5.8 ± 0.9%, with a coefficient of variation of 47%. The average mortality rate from disease was 4 2% per year, and from predators, accidents and loss 1.6% per year. The mean age at which cows died, obtained from 472 recorded dates, was 7.4 ± 0.1 years, with a coefficient of variation of 32.6%. Figure 18 indicates the age distribution at cow death, the peak being reached at 6 years.

Causes of death

Post-mortem examination forms were available for 452 calves and 341 breeding cows (Table 13). The post-mortem findings were recorded in remarkable detail and allowed a specific diagnosis to be made in about 90% of cases. In both calves and adults, infectious diseases and predators were the major causes of mortality. However, there were some striking differences between calves and adults in the causes of death. Thus, anaplas-

Table 12. *Overall performance achieved by Mkwaja Boran cattle, 1973–82.*

Trait	No. of records	Mean	SE	Coefficient of variation (%)
Reproductive performance				
Age at first calving (months)	4 460	47.0	0.12	14.1
Calving interval (months)	11 999	15.93	0.06	36.2
Calving percentage[a] (%)	11 999	75.3	NA[d]	NA
Viability				
Pre-weaning mortality (%)	18 266	8.0	0.20	332.3
Age at pre-weaning death (days)	975	82.1	2.6	87.8
Annual cow mortality (%)	45 852	5.8	0.91	47.0
Cow age at death (years)	472	7.4	0.1	32.6
Pre-weaning growth				
Birthweight (kg)	16 275	24.9	0.04	16.3
Pre-weaning growth (g/day)	16 275	453.8	0.92	21.5
Weaning weight at 8 months (kg)	16 275	133.5	0.23	18.0
Productivity				
Cow productivity index[b] (kg)	11 999	101.9	0.47	44.9
Herd productivity[c] (kg)	11 999	96.0	NA	NA
Post-weaning growth				
Heifer 36-month weight (kg)	2 252	261.0	0.67	11.4
Heifer post-weaning growth (g/day)	2 252	161.0	0.82	22.4
Steer 45-month weight (kg)	2 435	337.6	0.82	10.7
Steer post-weaning growth (g/day)	2 435	182.1	0.71	17.6
Mature cow weight				
Cow weight (kg)	564	286	1.3	10.0
Breeding herd replacement rate				
Annual cow culling rate (%)	45 852	12.8	1.0	23.0
Cow age at culling (years)	884	9.2	0.1	34.0
Annual cow replacement rate (%)	45 852	18.7	1.4	22.3

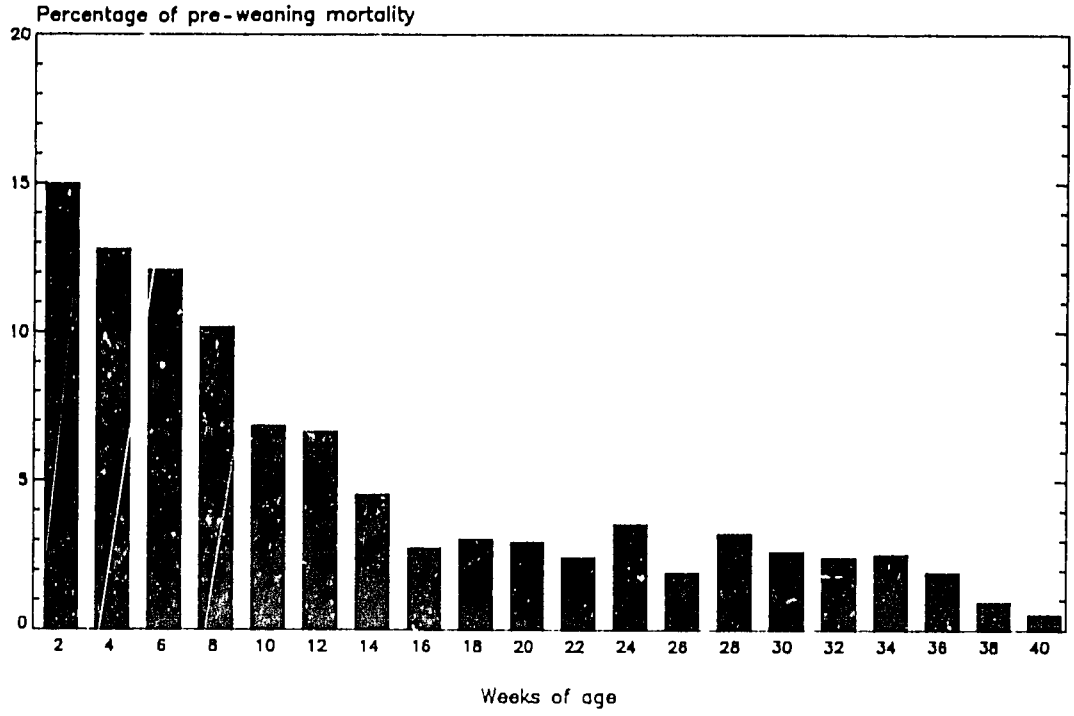
[a] Calving percentage = (365 ÷ calving interval) x 100.
[b] Total calf weaning weight per cow per year.
[c] (Cow productivity index x annual cow viability) ÷ 100.
[d] NA = not applicable.

mosis was confirmed in 79 cows (23.2% of all adults), whereas not a single case was diagnosed in calves. The diagnosis of anaplasmosis was made on the basis of the post-mortem findings of splenomagaly, generalised lymphadenopathy, anaemia and/or jaundice, and confirmed by the demonstration of *Anaplasma* sp. piroplasms in blood smears stained with giemsa. Presumably, *Anaplasma* sp. were being transmitted by biting flies, as no cases of other tick-borne infections, such as East Coast fever, *Theileria mutans*, babesiosis or heartwater, were diagnosed.

Salmonellosis accounted for the deaths of 98 calves (22% of all calf deaths), but only for 8 adult deaths (2.3% of total). Findings considered significant included an enlarged pale liver exhibiting focal areas of necrosis and haemorrhage, haemorrhagic gastroenteritis and generalised haemorrhages. In the majority of cases, the diagnosis was confirmed by the isolation of *Salmonella* sp., usually *S. dublin*, from the liver or spleen.

Trypanosomiasis did not appear to be a significant cause of death. It was diagnosed in three adults (trypanosomes identified) and suspected in a further seven animals. In calves, it was confirmed in two cases and suspected in another two. In the cases in which trypanosomes were not identified, trypanosomiasis was tentatively diagnosed by finding anaemic watery blood, enlarged lymph nodes and spleen, a flabby decompensated heart, indicating heart failure, and in some cases in which haemorrhagic *T. vivax* was suspected, a gut full of frank blood and generalised haemorrhages. In a further 20 necropsies (19 in adults),

Figure 17. *Age distribution of calf deaths, Mkwaja Ranch, 1973-82.*



anaemia was obvious but its cause could not be identified.

Snake bites accounted for over 5% of all necropsies. Diagnosis was made on the basis of the herdmans's report and the finding of an oedematous haemorrhagic bruised bite site. In addition, there were generalised haemorrhages. The snake responsible is believed to be the mamba. A diagnosis of plant poisoning was made in 28 adults and 2 calves. The findings believed to be characteristic

Figure 18. *Age distribution of cow deaths, Mkwaja Ranch, 1973-82.*

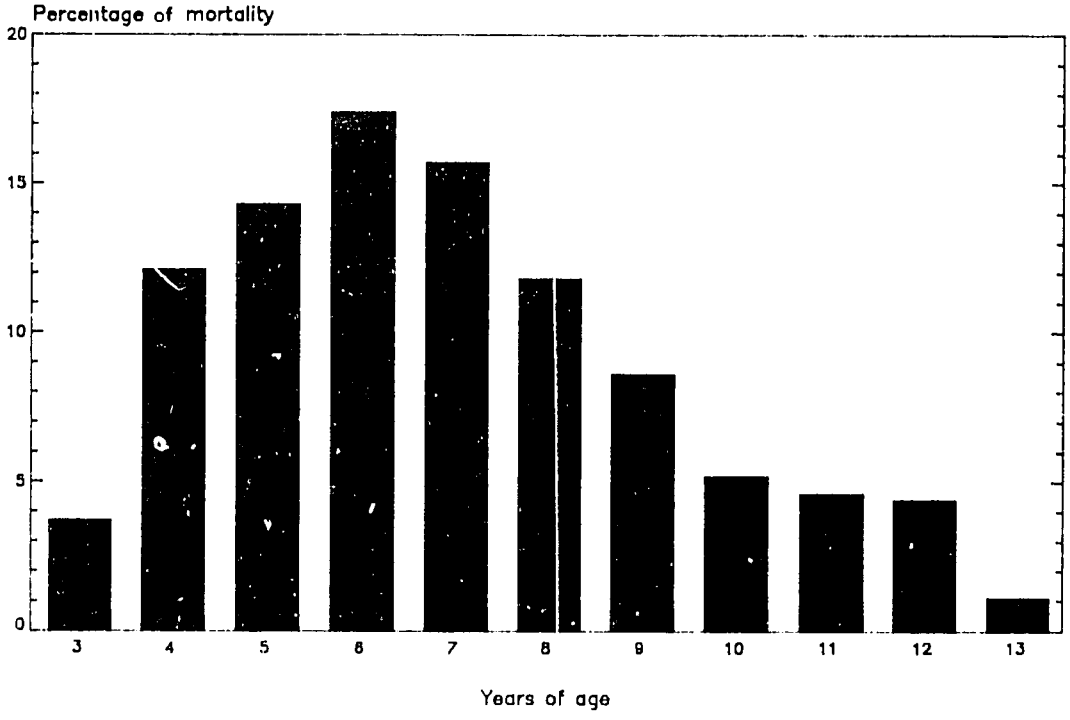


Table 13. *Cause of death among calves and cows, Mkwaja Ranch, 1973–82.*

Diagnosis of cause of death	Calves		Cows	
	n	(%)	n	(%)
Anaplasmosis	0		79	23.2
Salmonellosis	98	21.7	8	2.3
Pneumonia	9	2.0	10	2.9
Anaemia of unknown origin	1	0.2	19	5.6
Trypanosomiasis (incl. suspected)	4	0.9	10	2.9
Foot-and-mouth disease	9	2.0	1	0.3
Omphalophlebitis/navel ill	8	1.8	0	
Diarrhoea of unknown origin	3	0.7	4	1.2
Pyelonephritis/cystitis	3	0.7	2	0.6
Hepatitis	0		3	0.9
Septicaemia	2	0.4	0	
Meningoencephalitis/malacia	2	0.4	0	
Parasitic otitis	1	0.2	1	0.3
Dermatitis	1	0.2	0	
Jaundice of unknown origin	1	0.2	0	
Generalised pyaemia	0		1	0.3
Blackquarter	0		1	0.3
Acetonaemia	0		1	0.3
Bloat	0		2	0.6
Intestinal volvulus	0		1	0.3
Killed by predators	197	43.6	67	19.6
Plant poisoning	2	0.4	30	8.8
Snake bite	17	3.8	29	8.5
Starvation	38	8.4	0	
Trampled, killed by bulls, drowned	40	8.8	12	3.5
Dystokia	0		12	3.5
Prolapse of uterus	0		7	2.1
Ruptured uterus	0		4	1.2
Ruptured liver, spleen, kidney, abomasum	3	0.7	8	0.3
Toxaphene poisoning	1	0.2	0	
Inconclusive	12	2.7	29	8.5
Total	452		341	
Summary				
Infectious disease	142	31.4	139	40.8
Predators	197	43.6	67	19.6
Accident	44[a]	9.7	47[b]	13.8
Starvation	38	8.4	0	
Snake bite	17	3.8	29	8.5
Plant poisoning	2	0.4	30	8.8
Inconclusive	12	2.7	29	8.5

[a] Includes organ rupture and Toxaphene poisoning.

[b] Includes organ rupture and dystokia.

included myocardial haemorrhages, increased fluid in the body cavities, degeneration of the parenchymatous organs, namely the liver, kidneys and heart, and gastroenteritis, which occasionally was haemorrhagic. The plant *Dichapetalum* might have been responsible but this could not be confirmed. Starvation was confirmed as the cause of death in 38 calves; their dams had died or had become agalactic. Most calf deaths occurred over the first 8 weeks of life (Figure 17).

Predators were responsible for the deaths of a large number of animals, accounting for 44% of calf deaths and 20% of adult deaths. Lions were the main culprits.

Bodyweights

Weights at birth and 8 months were available for 16 275 calves, at 36 months for 2 252 heifers, at 45 months for 2 435 steers and at 9 years for 564 breeding cows.

The mean birthweight, 8-month weaning weight, and pre-weaning growth rate for calves born from 1973 to 1981 were 24.9 ± 0.04 kg, 133.5 ± 0.23 kg and 453.8 ± 0.92 g per day respectively, with coefficients of variation of 16.3%, 18.0% and 21.5% respectively.

The mean 36-month weight and post-weaning growth rate for heifers born from 1974 to 1978 were 216.0 ± 0.67 kg and 161.1 ± 0.082 g per day respectively, with coefficients of variation of 11.4% and 22.4% respectively. The mean 45-month weight and post-weaning growth rate for steers born from 1973 to 1978 were 337.6 ± 0.82 kg and 181.1 ± 0.71 g per day respectively, with coefficients of variation of 10.7% and 17.6% respectively.

The mean weight of cows, weighed approximately 10 months after their previous calf had been weaned, being an average of 9 years of age, was 286 ± 1.3 kg, with a coefficient of variation of 10%.

Cow productivity

The mean cow productivity (weight of weaner calf per cow per year) based on 11 999 records from 1973 to 1981 was 101.9 ± 0.47 kg, with a coefficient of variation of 44.9%. An estimate for mature cow weight of 293 kg, combined with the productivity of 101.9 kg of weaner calf per cow per year, resulted in a productivity of 161.2 kg of weaner calf per 100 kg metabolic weight of cow per year.

Adjustment of the two productivity indices to account for cow viability (94.2%) gave the most accurate estimates for overall herd productivity achieved. These were 96.0 kg of 8-month old calf per cow per year, and 151.9 kg of 8-month old calf per 100 $kg^{0.73}$ of cow per year.

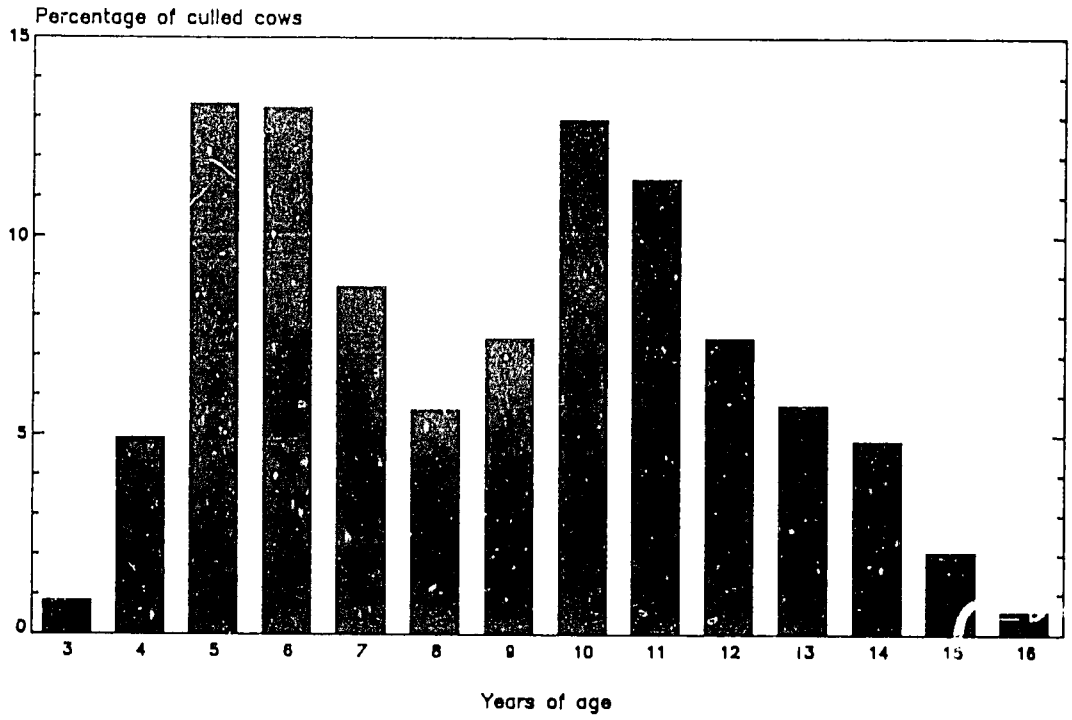
Cow culling

The mean breeding cow culling rate based on 45 852 annual cow records from 1973 to 1982 was 12.8 ± 1.0% with a coefficient of variation of 23%. The average age at culling, based on 884 available records was 9.2 ± 0.1 years with a coefficient of variation of 34.0%. Major peaks occurred at 5–6 years and at 10–11 years (Figure 19). The annual cow replacement rate was therefore 18.7% covering both culls and deaths.

PERFORMANCE LEVELS AT MKWAJA RANCH

Reproductive performance and viability are traits of outstanding importance in beef cattle enterprises. Possible genetic improvement in virtually

Figure 19. *Distribution of cow culling ages, Mkwaja Ranch, 1973-82.*



all traits of economic importance is closely tied to them.

The annual cow replacement rate of 18.7% at Mkwaja indicated an average of 5.3 years in the breeding herd. Thus with a calving interval of 15.9 months, five calves would be produced by each cow in its lifetime.

An appropriate definition of mortality rate in the context of genetic progress is the percentage of females that die before calving. By adding a post-weaning mortality rate of 4% (unpublished data) to the pre-weaning mortality, this percentage was approximately 12%. The rearing proportion is the proportion of births that produced a heifer that survived and was fertile. The rearing proportion at Mkwaja was 0.44. This means that once in 2.27 calvings a cow produced a heifer calf that could in turn calve in the herd. The average length of reproductive life was five calvings; therefore, approximately 45% of the females born were required as replacements to maintain herd size.

Genetic improvement per unit of time is more important than per animal generation. The average age at first calving was 47.0 months, and the average calving interval 15.9 months. To replace herself, a cow had to calve 2.27 times; thus, the average generation interval was 83.1 months or 6.9 years, which is within the normal reported range for tropical indigenous breeds.

Overall, the proportion of females required as replacements and the length of the generation interval would indicate considerable scope for implementation of selection programmes on growth traits. More stringent culling on reproductive performance could also well have relevance. The clinical and post-mortem findings indicated that the major problems that were not always effectively controlled were anaplasmosis, presumably transmitted by biting flies, salmonellosis in calves, plant poisoning and predators. Better control of these additional problems could make significant contributions to increased production.

6. ENVIRONMENTAL INFLUENCES ON PERFORMANCE TRAITS AT MKWAJA

Environmental factors that influence traits contributing to overall productivity are important on two counts. First, knowledge of certain factors and the magnitude of their effects on performance may enable development of more effective management systems for increased beef production. Second, in genetic improvement programmes, adjusting data for known environmental effects allows valid comparisons among individuals to be made, thus increasing selection efficiency.

The environmental influences measured were year and season of calving or birth, cow age, calf sex, and area and location of herd. The amount and timing of trypanocidal drug treatments required and their interactions with environmental influences were evaluated simultaneously. The performance traits involved were calving interval, pre-weaning mortality, pre-weaning growth characters, and cow productivity (weight of weaner calf per cow per year).

The significance of environmental and drug treatment effects and their interactions on all performance traits are indicated in Table 14. The actual effects related to year of calving or birth, season of calving or birth, age of cow, sex of calf, and ranch area and location are presented in Table 15.

EFFECT OF SPECIFIC FACTORS ON PERFORMANCE

Year of calving or birth

Year of calving or birth significantly affected all traits ($P < 0.05$ for calving interval, $P < 0.01$ for others). No general trends over years were apparent. Productivity was above average in 1981, 1980 and 1976. In 1980, the policy on use of trypanocidal drugs was changed, so that animals thereafter received prophylaxis approximately one third more often, but this was confounded with any other year effects. 1976 was the last year of a 3-year drought, and cows calving then had the longest subsequent calving interval. However, low calf mortality and high weaning weights resulted in above-average productivity in that year. Significant interaction effects between year and season for all traits presumably reflected the very variable seasonal rainfall values shown in Table 5. Significant interaction effects between year and geographical area of ranch for all traits are discussed below.

Area and location on ranch

Area of ranch had a significant effect on calving interval and birthweight ($P < 0.01$) and cow productivity ($P < 0.05$). Performance was superior in all three traits in the northern area (Table 15).

In 1967 an extensive programme of bush clearing was started in the northern area, and by 1981 about 9600 ha had been cleared, approximately 50% of the area. No bush clearance was attempted in the southern area. From November 1977 to December 1978 a tsetse fly control project was carried out in the northern area, the objectives being to reduce the tsetse population by application of insecticide, then to release sterile male *G. m. morsitans*. A tsetse barrier 1 km wide around the northern area was also completed at this time. The southern area served as the untreated control. Over the 9 years the calving interval was 6% shorter, birthweights were 7% higher and cow productivity was 6% greater in the more developed northern area.

There were significant interaction effects between area and year for all performance traits, and the interaction constants are shown in Table 16. Significant interactions were due mainly to

Table 14. *Mean squares for performance traits of cows and calves, Mkwaja Ranch, 1973–82.*

Source	df	Calving interval (days x 10)	Calf mortality (% x 10)	Birth-weight (kg x 10)	Pre-weaning growth (g/day x 10^{-2})	Weaning weight (kg)	Cow productivity (kg)
Year (A)	8	6505*	7225**	10127**	10389**	58915**	94952**
Season (B)	3	2434**	3686**	3716**	656**	3307**	16113**
Age (C)	3	9694**	606	1516**	5186**	33577**	31747**
Sex of calf	1	2243**	1287	72040**	36466**	295301**	64976**
Area (D)	1	4057**	1092	25599**	12	1764	12418*
Location/northern area	1	27	3686*	552	23678**	130720**	135312**
Location/southern area	2	398	973	704*	404*	1539	2174
Number of Samorin treatments	3	137	14956**	368	1426**	9285**	4228
Timing of first Samorin treatment (F)	3	302	2231*	1807**	266*	2171**	1728
Berenil treatment (G)	1	1073	3	198	407*	2737*	53
A x B	24	2239**	6600**	4289**	3998**	23037**	27002**
A x D	8	9295**	3138**	9438**	1932**	12448**	52643**
A x G	7	414	589	2148**	2132**	12290**	7508**
B x D	3	836	299	747**	1334**	7191**	7584*
C x E	9	782*	1157	222	426**	2533**	2879
C x G	3	920*	3352**	652**	3463**	20255**	32512**
D x E	3	241	771	398	99	404	3656
D x F	3	214	721	3224**	33	170	3422
D x G	1	993	436	5100**	619*	6752**	6704
E x G	3	319	1447	98	2376**	14219**	12419**
F x G	3	291	829	682**	105	664	7746*
Residual		333	709	165	95	573	2099
Residual df		11905	18172	16181	16181	16181	11905

* = $P < 0.05$
** = $P < 0.01$

Table 15. *Estimated least squares means for performance traits of cows and calves, Mkwuja Ranch, 1973–82.*

	Calving interval		Calf mortality		Birthweight		Calf growth	Weaning weight	Cow productivity	
	(Number[a])	(Months)	(Number[a])	(%)	(Number[a])	(kg)	(g/day)	(kg)	(Number[a])	(kg)
Overall	11999	16.58	18266	8.9	16275	25.5	446	132.3	11999	93.8
Year										
1973	1516	18.11a	1943	10.7bcd	1781	19.5d	492a	137.4a	1516	87.9a
1974	1829	17.16a	2376	13.7d	2095	25.2a	436b	129.4b	1829	85.1a
1975	1670	16.33b	2365	10.3bc	2133	25.2a	428b	127.7b	1670	89.5a
1976	1550	18.44a	2387	5.9ab	2225	27.8b	471a	140.5ad	1550	105.1c
1977	1172	16.97ab	1913	12.2cd	1627	27.4b	378c	117.8c	1172	76.2b
1978	910	17.37a	1507	11.5cd	1369	25.5a	373c	114.8c	910	70.5b
1979	842	17.42ab	1476	7.3abc	981	26.0ac	416b	125.6b	842	84.3ab
1980	1503	14.30c	2040	5.1a	1928	26.5c	527d	152.7e	1503	121.1cd
1981	1007	13.16d	2259	3.4a	2136	26.4c	493a	144.4d	1007	124.5d
Season										
January to February	874	17.60c	1354	12.1b	1143	26.5a	432a	129.9a	874	87.1a
March to May	1709	16.65a	2428	8.4a	2173	24.6b	445b	131.0a	1709	90.9a
June to September	7872	15.76b	11710	6.5a	10521	25.0c	453b	133.4b	7872	100.0b
October to December	1544	16.32ab	2774	8.6a	2438	26.0d	454b	134.6b	1544	97.2b
Age										
3 to 4 years	3591	17.96c	4854	8.9	4351	25.4a	448a	132.6a	3591	86.0b
5 to 6 years	3819	16.52a	5690	8.7	5009	25.7b	462b	136.3b	3819	97.8a
7 to 8 years	2777	15.77b	4303	9.6	3820	25.8b	451a	133.6a	2777	97.8a
9 years and over	1812	16.08ab	3419	8.5	3095	25.2a	423c	126.5	1812	93.6c
Sex of calf										
Male	5912	16.72a	9108	9.2	8067	26.2a	461a	136.5a	5912	96.1a
Female	6087	16.45b	9158	8.6	8208	24.8b	431b	128.0b	6087	91.5b
Area										
Northern	5365	16.09a	8088	9.4	7223	26.4a	446	133.0	5365	96.5a
Southern	6634	17.08b	10178	8.4	9052	24.7b	447	131.5	6634	91.0b
Location/area										
North 1	4130	16.16	5816	7.5a	5237	26.1	497a	145.0a	4130	113.5a
North 2	1235	16.01	2272	11.3b	1986	26.6	394b	120.9b	1235	79.6b
South 3	2847	17.06	4483	8.4	3955	24.8ab	444ab	131.1	2847	91.2
South 4	2812	17.31	4149	7.5	3766	25.0a	440a	130.2	2812	89.4
South 6	975	16.87	1546	9.2	1331	24.3b	456b	133.4	975	92.6

[a] Number of observations for which records were analysed.

Within variable groups, row means followed by the same letter do not differ significantly ($P<0.05$).

If no letter is used, this indicates that the variable group did not show a significant difference in the analysis of variance.

relatively superior performance in the northern area in 1973 and 1978 and relatively inferior performance in 1976 and 1980. Biological events that could have a possible bearing on these results are not known for 1973; 1976 was the final year of a 3-year drought spell affecting both areas; 1978 saw the temporary reduction of tsetse population in the northern area; and 1980 saw the start of more frequent prophylactic treatments in both areas.

Table 16. *Estimated least squares constants for interaction between area on ranch and year of calving or birth for performance traits, Mkwaja Ranch, 1973–82.*

	Estimated least squares constants for interaction between northern area[a] of ranch and year					
	Cow productivity (kg)	Calving interval (days)	Calf mortality (%)	Birth-weight (kg)	Calf growth (g/day)	Weaning weight (kg)
1973	14.9	-62	-2.5	1.6	-15	-2.0
1974	1.3	-3	0.4	0.4	-1	0.1
1975	-1.6	9	0.6	-1.1	0	-1.1
1976	-9.4	28	0.1	-1.3	-20	-6.1
1977	-0.5	-15	3.0	-0.2	12	2.6
1978	7.2	-19	-1.0	0	17	3.9
1979	1.7	-6	-1.4	0.1	7	1.7
1980	-9.3	54	-0.8	0.7	-7	-1.0
1981	-4.3	15	1.6	-0.2	8	1.7

[a] Estimated least squares constants for interaction between southern area and year are the same values with the sign reversed.

Significant interaction effects between area and season for calf weights and cow productivity presumably reflected different seasonal rainfall in the two areas.

Within the northern area, animals in location N1, where the bulk of the bush clearance had been carried out, had lower mortality and higher pre-weaning growth, weaning weight and cow productivity than those in location N2. There were only minor differences in birthweight and pre-weaning growth between animals in the three locations within the southern area.

Cow age

Cow age had a significant effect ($P < 0.01$) on all traits except calf mortality. Calving intervals fell from 17.96 months for 3- to 4-year-old cows to 15.77 months for 7- to 8-year-olds and increased slightly to 16.08 months for cows aged 9 years and over. Calf birthweight, pre-weaning growth and weaning weight were highest in progeny of 5- to 6-year-old cows, then fell off gradually. Overall cow productivity was lowest in 3- to 4-year-olds, highest in 5- to 8-years-olds, and fell off in cows aged 9 years and over.

For young cows, the longer calving interval, lower calf weights and lower cow productivity may reflect a higher nutritive requirement, because they still had requirements for growth in addition to those for lactation and maintenance. The lower trait values for the older cows is interpreted as being the result of reduced ability to cope with nutritional and other stress factors associated with the aging process.

Season of calving or birth

Season of calving or birth significantly affected all traits ($P < 0.01$). When seasonal effects on each performance trait were expressed as a percentage above or below the overall mean (Table 17), the largest seasonal differences were in calving interval, calf mortality, and cow productivity. Calving in the period June to September, the second dry season, gave the best results for these three traits.

Calving intervals following parturition in June to September were 4.9% shorter than the overall average. Calving during this period allowed conception during the short rains. Mortality rates following birth in June to September were 27% lower than the overall average. The highest mortality occurred in calves born in January to February; these animals had the long rains to contend with before weaning. Cow productivity fol-

Table 17. *Effect of season of calving or birth on performance traits, Mkwaja Ranch, 1973–82.*

Season	Percentage above or below overall mean					
	Calving interval[a]	Calf mortality[a]	Birth-weight	Pre-weaning growth	Weaning weight	Cow productivity
Jan. – Feb.	6.2	36.0	3.5	-3.1	-1.8	-7.1
March – May	0.4	-5.6	-3.5	-0.2	-0.9	-3.1
June – Sept.	-4.9	-27.0	-2.0	1.6	0.9	6.6
Oct. – Dec.	-1.6	-3.4	2.0	1.8	1.8	3.6

[a] Negative value more desirable.

lowing calving in June to September was 6.6% higher than the overall average.

Seasonal effects on birthweight, pre-weaning growth and weaning weight were less important. While calves born in January to February had the highest birthweights, their low pre-weaning growth resulted in their being the group with the lowest weaning weights.

Sex of calf

Sex of calf had a significant effect ($P < 0.01$) on all traits except calf mortality. Cows suckling a male calf took 8 days longer to conceive than those suckling a female. Male calves were 5.6% heavier at birth, grew 7% faster and were 6.6% heavier at weaning. Cows producing male calves had an average productivity 6% higher than those with female calves.

DEVELOPMENT OF EFFECTIVE MANAGEMENT SYSTEMS

Evaluation of environmental influences on performance has indicated a number of important points in relation to management and the development of more effective management techniques.

Superior animal performance in the northern area where bush clearance had been undertaken suggests that an evaluation of the costs of this work in the two northern locations, relative to the value of the increased production, should be attempted. This would allow logical decisions on the possibilities of further bush clearance and pasture improvement in other locations. The significant area by year interactions showed relatively higher productivity in the northern area in 1978 when a temporary reduction in the tsetse fly population had taken place. This suggests that further evaluation of approaches such as the use of traps to reduce the tsetse population could be relevant.

From the analysis of age of cow effects, the fact that cows did not decrease in overall productivity until aged 9 years and over (consistent with numerous reports in the literature from non-trypanosomiasis-risk situations) indicates that the multiple inoculation of trypanocidal drugs (approximately 40 times by 9 years of age) did not raise any serious problems for animals.

The calving season was shown to have a major effect on productivity. Calving in the optimal season resulted in a productivity 9% higher than that over the rest of the year. The fact that two thirds of cows were already bred to calve in this season shows this effect to have been well recognised. However, further emphasis on the optimal calving season would raise productivity still more.

INCREASING SELECTION EFFICIENCY

The major effects of year, season, cow age and calf sex on virtually all performance traits, and of location and area of ranch on several traits, illustrate the importance of taking these environmental influences into consideration in analyses. Highly significant year and season of calving or birth effects and their interaction were as expected, in view of the very marked differences between years and seasons in terms of rainfall and pasture availability. Cow age effects were consistent with numerous reports in the literature. Very young cows that still have a nutritive requirement for growth show longer post-partum intervals and provide a poorer maternal environment for their calves than do older cows. Very old cows also have lower production capabilities as a result of their reduced ability to cope with nutritional and other stress factors associated with the aging process. Finally, the calf sex differences were entirely consistent with reports in the literature for suckling calf situations.

7. CHEMOPROPHYLAXIS AT MKWAJA

PROPHYLACTIC AND THERAPEUTIC REGIME

The necessity for prophylactic treatment at Mkwaja, to enable cattle ranching to be undertaken in this situation, has been described in Chapter 3.

From 1973 to June 1980, breeding cows, heifers, bulls, young bulls and steers were maintained under Samorin prophylaxis (0.5 mg/kg bodyweight) administered on a herd basis, with the dates on which each herd was treated being recorded. Infection was monitored by a programme of blood sampling. Thick blood smears were used to establish whether infection was present and thin smears to identify the species of trypanosome. Between 30 and 40 animals per herd were tested, beginning 1 month after the last herd prophylaxis. This was repeated every 1 or 2 weeks depending on a subjective assessment of the level of challenge. Animals selected for blood sampling were not representative of the whole herd but included any animals which looked in poor condition. The results of the bood sampling, together with a subjective assessment of the health of the whole herd, were used to decide on the need for prophylaxis. If 20% of slides in a sample were trypanosome-positive this would result in treatment of that herd with Samorin. If less than 20% of slides were positive from a herd which was judged to be in generally good health, this would not result in immediate herd treatment, but in treatment of the individually positive animals with Berenil. However, a similar proportion of positive slides found in a herd where the animals appeared not to be in good health would result in treatment of all cattle with Samorin.

Blood samples were also taken from individual animals if they appeared to be sick on being counted in and out of the night paddocks. If a slide revealed parasitaemia, and the next Samorin treatment for the herd was not yet due, the animal would be treated with a curative dose of Berenil. Records for these treatments administered on an individual basis were not available but represented approximately 4% of the total number of treatments. Berenil was also used occasionally on a herd basis. This was either done strategically, when a particularly high infection rate was detected (e.g. August 1974), or to overcome periods of shortages of Samorin (e.g. 1978). When Berenil was used on a herd basis, the date of treatment for each herd was recorded. Calves received Berenil approximately once a month on a herd basis and were treated with Samorin just before weaning.

In June 1980 the criteria for herd treatment and the drug regime employed were changed. Beginning 2 months after the last prophylaxis, as soon as routine sliding indicated the first parasitaemia, all cows in a herd, together with their calves, were to be treated with Berenil (3.5 mg/kg bodyweight). Approximately 1 week later this was to be followed up with Samorin at 1.0 mg/kg. However, during late 1981 and 1982, due to drug shortages, treatment with Berenil often did not precede treatment with Samorin. The records however showed the dates each herd received either Samorin or Berenil.

TRYPANOSOMIASIS DIAGNOSIS FROM BLOOD SMEARS

Table 18 shows the results of thick blood smear examinations from 1973 to 1982, grouped by area, location, year and season.

From more than 37 000 thick blood smears examined, 10.6% were found to be positive for trypanosomes. In over 90% of the positive cases *T. congolense* was identified; *T. vivax* was identified in most of the remainder; *T. brucei* was found in only 1%. As the experimental studies reported in Chapter 3 show, the level of tsetse chal-

Table 18. *Evaluation of thick blood smears from cattle, Mkwaja Ranch, 1973–82.*

	Number of smears examined	Number positive for trypanosomiasis	% positive for trypanosomiasis
Total	37 484	3 974	10.6
Area			
Northern	16 924	1 979	11.7
Southern	20 560	1 995	9.7
Location			
N1	13 158	1 325	10.1
N2	3 766	654	17.4
S3	6 757	787	11.6
S4	9 611	753	7.8
S6	4 192	455	10.9
Year			
1973	6 101	736	12.1
1974	5 986	473	7.9
1975	2 558	267	10.4
1976	3 913	287	7.3
1977	3 660	275	7.5
1978	3 101	213	6.9
1979	2 493	323	13.0
1980	2 887	348	12.1
1981	2 985	343	11.5
1982	3 800	709	18.7
Season			
Jan. to Feb.	5 502	574	10.4
March to May	11 624	1 233	10.6
June to Sept.	12 788	1 516	11.9
Oct. to Dec.	7 570	651	8.6

lenge at Mkwaja is so high that all cattle must eventually become infected. Thus the results given in Table 18 do not reflect the overall prevalence of trypanosomes, but rather the decision-making strategy of treating herds based on a 20% detection rate of trypanosomes in a sample, coupled with assessment of general herd condition. A higher proportion of positive smears were found in animals sampled in the northern area (11.7%) than in the southern area (9.7%). The 'maximum' and 'minimum' locations were N2 (17.4%) and S4 (7.8%). Year means ranged from 6.9% positive smears in 1978 to 18.7% in 1982. As far as seasonal effects were concerned, October to December (the short rainy season following a dry period) yielded the lowest percentage of positive smears (8.6%).

ENVIRONMENTAL INFLUENCES ON NUMBER OF TREATMENTS REQUIRED

The numbers of trypanocidal drug treatments required annually, calculated from the numbers given from one calving to the next, were 4.4 ± 0.02 Samorin treatments with a coefficient of variation of 41% and 0.6 ± 0.01 Berenil treatments with a coefficient of variation of 124%. The significance of environmental influences on the numbers of Samorin and Berenil treatments required is indicated in Table 19. The actual effects related to year of calving, season of calving, age, sex of calf, and ranch area and location are presented in Table 20.

Year of calving. Cows calving from 1973 to 1978 were maintained under the same criteria for prophylactic treatment. In general, they were treated with Samorin when 20% trypanosome positive slides were detected in a 10% sample of animals from their herd, usually selected as the poorest looking individuals. Occasionally shortages of Samorin meant that Berenil was substituted. A change in criteria for treatment, instigated in 1980, affected all cows calving from 1979 onwards. In these years, as soon as the sample sliding indicated the first parasitaemia in a herd, all cows were treated with Samorin. It had been intended that they should additionally be treated with Berenil, but due to shortages this often did not take place.

As indicated in Table 20, there was a marked increase in the number of annual Samorin treatments during the period 1975 to 1978 (average of 4.8) compared with the period 1973 to 1974 (average 3.5). The number of Berenil treatments also

Table 19. *Mean squares for number of Samorin and Berenil treatments required annually, Mkwaja Ranch, 1973–82.*

Source	df	Number of Samorin treatments	Number of Berenil treatments	Total number of treatments
Year (A)	8	1892**	2978**	7319**
Season (B)	3	68**	411**	352**
Age	3	46**	830**	1132**
Sex of calf	1	0	2	0
Area (C)	1	4463**	22	5108**
Location/northern area	1	397**	1856**	4036**
Location/southern area	2	140**	394**	203**
A x B	24	423**	329**	770**
A x C	8	479**	407**	871**
B x C	3	262**	186**	614**
Remainder	11944	6	6	12

** = $P < 0.01$

increased from approximately 0.1 per year in 1973 to 1974 to 0.3 per year in 1975 to 1978. One possible explanation for the increase in the number of annual treatments between 1973 and 1978 is variation in tsetse challenge; precise information to confirm or disprove this is not available. On the other hand, the increase in the number of treatments from 1973 to 1978 could reflect a progressive reduction in the sensitivity of the trypanosome population to Samorin; however, for reasons discussed later in this chapter there is circumstantial evidence that Samorin resistance was not developing. The altered criteria for treatment affecting 1979 to 1981 calvings led to a further increase to 5.2 Samorin treatments and 1.8 Berenil treatments per year over that period.

Season of calving. There was no significant difference in number of Samorin treatments due to season of calving. There was some indication that cows calving from March to September had slightly more Berenil treatments than those calving during the remaining months of the year.

Age. There was no evidence of any differences in numbers of Samorin or Berenil treatments due to age of cows.

Sex of calf. The sex of a calf had no effect on the number of Samorin or Berenil treatments received by its dam.

Area or location. There was a marked difference between the northern and southern areas of the ranch in the number of Samorin treatments (4.3 in the north, 4.9 in the south) but no differences in the number of Berenil treatments. The major location difference was between locations N1 and N2 in the northern area (4.0 versus 4.5 for Samorin and 0.1 versus 1.3 for Berenil). Both area and location differences could have been influenced by bush clearance work which had taken place in the northern area but not in the southern and which was concentrated on the N1 location very much more than the N2 location. This bush clearance has had a considerable effect in reducing tsetse densities in the northern area and especially in location N1.

EFFECT OF TRYPANOCIDAL TREATMENTS REQUIRED ON PERFORMANCE

Table 21 summarises the significance of trypanocidal treatments required, and their interactions, on performance traits. The actual significance values are presented in Table 14.

The period from parturition to 240 days after parturition is the optimal period for evaluation of treatment effects in relation to calving interval (mean reconception period is 7.3 months), calf viability, pre-weaning growth and weaning weight (8 months), and cow productivity index (8 months).

In interpreting the effects of drug treatments and their interactions on performance traits, the strategy of the prophylactic regime has to be kept in mind. The number of Samorin treatments that animals received over the 240-day period from parturition was based on blood smear evaluations and assessments of herd condition. These almost

Table 20. *Estimated least squares means for number of Samorin and Berenil treatments required annually, Mkwaja Ranch, 1973–82.*

Variable	Number of cows	Number of Samorin treatments	Number of Berenil treatments	Total number of treatments
Overall	11 999	4.6	0.7	5.3
Year of calving				
1973	1 516	3.4a	0.0a	3.4a
1974	1 829	3.5a	0.2b	3.7b
1975	1 670	4.4b	0.1a	4.6c
1976	1 550	4.7b	0.0a	4.7c
1977	1 172	4.5b	0.4c	5.0d
1978	910	5.2c	0.4c	5.6e
1979	842	5.3c	1.1d	6.4f
1980	1 503	5.1c	2.6f	7.7g
1981	1 007	5.0c	1.6e	6.6f
Season of calving				
Jan. to Feb.	874	4.6a	0.3a	4.9a
March to May	1 709	4.7a	0.9c	5.6c
June to Sept.	7 872	4.5b	1.1d	5.5c
Oct. to Dec.	1 544	4.5b	0.6b	5.1b
Age				
3 to 4 years	3 591	4.5a	0.5a	5.0a
5 to 6 years	3 819	4.5a	0.9c	5.4c
7 to 8 years	2 777	4.6b	0.8c	5.5c
9 years and over	1 812	4.6ab	0.7b	5.3b
Sex of calf				
Male	5 912	4.6	0.7	5.3
Female	6 087	4.6	0.7	5.3
Area				
Northern	5 365	4.2a	0.7	4.9a
Southern	6 634	4.9b	0.7	5.7b
Location/area				
North 1	4 130	4.0a	0.1a	4.1a
North 2	1 235	4.5b	1.3b	5.8b
South 3	2 847	5.0b	0.5a	5.5a
South 4	2 812	5.1b	0.5a	5.6a
South 6	975	4.7a	1.2b	5.9b

Within variable groups, row means followed by the same letter do not differ significantly ($P < 0.05$). If no letter is used it indicates the variable group did not show a significant difference in the analysis of variance.

certainly reflected the level of tsetse challenge that animals were subjected to in a particular geographical situation on the ranch, in a particular year, and at a particular season of the year. The basic strategy was to treat a herd as soon as a small proportion of animals had become affected by trypanosomiasis, and restore the health status of the herd as rapidly as possible.

Number of Samorin treatments required

The effects of number of Samorin treatments required from parturition to 240 days after parturition on the performance traits of calving interval, calf viability, calf pre-weaning growth, calf weaning weight and cow productivity index are given in Table 22.

In general, performance deteriorated as the number of Samorin treatments required during the 240 days after parturition increased. This would be the logical expectation from the strategy of Samorin treatment as soon as a small proportion of animals in a herd had become affected by trypanosomiasis.

Number of Samorin treatments required had a significant interaction with Berenil treatment given and with age for some performance traits. No patterns could be identified for the interaction with age. The interaction with Berenil treatment given is discussed below.

Berenil treatment given

The effects of any Berenil treatments given from parturition to 240 days after parturition on the performance traits of calving interval, calf viability, calf pre-weaning growth, calf weaning weight and cow productivity index are given in Table 23.

Table 21. *Summary of significance of trypanocidal treatments and their interactions on performance traits, Mkwaja Ranch, 1973–82.*

	Calving interval	Calf viability	Birth-weight	Pre-weaning growth	Weaning weight	Cow productivity
Number of cow Samorin treatments		**		**	**	
Timing of cow Samorin treatments		*	**	*	**	
Cow Berenil treatment				*	*	
Number of cow Samorin treatments x cow Berenil treatment				**	**	**
Timing of cow Samorin treatments x cow Berenil treatment			**			*
Area x timing of cow Samorin treatments			**			
Area x cow Berenil treatment			**	*	**	
Age x number of cow Samorin treatments				**	**	
Age x cow Berenil treatment	*	**	**	**	**	**
Year x cow Berenil treatment	*		**	**	**	**

* = P < 0.05
** = P < 0.01

Performance deteriorated if any Berenil treatment was given during the 240 days after parturition. Again, this would be the logical expectation from the strategy of Berenil treatment, either as a substitute for Samorin (1973 to 1979) or in addition to Samorin (1980 to 1982), as soon as a small proportion of animals in a herd had become affected by trypanosomiasis.

Berenil treatment given had a significant interaction with number of Samorin treatments required, and with age, area and year of calving, for some performance traits. No patterns could be identified for the interactions with age, area and year of calving. The interaction with number of Samorin treatments required is discussed below.

Interaction between Samorin and Berenil treatments: Its relevance to drug resistance

The interaction constants between Berenil treatment given and number of Samorin treatments required, from parturition to 240 days after parturition, on the performance traits of calving interval,

Table 22. *Effects of number of Samorin treatments required from parturition to 240 days after parturition, on performance traits, Mkwaja Ranch, 1973–82.*

Trait	Significance in ANOVA	No. of Samorin treatments required			
		1	2	3	4
Calving interval (days)	NS	511	499	504	505
Calf viability (%)	**	96.1	92.5	89.5	86.4
Pre-weaning growth (g/day)	**	460	451	438	436
Weaning weight (kg)	**	135.8	133.6	130.1	129.5
Cow productivity index (kg)	(*)	96.1	95.4	93.4	90.3

NS = Not significant
(*) = Approaching significance
** = P < 0.01

Table 23. *Effects of Berenil treatment given between parturition to 240 days after parturition, on performance traits, Mkwaja Ranch, 1973–82.*

Trait	Significance in ANOVA	No Berenil treatment given	Berenil treatment given
Calving interval (days)	(*)	494	515
Calf viability (%)	NS	89.5	88.6
Pre-weaning growth (g/day)	*	452	441
Weaning weight (kg)	*	133.6	130.9
Cow productivity index (kg)	NS	94.0	93.5

NS = Not significant
(*) = Approaching significance
* = $P < 0.05$

calf viability, calf pre-weaning growth, calf weaning weight and cow productivity index are given in Table 24. The numbers of records in each class are indicated in Table 25.

The interaction constants in Table 24 show that in all traits the use of Berenil treatment had the greatest relative effect on performance in the situation where only one Samorin treatment was required. The relative effect of Berenil treatment decreased as the number of Samorin treatments required increased.

This would suggest that at a location and time where only one Samorin treatment is required over the 240-day period, the level of trypanosomiasis risk must be relatively low, and therefore the average time for trypanosomiasis reinfection relatively long. A Berenil treatment given in this situation will have a curative effect and the treated animal is likely to remain uninfected for a relatively long period. In contrast, when a cow receives four or more Samorin treatments during the 240-day period, the level of challenge must be high, and the average time to trypanosomiasis reinfection relatively short. A Berenil treatment in such a case will also have a curative effect, but the treated animal is likely to become reinfected rapidly.

Cross-resistance between Samorin and Berenil is thought to be rare (Leach and Roberts, 1981). Thus in a situation where resistance to Samorin existed, it would be expected that use of an occasional Berenil treatment would be more effective than an additional Samorin treatment. In terms of maintaining overall productivity, Table 23 shows that the effects of an occasional Berenil treatment are very similar to those of a Samorin treatment (Table 22). Further, if resistance to Samorin was to develop, this would be

Table 24. *Interaction constants between Berenil treatment given and number of Samorin treatments required from parturition to 240 days after parturition, on performance traits, Mkwaja Ranch, 1973–82.*

Trait	Significance in ANOVA	No. of Samorin treatments required			
		1	2	3	4
Calving interval (days)[a]	NS	−12	1	7	4
Calf viability (%)[b]	(*)	+ 1.2	−0.5	+0.3	−1.0
Pre-weaning growth (g/day)[b]	**	+14	+8	−2	−19
Weaning weight (kg)[b]	**	+ 3.3	+2.0	−0.6	−4.7
Cow productivity index[b]	**	+ 8.0	+0.5	−2.5	−6.0

[a] Lowest value most desirable
[b] Highest value most desirable
NS = Not significant
(*) = Approaching significance
** = $P < 0.01$

Table 25. *Numbers of records in interaction classes between Berenil treatment given and number of Samorin treatments required, from parturition to 240 days after parturition, Mkwaja Ranch, 1973–82.*

Trait	Berenil treatment given	No. of Samorin treatments required			
		1	2	3	4
Calving interval	No	136	1896	3690	1754
	Yes	368	1501	1968	686
Calf viability	No	564	3024	5261	2560
	Yes	615	2393	2726	1123
Pre-weaning growth	No	537	2788	4646	2050
	Yes	557	2192	2510	995
Weaning weight	No	537	2788	4646	2050
	Yes	557	2192	2510	995
Cow productivity index	No	136	1896	3690	1754
	Yes	368	1501	1968	686

expected in a high trypanosomiasis-risk situation where Samorin treatments are required very frequently, rather than in a low-risk situation where only infrequent treatments are necessary. Table 24 illustrates, however, that Berenil has relatively less impact in a high-risk than in a low-risk situation.

Thus, the simultaneous evaluation of the effects of Samorin and Berenil treatments and their interaction, on the major performance traits, suggests that at Mkwaja over the period 1973 to 1982 there are no indications from productivity levels of any resistance to Samorin having developed.

Timing of Samorin treatment

The effects of four stages at which the first Samorin treatment was required on the performance traits of calving interval, calf viability, birthweight, pre-weaning growth, weaning weight and cow productivity index are shown in Table 26.

In general, performance was best if the first cow Samorin treatment took place shortly before calving, with a gradual falling-off as the first Samorin treatment date moved further away from the calving date. There was no indication that the use of Samorin in pregnant animals had any negative effect on performance. Timing of Samorin

Table 26. *Effect of timing in relation to calving date of first Samorin treatment required, on performance traits, Mkwaja Ranch, 1973–82.*

Traits	Significance in ANOVA	Shortly before[a] calving	At[b] calving	Shortly after[c] calving	Longer after[c] calving
Calving interval (days)	NS	509	502	500	506
Calf viability (%)	*	92.4	90.9	90.7	90.4
Birthweight (kg)	**	25.9	25.4	25.2	25.6
Pre-weaning growth (g/day)	*	450	447	445	442
Weaning weight (kg)	**	133.5	132.4	131.7	131.4
Cow productivity index (kg)	NS	95.0	94.1	92.8	93.2

[a] 30 to 11 days before parturition
[b] 10 days before to 10 days after parturition
[c] 11 days after to 30 days after parturition
[d] 31 days after to 240 days after parturition
NS = not significant
* = $P < 0.05$
** = $P < 0.01$

treatment had a significant interaction with Berenil treatment given and area, for some traits, but no patterns could be identified.

CONCLUSIONS

This work was carried out in a situation where it had been clearly shown that without chemoprophylactic treatments, animals would die (Chapter 3). The decision to treat animals, based on blood smear evaluation and assessment of herd condition, was such that the number of treatments required reflected the level of trypanosomiasis risk that animals were subjected to, at a particular time and location.

The number of treatments given increased from 1973 to 1981, and could have been related to reduced efficiency of the drug (not borne out by other circumstantial evidence), fluctuations in tsetse challenge (no precise information was available), or to changes in drug strategy (this was known to be the case from 1979 onwards).

Old cows required exactly the same number of treatments as young cows. In Chapter 6 it was shown that cows did not start becoming less productive until 9 years of age and over, consistent with numerous reports from non-trypanosomiasis situations. Thus, maintenance under continuous prophylactic treatment until 9 years of age did not lead to increased requirements for treatment or to an early decline in productivity.

The interaction effects on animal performance between Berenil and Samorin showed Berenil to be relatively more effective in a lower challenge situation than in a higher one. This indicated that, as cross-resistance between Berenil and Samorin is thought to be rare, maintenance under continuous Samorin prophylaxis had not led to the development of resistance to the drug.

There was no indication that the use of Samorin in pregnant animals had any negative effects. In fact a treatment between 30 days before and 10 days after parturition appeared beneficial.

8. LINKS BETWEEN TSETSE POPULATION DYNAMICS AND CATTLE PRODUCTIVITY AT MKWAJA

INTRODUCTION

Between 1976 and 1979 Mkwaja Ranch was the site of a major tsetse fly control project to determine if a technique involving the application of insecticide and the release of sterilised male tsetse flies could constitute an effective method of control (Tarimo et al, 1983; Williamson et al, 1983; 1983a). As part of this study, extensive tsetse surveys were carried out to obtain estimates of pretreatment fly densities and distribution and later to monitor the effectiveness of the insecticide application and the sterile male release programme.

The aims of this chapter are to use these data to examine any possible links between tsetse population estimates, diagnosis of trypanosomiasis, number of Samorin and Berenil treatments required, and resulting cattle performance, over the period from October 1976 to May 1979.

To obtain tsetse population data, 200 km of 'fly rounds' were established throughout the ranch. Collection teams consisting of three men, two carrying a 1.0 x 1.3 m black screen, traversed the fly rounds weekly, stopping every 200 m to capture all flies. A spot of oil paint was applied to the thorax of each fly prior to release. Capture-recapture data were analysed following the methods of Jolly (1965) and Seber (1965).

The objectives of the tsetse fly control project were first to reduce the tsetse population in the experimental part of the ranch by application of insecticide, and then to release sterile male *G. m. morsitans* in this area. The northern half of the ranch, encircled by the 1 km-wide fly barrier, served as the experimental area, and the southern half served as the untreated control. Of additional value was the presence of two *Glossina* species. The *G. m. morsitans* population in the north of the ranch was reduced initially by the use of insecticide and then the sterile males were released. The *G. pallidipes* population in the experimental area was reduced by the insecticide but no sterile males were released against them. Thus the impact of the insecticide plus sterile male release and insecticide only, could be evaluated. Two aerial applications (20 g/ha) of endosulphan, a non-residual insecticide, were made to the experimental area using a Cessna aircraft fitted with a rotary atomizer. The first application was made during the night of 3/4 November 1977. Due to the prevailing wind direction and an extension of the spray cut-off point beyond the experimental area, high tsetse mortality rates were recorded in both the northern (experimental) and southern (control) sections of the ranch. After the first endosulphan application, sterile male *G, m. morsitans* were released in the experimental area against the teneral females emerging from pupae which had been underground, and therefore protected from the endosulphan. The second spray was applied during the night of 1/2 December 1977, and was confined to the experimental area. Sterile male *G. m. morsitans* were then released from December 1977, twice weekly, at 120 release stations throughout the northern area. An average of 135 males/km^2 were released monthly until December 1978.

COMPARISON OF NORTHERN AND SOUTHERN AREAS

Table 27 presents the estimated tsetse densities, blood smear diagnosis, trypanocidal treatments required, and livestock performance during the pre-spray (October 1976 to October 1977) and post-spray (November 1977 to May 1979) periods for the northern and southern areas.

Figure 20 shows, on a monthly basis, the estimated densities of *G. m. morsitans* and *G. pal-*

Table 27. *Comparison of estimated tsetse densities, blood smear diagnosis, trypanocidal treatments required and resultant livestock performance in northern and southern areas of Mkwaja Ranch, October 1976 to May 1979.*

	Northern area		Southern area	
	Pre-spray	Post-spray	Pre-spray	Post-spray
Tsetse density				
G.m. morsitans				
Mean estimated density (males/km^2)	513 ± 32	69 ± 8	918 ± 65	524 ± 31
Relative density (northern v southern)	1.0	1.0	1.8	7.6
G. pallidipes				
Mean estimated density (males/km^2)	184 ± 21	158 ± 12	174 ± 28	163 ± 13
Relative density (northern v southern)	1.0	1.0	0.9	1.0
Blood smear diagnosis				
Number of slides examined	2193	2219	2280	2586
Number of trypanosome positive	148	160	173	240
Percentage positive	6.8	7.2	7.6	9.3
Trypanocidal treatments required				
Number of Samorin treatments required per 240 days	2.5	3.1	3.3	3.6
Calculated Samorin treatment interval (days)	96	77	73	67
Number of Samorin + Berenil treatments required per 240 days	2.7	3.4	3.6	4.0
Calculated treatment interval (days)	89	70	67	60
Resultant livestock performance				
Calving percentage	73.4	72.2	69.1	64.4
Calf viability (%)	89.2	86.5	93.8	87.9
Weaning weight (kg)	129.6	115.9	129.5	107.6
Calculated productivity index (kg)	84.8	72.4	83.9	60.9

Figure 20. *Monthly estimated tsetse densities and blood smear diagnosis, Mkwaja Ranch, October 1976 to May 1979.*

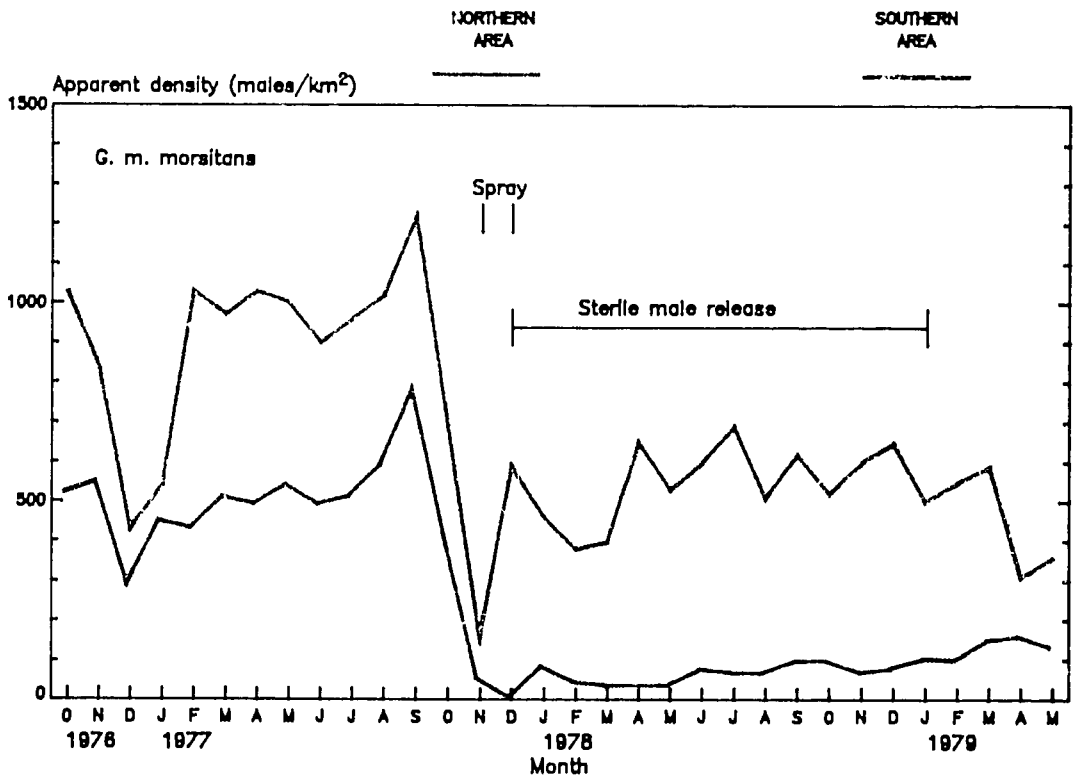
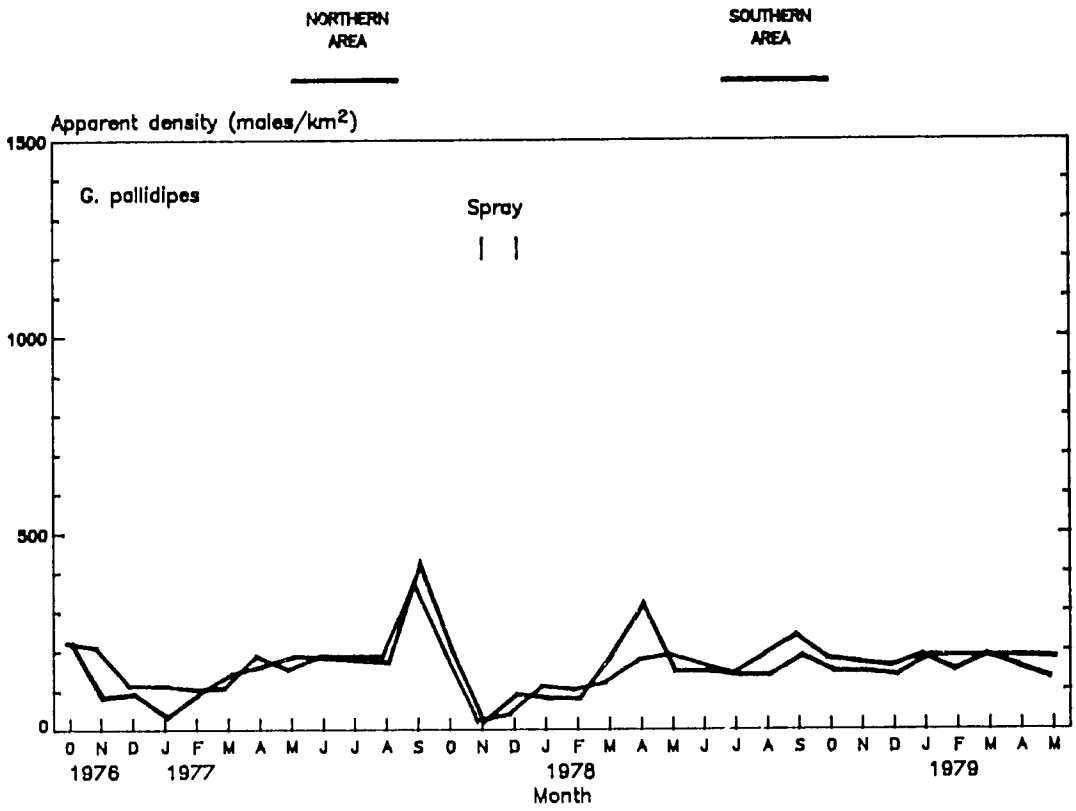
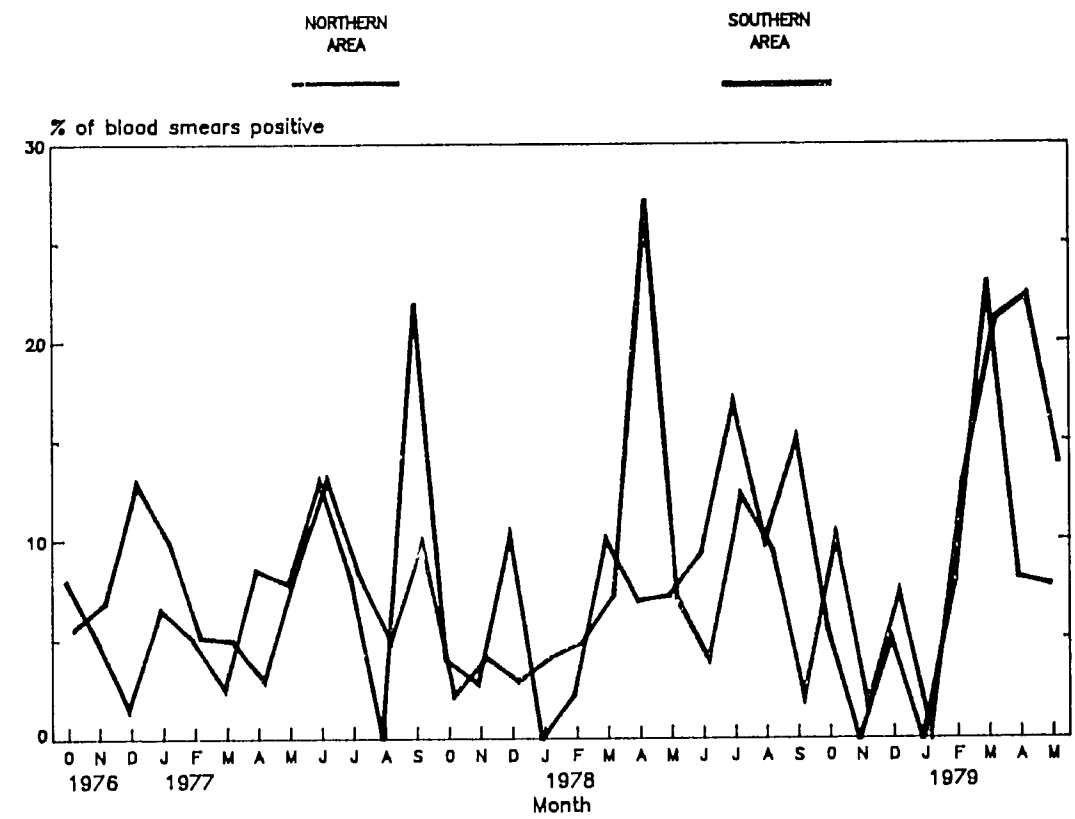


Figure 20 *(cont.)*





lidipes (Williamson et al, 1983; 1983a) and the results of blood smear diagnosis for the northern and southern areas from October 1976 to May 1979. Following the two endosulphan applications in November and December 1977, sterile male *G. m. morstisans* were released in the northern area of the ranch. Figure 20 shows the initial sharp reduction in the estimated density for this species in the northern area due to the insecticide, followed by a sustained reduction in the population to between 5 and 20% of the normal level (based on a pre-spray estimate) throughout 1978, the period of sterile male release. There is no clear indication in Figure 20 of any link between the reduction in *G. m. morsitans* in the northern area from December 1977 to May 1979 and any corresponding reduction in the percentage of blood smears found to be positive.

Table 27 shows that in the southern control area the increase in positive blood smears in the post-spray compared to the pre-spray period was greater than in the northern treated area (7.6 to 9.3% compared with 6.8 to 7.2%). However, while the actual number of Samorin and Berenil treatments required was higher in the southern area, the increase in the post-spray compared to the pre-spray period was lower in the southern area than in the northern area (3.6 to 4.0 treatments per 240 days, compared with 2.7 to 3.4).

Figure 21 attempts to give the best estimates of the traits of calving percentage, calf viability and calf weaning weight, related to each month from October 1976 to May 1979, and a small positive relationship appeared to exist.

In the northern treated area (Table 27), the decrease in livestock performance in the post-spray period compared to the pre-spray period was much less than in the southern control area (1.2% reduction in calving percentage compared to 4.7%; 2.7% reduction in calf viability compared to 5.9%; 13.7 kg reduction in weaning weight compared to 21.9 kg; and 12.4 kg reduction in calculated productivity index compared to 23 kg).

Figure 21. *Monthly estimated performance trait values, Mkwaja Ranch, October 1976 to May 1979.*

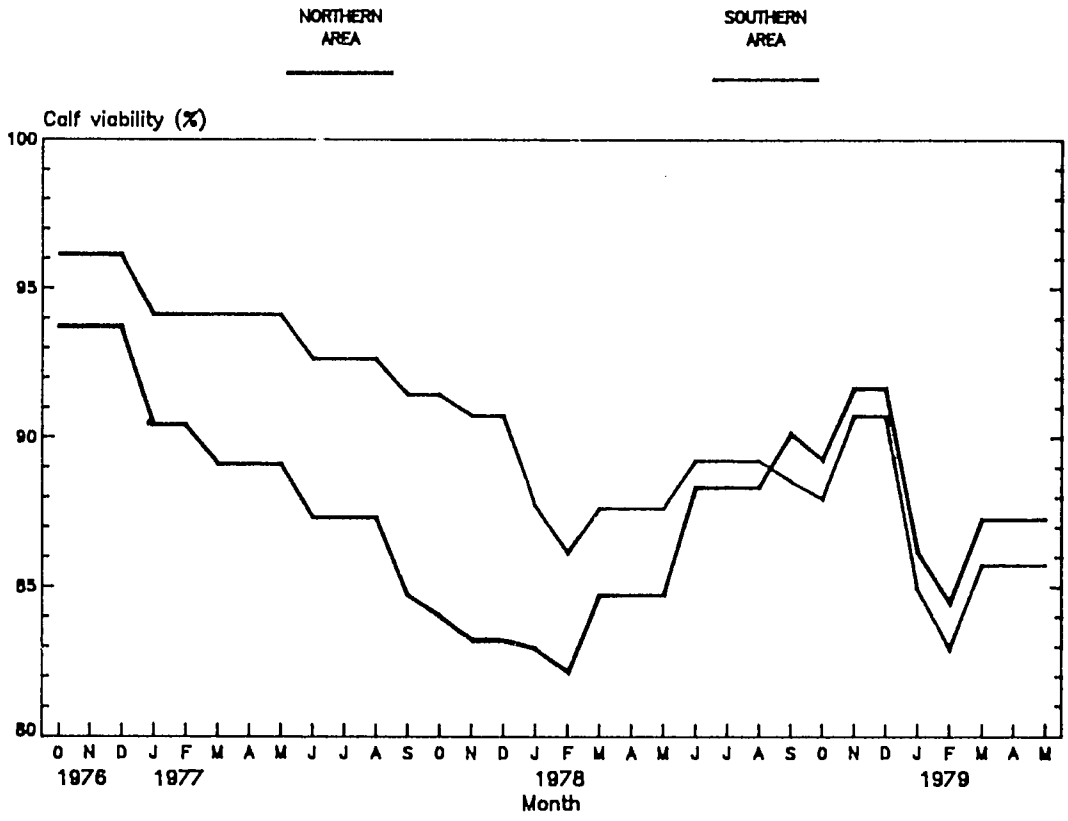
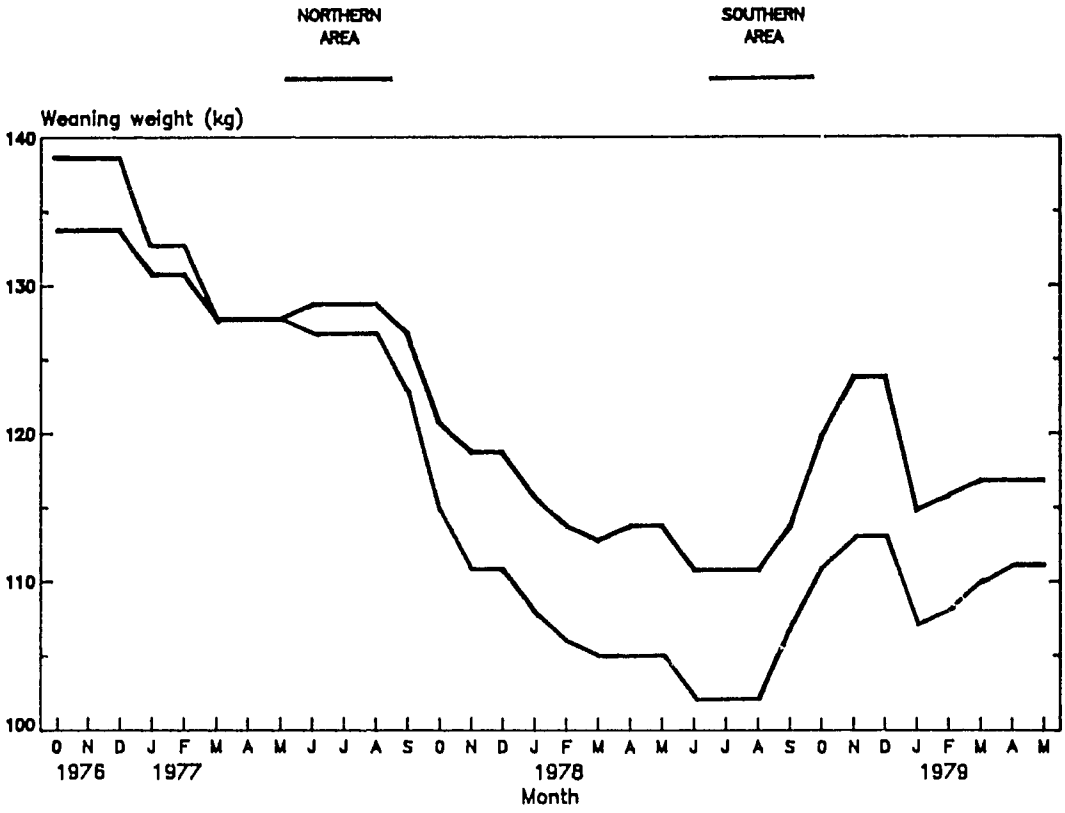
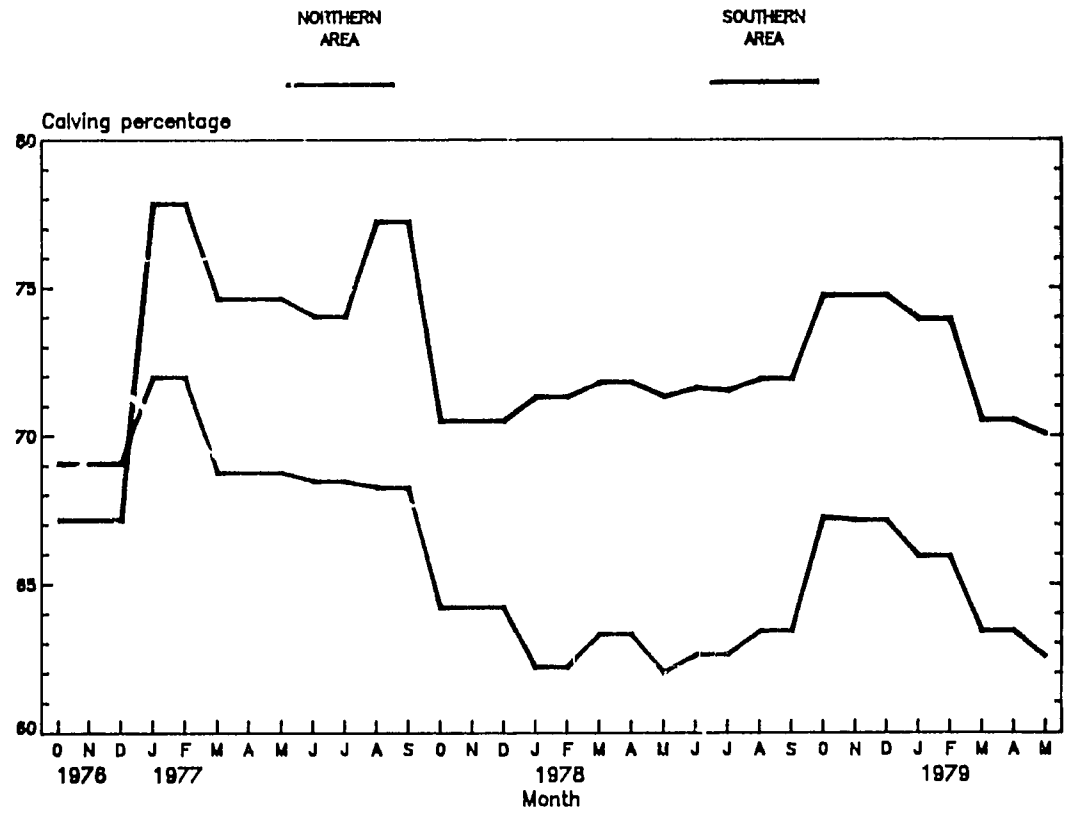


Figure 21 *(cont.)*





9. COMPARISON OF BORAN GENOTYPES AT MKWAJA

INTRODUCTION

In Chapter 10, it is shown that the performance of Boran cattle at Mkwaja was inferior to Kenya Boran cattle under trypanosomiasis-free ranching conditions. It might be expected that this difference in performance is due largely to the different ecological and disease environments pertaining to Mkwaja and the areas of Kenya involved. However, it is of considerable value to try to determine if genetic differences between the two Boran populations are likely to have contributed significantly to the different productivity levels achieved.

Grading up of the original small East African Zebu to Boran has taken place at Mkwaja since 1958. The use of Boran semen from the Kenya National Artificial Insemination Centre over the 8 years from 1974 to 1981 allows comparison of birth, pre-weaning growth, and weaning weight data from 967 progeny of five Kenya A.I. stud bulls, with those from 7264 progeny of over 100 Mkwaja Boran bulls.

Artificial insemination was carried out at two locations, and Table 28 shows the number of records of birth, pre-weaning growth and weaning weight available from Kenya Boran-sired calves from 1974 to 1981, together with their contemporaries sired by Mkwaja Boran bulls.

In the least squares analysis, the effects fitted to the pre-weaning growth data were genotype (sired by Kenya or Mkwaja bulls), individual Kenya Boran sire, location, year of birth, season of birth, age of dam, sex, number and timing of dam's prophylactic treatment and various interactions between these. The significance of the effects on birthweight, pre-weaning growth and weaning weight is shown in Table 29.

GENOTYPE EFFECTS ON PRE-WEANING GROWTH CHARACTERS

The estimated least squares means for genotype are given in Table 30.

Table 28. *Number of birth, pre-weaning growth and weaning weight records available from calves sired by Kenya and Mkwaja Boran bulls, Mkwaja Ranch, 1974–81.*

Year of birth	Kenya Boran	Mkwaja Boran	% Kenya Boran
1974	88	981	8.2
1975	47	1017	4.4
1976	52	1106	4.5
1977	82	769	9.6
1978	253	561	31.1
1979	105	422	19.9
1980	178	1162	13.3
1981	162	1246	11.5
Total	967	7246	11.7

Table 29. *Mean squares for pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Source	df	Birth-weight (kg x 10)	Pre-weaning growth (g/day x 10^{-2})	Weaning weight[b] (kg)
Genotype (A)	1	1255**	464*	3931**
Location (B)	1	2158**	9140**	59787**
Year of birth (C)	7	848**	3122**	19208**
Season of birth (D)	2	1470**	524**	4344**
Age of dam (E)	3	645**	776**	5407**
Sex	1	36913**	18104**	147231**
No. of dam Samorin treatments (F)	3	660**	351*	1715*
Timing of first dam Samorin treatment (G)	3	732**	54	77
Dam Berenil treatment (H)	1	36	426*	2609*
Sire within genotype 1[a]	4	297	71	529
A x B	1	69	1056**	6535**
A x C	7	1721**	271**	1790**
B x C	7	3372**	2168**	13889**
B x D	2	468*	1056**	5159**
B x F	3	477*	179	1021
B x G	3	1104**	47	405
B x H	1	2814**	529*	5151**
C x D	10	958**	1186**	7256**
E x F	9	428**	224*	1333*
E x H	3	415*	664**	4239**
F x H	3	1797**	1025**	6952**
G x H	3	589**	159	831
Residual	8152	154	95	568

[a] Genotype 1 = Sired by Kenya Boran semen
[b] 8 months
* = $P < 0.05$
** = $P < 0.01$

The progeny of Kenya Boran sires were superior to those of Mkwaja Boran sires by 0.8 kg, 16 g and 4.6 kg for birthweight, pre-weaning growth per day and weaning weight respectively, in each case this superiority being by 3.3%.

Table 30. *Genotype effects on pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Trait	Progeny of		Superiority of Kenya Boran progeny	
	Kenya Boran bulls	Mkwaja Boran bulls	Units	Percent
Birthweight (kg)	25.5	24.7	0.8**	3.3
Pre-weaning growth (g/day)	490	474	16*	3.3
Weaning weight (kg)	142.6	138.0	4.6**	3.3

* = $P < 0.05$
** = $P < 0.01$

GENOTYPE X YEAR OF BIRTH INTERACTION EFFECTS ON PRE-WEANING GROWTH CHARACTERS

Genotype x year of birth interactions were significant for all three traits and the constants are presented in Table 31.

Figures 22, 23 and 24 illustrate that whereas the progeny of Kenya Boran sires were superior to those of Mkwaja Boran sires from 1974 to about 1978, from then onwards the two groups were very similar.

Table 31. *Least squares constants for interaction between genotype and year for pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Year	Birthweight (kg) of progeny of		Pre-weaning growth (g/day) of progeny of		Weaning weight (kg) of progeny of	
	Kenya Boran bulls	Mkwaja Boran bulls	Kenya Boran bulls	Mkwaja Boran bulls	Kenya Boran bulls	Mkwaja Boran bulls
1974	1.5	-1.5	3	-3	2.1	-2.1
1975	2.1	-2.1	8	-8	3.9	-3.9
1976	-0.1	0.1	10	-10	2.2	-2.2
1977	-0.2	0.2	9	-9	2.1	-2.1
1978	0.2	-0.2	-6	6	-1.2	1.2
1979	-1.1	1.1	-13	13	-4.1	4.1
1980	-1.2	1.2	7	-7	0.5	-0.5
1981	-1.2	1.2	-18	18	-5.6	5.6

Figure 22. *Birthweight of progeny of Mkwaja Boran and Kenya Boran bulls, 1974-81.*

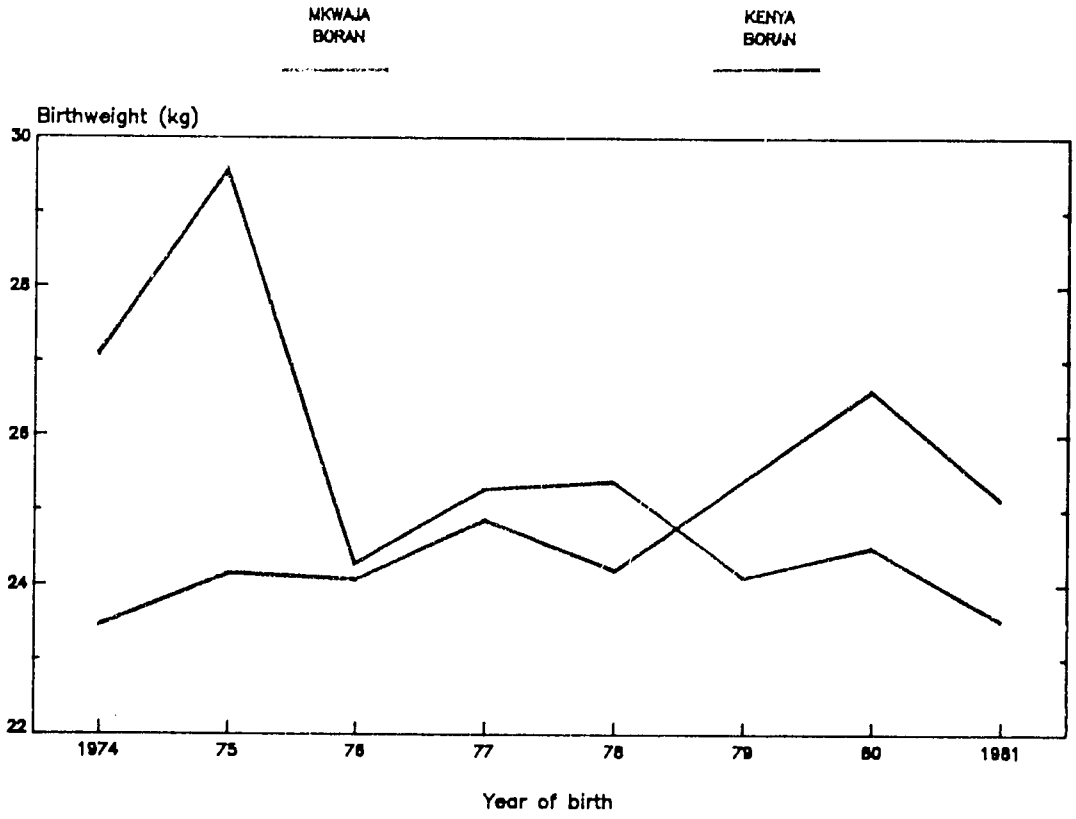


Figure 23. *Pre-weaning growth of progeny of Mkwaja Boran and Kenya Boran bulls, 1974-81.*

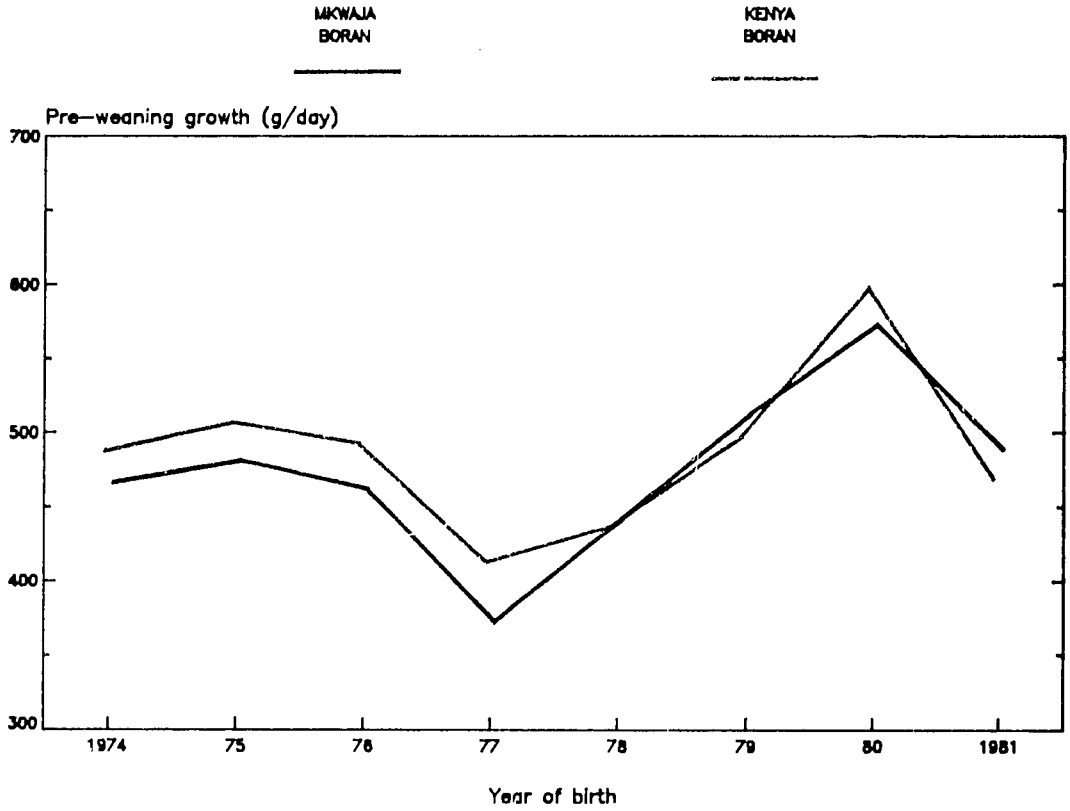
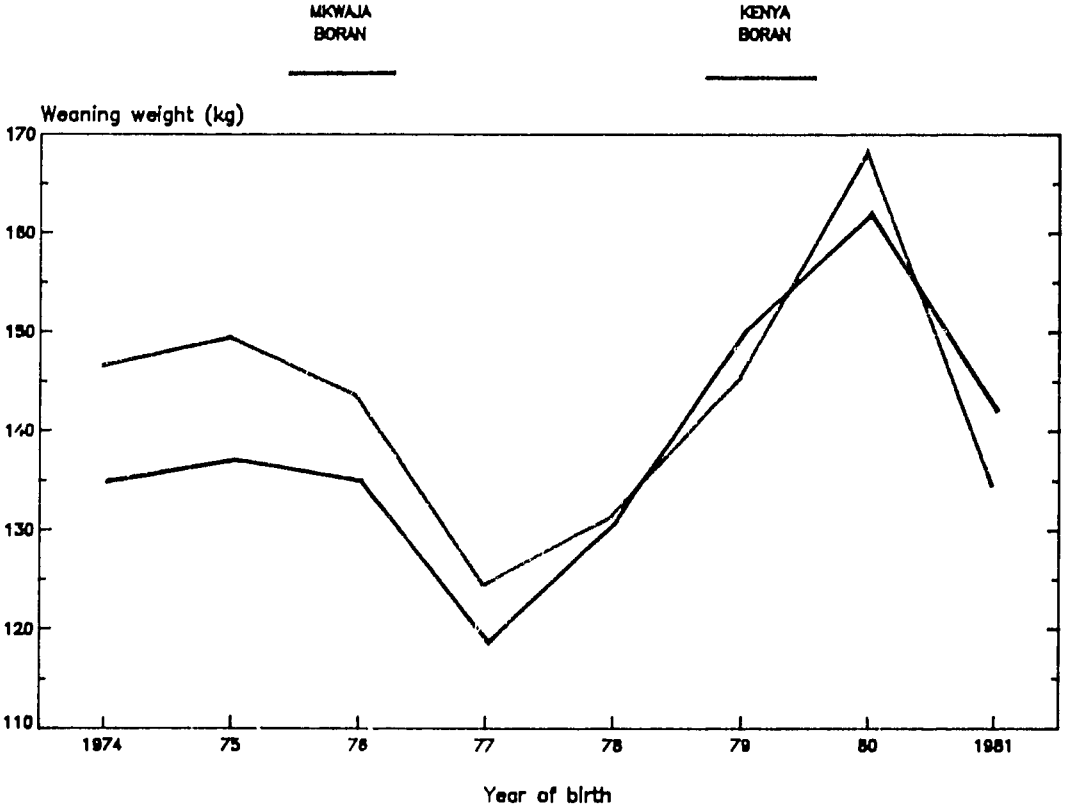


Figure 24. *Weaning weight of progeny of Mkwaja Boran and Kenya Boran bulls, 1974-81.*



To determine any linear trends in birthweight, pre-weaning growth and weaning weight from 1974 to 1981, the regressions of the differences between genotypes on year of birth (represented as 1 to 8) were calculated (Table 32). The

Table 32. *Regressions of differences between genotypes on year of birth, for pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Trait	b	SE_b
Birthweight differences (kg)	−0.90	0.08
Pre-weaning growth differences (g/day)	−5.54	2.83
Weaning weight differences (kg)	−2.22	0.65

regressions were significant for all three traits and indicated that the initial superiority of the progeny sired by Kenya Boran bulls decreased by 0.9 kg per year for birthweight, by 5.5 g per day per year for pre-weaning growth and by 2.2 kg per year for weaning weight. This would suggest that as the percentage of pure Boran genes contributed to all calves from their dams increased from 1974 to 1981, and as the percentage of pure Boran genes from Mkwaja Boran bulls followed suit, so the relative effects of the pure Boran genes from the Kenya sires decreased.

LOCATION EFFECTS ON PRE-WEANING GROWTH CHARACTERS

Comparisons of progeny sired by Kenya Boran and Mkwaja Boran were available at two locations: N1 and S3 (Figure 11). The estimated least squares means for locations are presented in Table 33.

Performances at location N1 were superior to those at location S3 by 1.4 kg for birthweight, 94 g per day for pre-weaning growth and 24.1 kg for weaning weight. These represented advantages of 5.9%, 21.7% and 18.8% respectively. The possible reasons for the much higher productivity achieved at all times at location N1 compared with all other locations have been discussed in Chapters 7 and 8.

GENOTYPE X LOCATION INTERACTION EFFECTS ON PRE-WEANING GROWTH CHARACTERS

Genotype x location interactions were significant for pre-weaning growth and weaning weight, but not for birthweight. The constants are presented in Table 34.

Table 35 illustrates that whereas the progeny of Kenya Boran sires were superior to those of Mkwaja Boran sires for all three traits at location N1, there were no differences between the two genotypes at location S3. This would suggest that the overall superiority of the progeny of Kenya Boran sires (Table 30) could not be expressed in the harsher environment of location S3.

GENOTYPE X YEAR X LOCATION EFFECTS ON PRE-WEANING GROWTH CHARACTERS

Figure 25 illustrates the birthweights of the two genotypes from 1974 to 1981 for each location. Birthweight differences between the two genotypes followed an almost identical pattern over the period in both the superior and harsher locations.

Figure 26 presents the differences between the two genotypes for pre-weaning growth from 1974 to 1981 for each location. The superior pre-weaning growth of progeny of Kenya Boran sires is clearly indicated at location N1, in all years until 1981. At the harsher location S3, however, a different situation exists and there are no significant differences between the two genotypes.

Figure 27 illustrates the differences between the two genotypes for weaning weight from 1974 to 1981 for each location. As would be expected, the weaning weight picture closely follows that of

Table 33. *Location effects on pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Trait	Location		Superiority of calves at location N1	
	N1	S3	Units	Percent
Birthweight (kg)	25.8	24.4	1.4**	5.9
Pre-weaning growth (g/day)	529	435	94**	21.7
Weaning weight (kg)	152.4	128.3	24.1**	18.8

** = $P < 0.01$

Table 34. *Least squares constants for interaction between genotype and location for pre-weaning growth characters, Mkwaja Ranch, 1974–81.*

Trait	Genotype[a]	Location	
		N1	S3
Birthweight (kg)	K	0.1 (793)[b]	−0.1 (174)
	M	−0.1 (3890)	0.1 (3374)
SE of interaction constant		0.16	
Interaction constant as % of μ		0.4	
Pre-weaning growth (g/day)	K	13 (793)	−12 (174)
	M	−13 (3890)	13 (3374)
SE of interaction constant		3.9	
Interaction constant as % of μ		2.7	
Weaning weight (kg)	K	3.2 (793)	−3.2 (174)
	M	−3.2 (3890)	3.2 (3374)
SE of interaction constant		0.94	
Interaction constant as % of μ		2.3	

[a] Genotype K = Progeny of Kenya Boran bulls.
Genotype M = Progeny of Mkwaja Boran bulls.
[b] Numbers in parentheses are the numbers of animals in each sub-class.

closely follows that of pre-weaning growth, the last contributing 81% towards weaning weight.

Over the 8 years from 1974 to 1981 the calves with from 6 to 12% more Boran genes averaged 3.3% higher birthweights, pre-weaning growth and weaning weights overall. From 1978 to 1981, when the difference in level of Boran genes between the two groups had fallen to about 8%, the performance levels were similar.

When performance was looked at separately in the improved and unimproved locations, while the birthweight picture remained the same, the higher grade Boran group had significantly higher growth rates and weaning weights throughout in the improved environment.

CONCLUSION

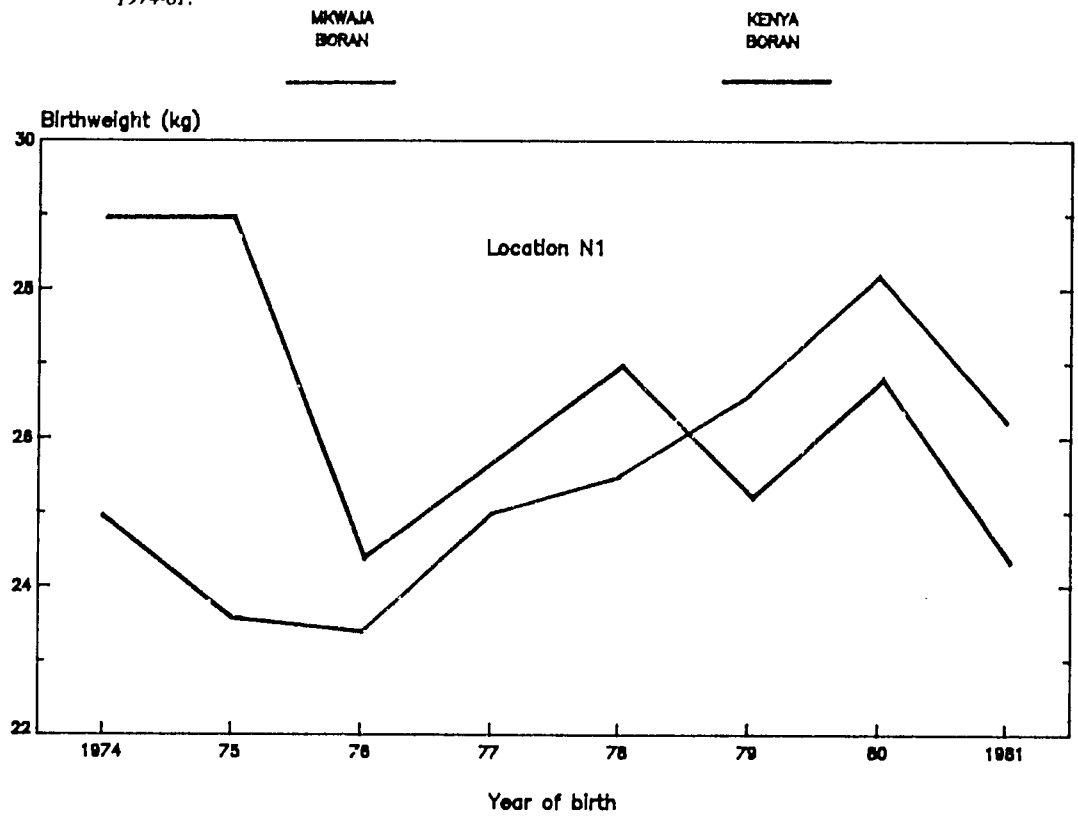
Thus the calves with higher levels of Boran genes (up to 82% Boran) were superior in the improved environment, but in the unimproved environment were not superior to calves that were 60% Boran. Grading up to high level Boran could therefore be advantageous in the areas where bush clearance and tsetse control are implemented, but would not be of value in the remainder of the ranch.

Table 35. *Genotype effects on pre-weaning growth characters in locations N1 and S3, Mkwaja Ranch, 1974–81.*

Trait	Progeny of		Superiority of Kenya Boran progeny	
	Kenya Boran bulls	Mkwaja Boran bulls	Units	Percent
Location N1				
Birthweight (kg)	26.4	25.3	1.0**	4.1
Pre-weaning growth (g/day)	549	508	42**	8.2
Weaning weight (kg)	157.9	146.9	11.0**	7.5
Location S3				
Birthweight (kg)	24.7	24.1	0.6	2.5
Pre-weaning growth (g/day)	430	439	−10	−2.3
Weaning weight (kg)	127.4	129.2	−1.8	−1.4

** = $P < 0.01$

Figure 25. *Birthweight of progeny of Mkwaja Boran and Kenya Boran bulls at locations N1 and S3, Mkwaja Ranch, 1974-81.*



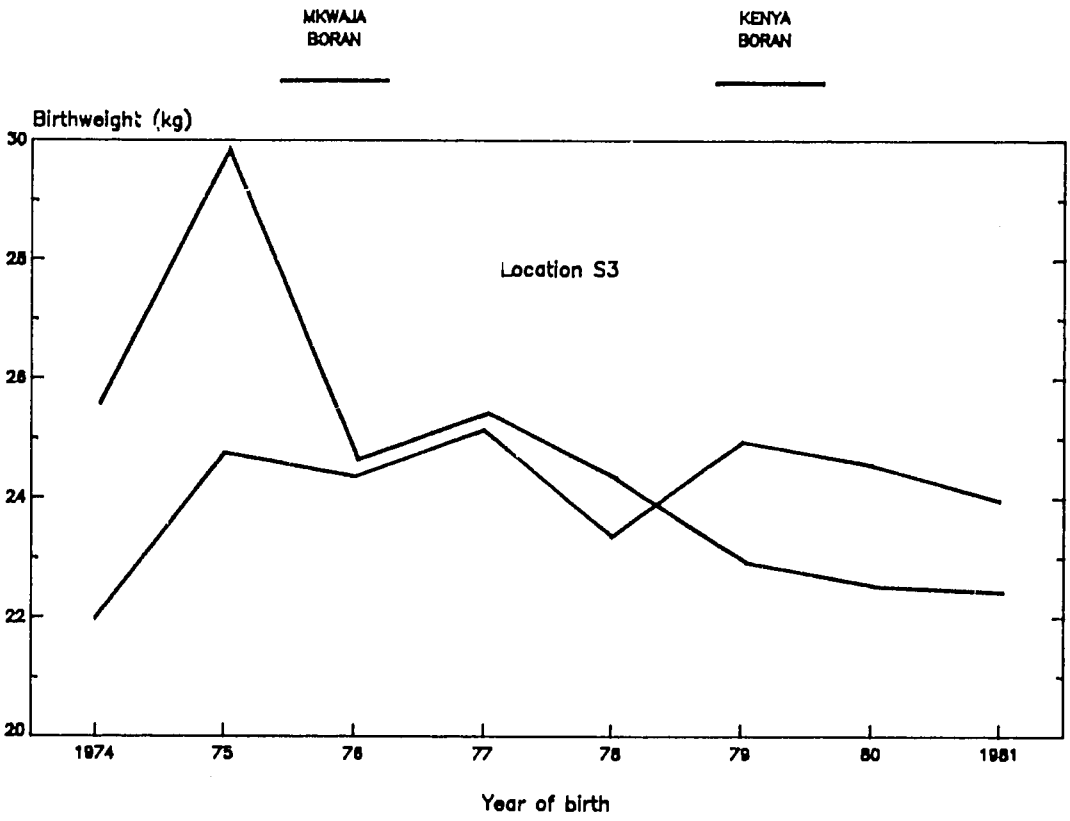
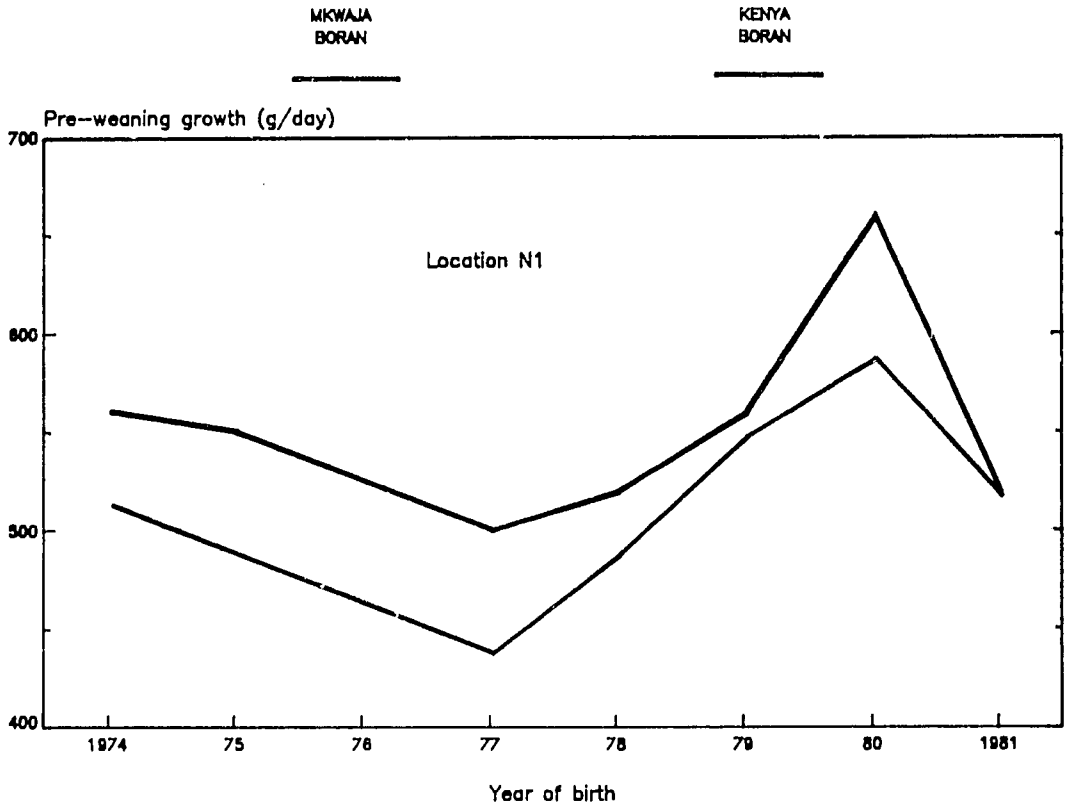


Figure 26. *Pre-weaning growth of progeny of Mkwaja Boran and Kenya Boran bulls at locations N1 and S3, Mkwaja Ranch, 1974-81.*



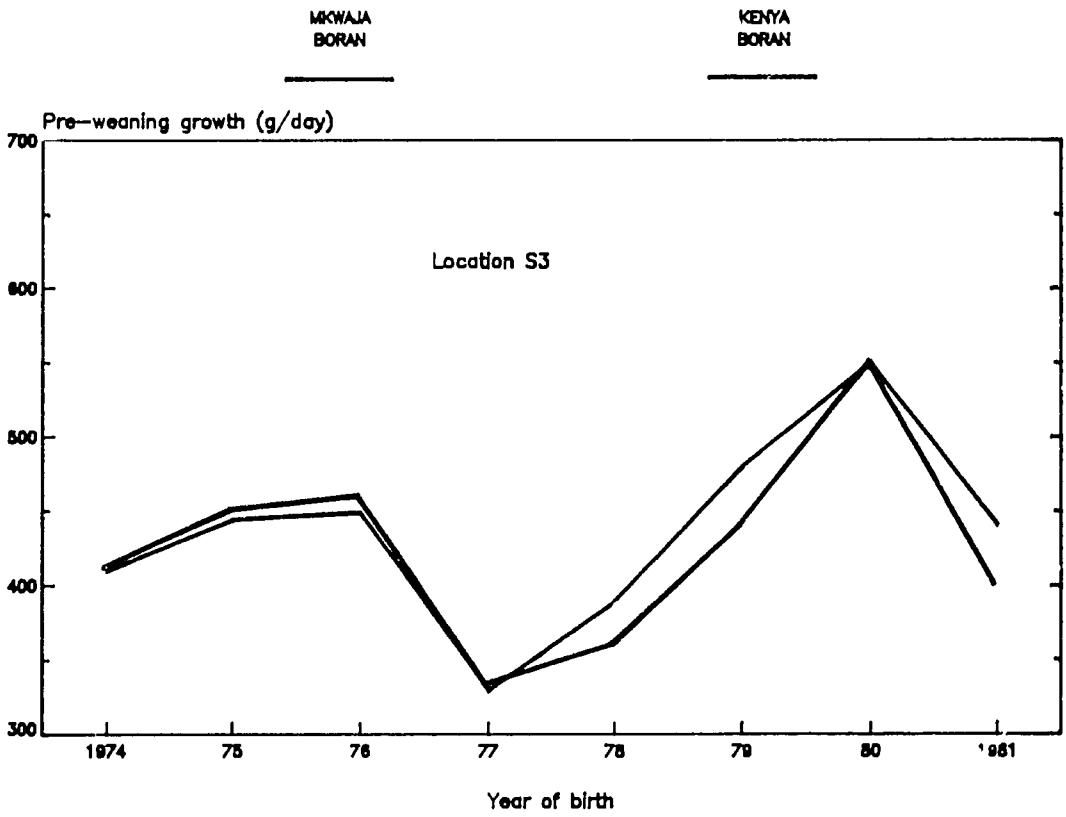
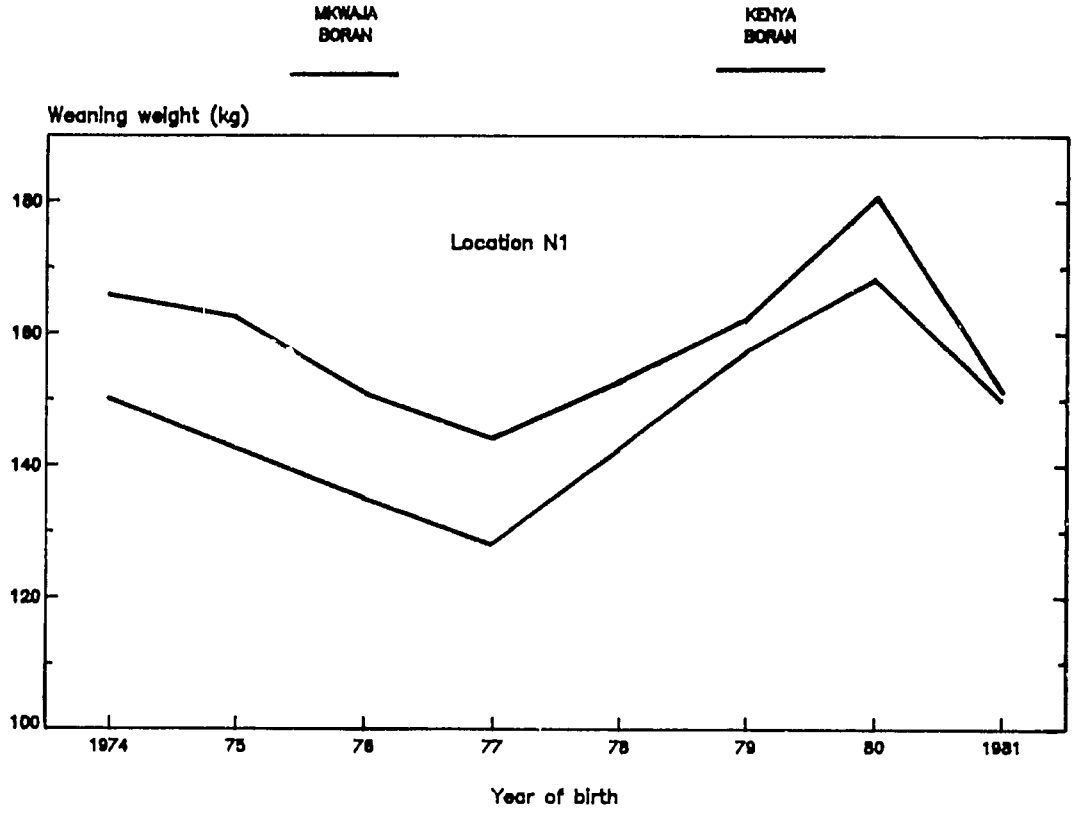
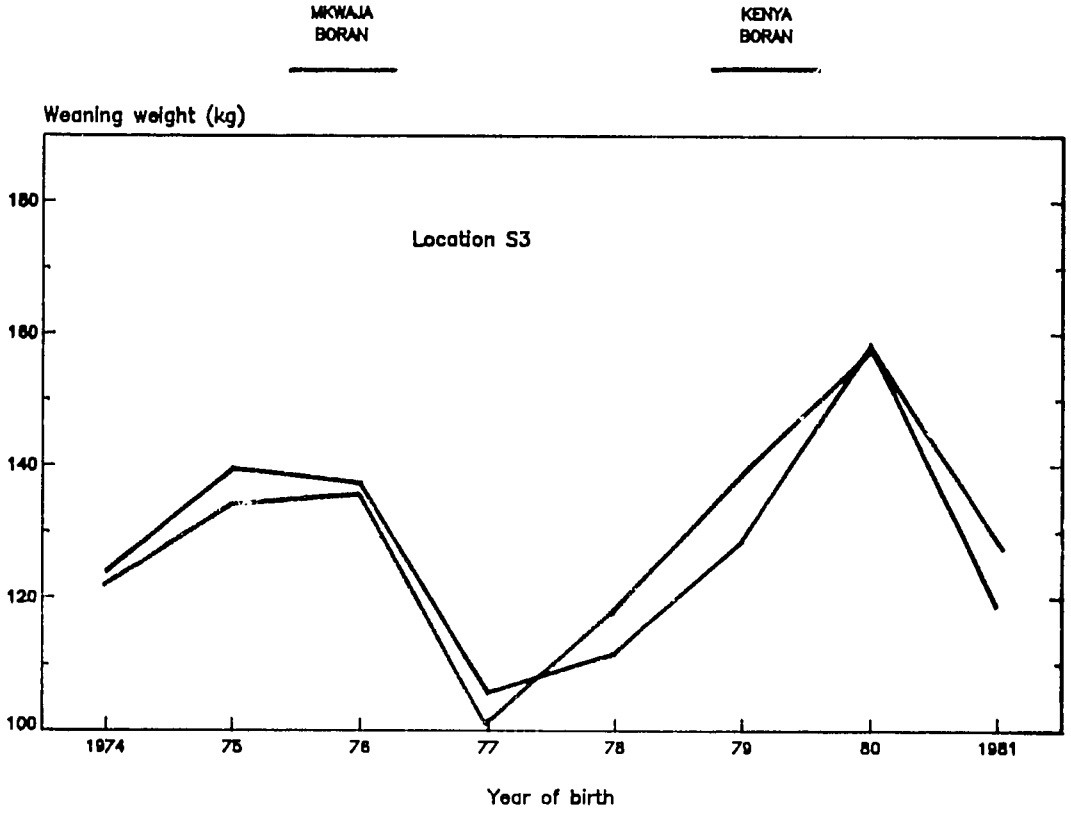


Figure 27. *Weaning weight of progeny of Mkwaja Boran and Kenya Boran bulls at locations N1 and S3, Mkwaja Ranch, 1974-81.*





10. MKWAJA CATTLE PRODUCTIVITY IN AN AFRICAN CONTEXT

The performance levels achieved at Mkwaja have been evaluated in detail in Chapter 5. It is of considerable value to be able to compare these with other major ranching situations in Africa. There are very few data sets of comparable size and complexity available for this purpose, but two sets do exist. ILCA has collected information covering various performance traits from 11 Boran ranches in Kenya (Trail et al, in preparation) comprising around 16 000 data per trait. Since the cattle at Mkwaja have been graded up to Kenya Boran over many years, a comparison between the two situations allows the impact of environmental differences to be quantified for animals of similar genotypes. The Kenya Boran ranches are located in tsetse-free areas, and a major environmental difference between them and Mkwaja is undoubtedly the high trypanosomiasis risk at Mkwaja.

A second data set, also compiled by ILCA (1979), has been built up from nine ranches carrying trypanotolerant N'Dama cattle in medium to high trypanosomiasis-risk situations in West and central Africa. This information covers important performance traits and contains approximately 4000 data per trait. Thus, in similar trypanosomiasis-risk situations, the performances of two dissimilar genotypes can be compared, one genotype possessing genetic resistance to trypanosomiasis, the other being maintained under a chemoprophylactic regime.

Productivity indices, built up from the important performance traits, on both an individual and a herd basis, are of value in comparing different livestock situations. When expressed on the basis of output per unit weight or per unit metabolic weight of cow per year, they permit comparisons between animals of different mature bodyweights. Clearly any comparison based simply on output per cow would tend to favour heavier individuals or breeds. Indices expressed in terms of metabolic bodyweight have the advantage of more accurately reflecting the differences in maintenance costs of cows of different bodyweights.

The objective of this chapter is to present the productivity levels achieved at Mkwaja in the widest possible context. By comparison with animals of similar genotype in trypanosomiasis-free situations in Kenya, the effects of the adverse cattle production environment at Mkwaja can be examined. Comparison with trypanotolerant N'Dama allows two contrasting approaches to cattle production in tsetse-infested areas to be evaluated.

COMPARISON OF MKWAJA BORAN WITH BORAN IN KENYA

Table 36 summarises the overall performance achieved by Boran cattle at Mkwaja and at the ranches in trypanosomiasis-free areas of Kenya.

Boran at Mkwaja were inferior in all performance traits to those in Kenya (Figure 28). Mkwaja Boran were approximately 3% inferior in viability traits, 16% inferior in reproductive performance, and 26% inferior in bodyweights. Calculated cow and herd productivity indices reflected these differences, with differences in productivity per cow between the two situations being relatively greater than differences per unit weight of cow or per unit metabolic weight of cow, due to the lower mature cow weights attained at Mkwaja. The herd productivity, which probably gives the most meaningful comparison, expressed as weight of 8-month-old weaner calf produced per 100 kg metabolic weight of cow per year, was 20% less for the Mkwaja Boran. However, in the most developed area of Mkwaja Ranch (NI), where considerable bush clearance and tsetse control had been carried out, the productivity levels were equal to the average of the Kenya ranches.

Table 36. *Overall performance of Mkwaja Boran compared with Boran in Kenya under trypanosomiasis-free ranch management.*

Trait	Mkwaja Boran[a] High trypanosomiasis risk. Prophylaxis A	Kenya Boran[b] No trypanosomiasis risk. No prophylaxis B	$\frac{(A-B)}{B} \times 100\%$
Reproductive performance			
Age at first calving (months)	47.0	39.7	+18.4
Calving percentage	75.3	87.0	−13.4
Viability			
Pre-weaning viability (%)	92.0	94.6	− 2.7
Annual cow viability (%)	94.2	(98.0)	− 3.9
Bodyweights			
Weaning weight at 8 months (kg)	133.5	174.0	−23.3
Estimated mature cow weight (kg)	293	414	−29.2
Calculated cow productivity			
Productivity[c] per cow per year	92.5	143.2	−35.4
Productivity per 100 kg of cow per year	31.6	34.6	− 8.7
Productivity per 100 $kg^{0.73}$ of cow per year	146.3	176.0	−16.9
Calculated herd productivity			
Productivity per cow per year	87.1	140.3	−37.9
Productivity per 100 kg of cow per year	29.8	33.9	−12.1
Productivity per 100 $kg^{0.73}$ of cow per year	137.8	172.5	−20.1

[a] From Mkwaja Ranch, approximately 12 000 data per trait.

[b] From 11 ranches, approximately 16 000 data per trait, constructed from Trail et al (in preparation).

[c] Productivity = Weight of 8-month-old weaner calf.

Figure 28. *Boran cow in Kenya.*

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Table 37. *Overall performance of Mkwaja Boran compared with trypanotolerant N'Dama in medium trypanosomiasis-risk situations on West and central African ranches.*

Trait	Mkwaja Boran[a] High trypanosomiasis risk. Prophylaxis A	West Africa N'Dama[b] Medium-high trypanosomiasis risk. No prophylaxis B	$\frac{(A-B)}{B} \times 100\%$
Reproductive performance			
Age at first calving (months)	47.0	NA	NA
Calving percentage	75.3	72.2	+ 4.3
Viability			
Pre-weaning viability (%)	92.0	91.1	+ 1.0
Annual cow viability (%)	94.2	98.0	− 3.9
Bodyweights			
Weaning weight at 8 months (kg)	133.5	90.4	+47.7
Estimated mature cow weight (kg)	293	256	+14.5
Calculated cow productivity			
Productivity[c] per cow per year	92.5	59.5	+55.5
Productivity per 100 kg of cow per year	31.6	23.2	+36.2
Productivity per 100 $kg^{0.73}$ of cow per year	146.3	103.9	+40.8
Calculated herd productivity			
Productivity per cow per year	87.1	58.3	+49.4
Productivity per 100 kg of cow per year	29.8	22.7	+31.3
Productivity per 100 $kg^{0.73}$ of cow per year	137.8	101.8	+35.4

[a] From Mkwaja Ranch, approximately 12 000 data per trait.
[b] From nine ranches, approximately 4000 data per trait, constructed from ILCA (1979).
[c] Productivity = Weight of 8-month-old weaner calf.
NA = Not available

COMPARISON OF MKWAJA BORAN WITH N'DAMA IN WEST AND CENTRAL AFRICA

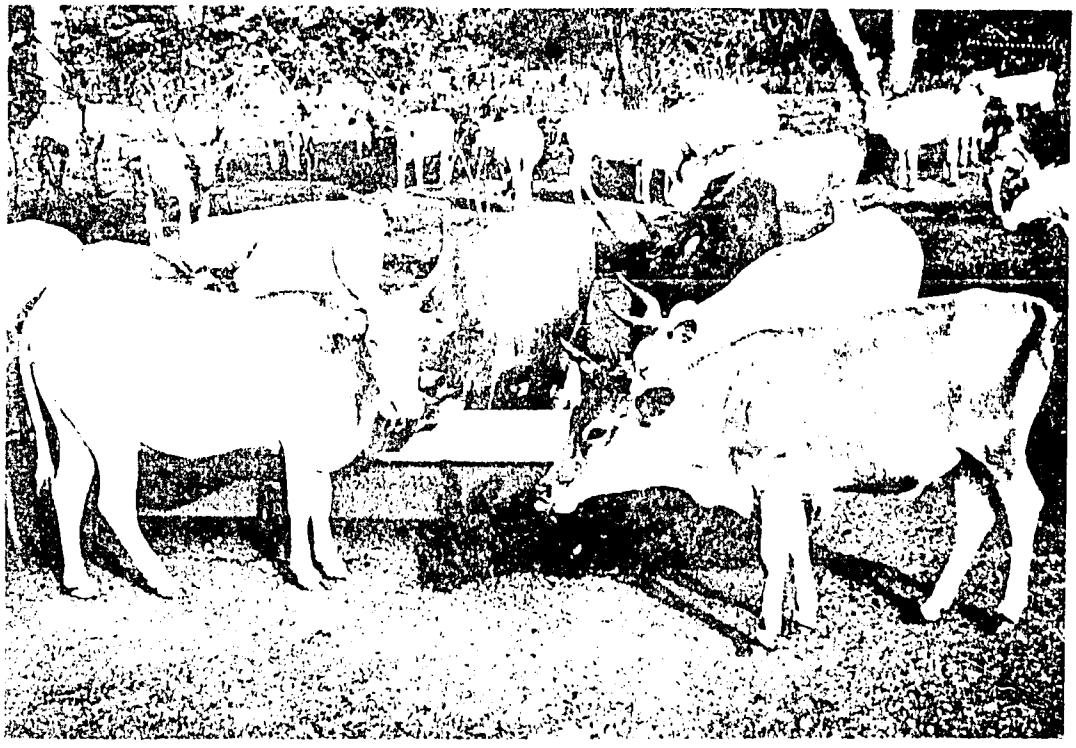
Table 37 summarises the overall performance achieved by Boran cattle at Mkwaja and by trypanotolerant N'Dama cattle on ranches in West and central Africa (Figure 29).

Data were not available from N'Dama cattle for age at first calving, but for all other traits, except cow viability, performances of Mkwaja Boran were superior to those of trypanotolerant cattle in West Africa. Major differences in bodyweights were evident between the two situations. Comparisons of productivity indices reflected this, the superiority of the Mkwaja Boran being less on the basis of unit weight or unit metabolic weight of cow than on a per cow basis. Herd productivity, expressed as weight of 8-month-old weaner calf produced per 100 kg metabolic weight of cow per year, was 35% higher for the Mkwaja Boran than for the trypanotolerant N'Dama.

CONCLUSION

The data sets compared in this chapter are among the largest available in Africa on beef cattle production. Based on the weight of weaner calf produced per unit metabolic weight of cow per year, the productivity levels of the grade Boran cattle maintained under chemoprophylaxis at Mkwaja fall between those achieved by Boran in the trypanosomiasis-free ranches in Kenya (20% less) and those achieved by N'Dama in medium to high trypanosomiasis-risk areas of West and central Africa (35% more).

Figure 29 N'Dama cattle in Nigeria.



11. CONCLUSIONS AND RECOMMENDATIONS

THE TRYPANOSOMIASIS PROBLEM

Tsetse-transmitted African trypanosomiasis is the most significant single factor in Africa's deteriorating food production situation. When all the complex factors involved are taken into consideration, it is estimated that livestock and agricultural development of tsetse-infested Africa could generate a further US$ 50 billion annually. The cost of tsetse control, the lack of a field vaccine and the limited prospects of new trypanocidal drugs appearing in the near future make reliance on the trypanocidal drugs currently available an unavoidable necessity.

UNIQUE NATURE OF MKWAJA DATA

There is a serious lack of fully documented information on livestock productivity levels attainable using trypanocidal drugs in trypanosomiasis-risk situations. The reports published in Africa over the past 25 years on livestock productivity under chemoprophylaxis and chemotherapy are listed in Table 38. A total of 2931 animals are involved, recorded over an average of 1.6 years. The performance traits covered are almost always growth and viability, some 4097 animal-traits being involved (more than one trait can be recorded on an individual animal), this providing a data volume of some 6000 trait-years only.

Thus the availability of 10 years of matching animal productivity and health data at Mkwaja Ranch offered the unique opportunity of evaluating some 134 000 trait-years of new data, or more than 20 times as much information on livestock productivity under chemoprophylaxis as had been made available in the whole of Africa over the previous 25 years.

TRYPANOSOMIASIS RISK AT MKWAJA RANCH

At Mkwaja it has been clearly demonstrated in planned experiments that cattle cannot survive without trypanocidal drugs. If left untreated, all die of trypanosomiasis or are killed by predators. Tired anaemic animals suffering from trypanosomiasis must be more liable to attack by predators. Samorin was clearly superior to Berenil in these experiments, including at the pre-weaning stage, where the chemical has not previously been used in large-scale commercial herds.

OUTCOME OF THE SAMORIN PROPHYLACTIC STRATEGY

a. The Mkwaja cattle maintained under Samorin prophylaxis appear to be highly successful, being 80% as productive as Boran cattle on trypanosomiasis-free ranches in Kenya and 35% more productive than trypanotolerant N'Dama cattle in medium to high trypanosomiasis-risk ranching situations in West and central Africa. In the situation where bush clearance and tsetse control had been carried out, it was possible to achieve the average Kenya ranching productivity level.
b. There were no indications of any resistance to Samorin developing over the 10-year period.
c. The animal health programme employed at Mkwaja and its management appeared excellent; there were very few cases of trypanosomiasis and virtually no tick-borne infections.
d. Samorin appeared to have no deleterious effects on reproductive performance, as gauged by its completely non-significant influence on calving intervals.
e. The multiple inoculation of Samorin did not raise any serious problems for animals in terms of local reactions and did not lead to increased

Table 38. *Published reports on livestock productivity under chemoprophylaxis and chemotherapy, 1960–84.*

Trypanocide(s)[a]	Number of records for				Duration of trial (months)	Source
	Growth	Viability	Reproduction	Untreated controls		
P, A	–	210	–	75	12	Lyttle (1960)
M, MS, P, A	120	120	–	8	6	Smith and Brown (1960)
M, MS	10	10	–	2	–	Stephen (1960)
M, A	–	38	–	5	6	Kirkby (1961)
M, E, A	28	28	–	4	6	Kirkby (1961a)
A, P, M	21	21	–	2	9	Kirkby (1961b)
A, M, ME, MS	20	20	–	5	8	Gray and Stephen (1962)
A, M, S	–	76	–	26	13	Robson (1962)
M, B	–	60	–	–	17	Fairclough (1963)
E, S, B	–	69	–	–	13	Fairclough (1963)
S, N, A	–	12	–	4	3	Kirkby (1963)
S, P, A, B, N	–	60	–	5	6	Kirkby (1964)
S	15	15	–	5	3	Jones-Davis (1967a)
A, P, S	–	400	–	10	9	Wiesenhutter et al (1968)
S	–	60	–	20	1	Na'Isa (1969)
B	25	39	45	–	45	Wilson et al (1975)
S, B	40	40	–	15	29	Wilson et al (1975a)
B, S	–	450	–	–	60	Bourn and Scott (1978)
S, B	80	80	–	20	21	Blaser et al (1979)
S, B	60	60	–	20	24	Blaser et al (1979)
S	15	15	–	2	15	Omwero-Wafula and Mayende (1979)
A, S, B	51	51	–	73	8	Griffin and Allonby (1979)
SD	20	20	–	3	4	Aliu and Sannusi (1979)
S, B	10	10	–	5	11	Specht (1982)
S	89	89	–	146	6	Kanyari et al (1983)
S, B, P	280	280	–	30	9	Wilson et al (1983)
S, B	59	66	18	–	21	Logan et al (1984)

[a] Key for trypanocides:

A = Antrycide (quinapyramine)
B = Berenil (diminazene aceturate)
E = Ethidium (homidium bromide)
M = Metamidium
ME = Metamidium embonate
MS = Metamidium suramin salt
N = Novidium (homidium chloride)
P = Prothidium (pyrithidium chloride)
S = Samorin/Trypamidium (isometamidium chloride)
SD = Isometamidium-dextran complex

requirements for treatment or to an earlier decline in productivity.

f. The use of Samorin on the basis of treatment when 20% of a 10% herd sample, usually the poorest looking individuals, were slided as positive, gave an average period between treatments of about 80 days. This appeared a very satisfactory regimen. The last 2 years' data suggested that the policy of treatment when the first positive slide was detected, resulting in an average of 70 days between treatments, could well lead to even higher productivity.

INSECTICIDE APPLICATION AND RELEASE OF STERILE MALE TSETSE FLIES

The reduction of the *G. m. morsitans* populations following insecticide application in the northern area of the ranch appeared to have little effect on positive blood smear results or trypanocidal treatments required. Livestock productivity did appear to increase relative to the control area, but as bush clearance work was taking place only in the northern area, this must be interpreted with caution.

MKWAJA AND KENYA BORAN

As far as pre-weaning growth traits were concerned, the higher grade Kenya Boran progeny were shown to be superior, but their superiority could not be expressed in the harsher location of the uncleared southern block.

CAN PRODUCTIVITY BE INCREASED?

a. The animal health programme at Mkwaja and its management would appear to be working well. Based on post-mortem examinations, there are few cases of trypanosomiasis under Samorin prophylaxis, despite the fact that in experimental studies at Mkwaja all cattle left untreated became infected with trypanosomes. In the same way, the acaricide control programme is highly effective with no cases of theileriosis or babesiosis being reported in the 10-year study period. Based on these good results, one must be hesitant in making any recommendations for improvement. Nevertheless, one consideration might be to change the method used for detecting trypanosomes from the thick blood smear to the buffy coat phase-contrast technique, a method which is significantly more sensitive (Paris et al, 1982). This would help improve decision-making with regard to the timing and dosage of trypanocidal drug administration. In addition, the measurement of packed red cell volume (PCV) as an estimation of anaemia would help to give a better overall picture of the health status of the herd.

b. The clinical and post-mortem findings indicated that the major problems on the ranch that were not always effectively controlled were anaplasmosis, presumably transmitted by biting flies, salmonellosis in calves, plant poisoning and predators. Better control of any one of these should be given consideration as it is likely that this would make a significant contribution to improved production.

c. Because of the high persistent tsetse challenge at Mkwaja and the lack of evidence of drug resistance to Samorin, no obvious advantages in the use of Berenil emerged in the overall drug regime. However, its continued use instead of Samorin in individual adult animals which become infected in the interval between Samorin treatments of the herd, as well as in preweaners, is recommended in order to reduce the risk of development of drug resistance to Samorin.

d. The pasture improvement that has taken place in one major location in the northern block has had a very significant effect on livestock productivity. The attachment of economic parameters to the biological increase in productivity demonstrated, will allow decisions on further pasture improvement at other locations to be made.

e. Breeding season has been shown to have a major effect on productivity, and the fact that two thirds of cows are already bred in the optimal periods shows this to have been well recognised.

IMPLICATIONS FOR OTHER TSETSE-INFESTED AREAS

The results of this study have shown that cattle production under Samorin prophylaxis is possible in areas heavily infested with tsetse. The fact that this result is based on one of the largest data sets ever analysed offers immediate hope for increased exploitation of tsetse-infested areas by encouraging the more widespread rational use of chemoprophylaxis as an integral part of management. These findings should also provide encouragement to pharmaceutical companies and international agencies to develop new and improved trypanocidal drugs.

ABBREVIATIONS USED IN THE TEXT

A.I.	artificial insemination
ANOVA	analysis of variance
Antrycide	quinapyramine
Berenil	diminazene aceturate
df	degrees of freedom
Ethidium	homidium bromide
FAO	Food and Agriculture Organisation of the United Nations
ILCA	International Livestock Centre for Africa
ILRAD	International Laboratory for Research on Animal Diseases
n	number of records
Novidium	homidium chloride
OIE	Office International des Epizootics
P	statistical probability
PCV	packed red cell volume (%)
Prothidium	pyrithidium chloride
Samorin	isometamidium chloride
SD	standard deviation
SE	standard error
sp.	species
Trypamidium	isometamidium chloride
USAID	United States Agency for International Development
WHO	World Health Organisation

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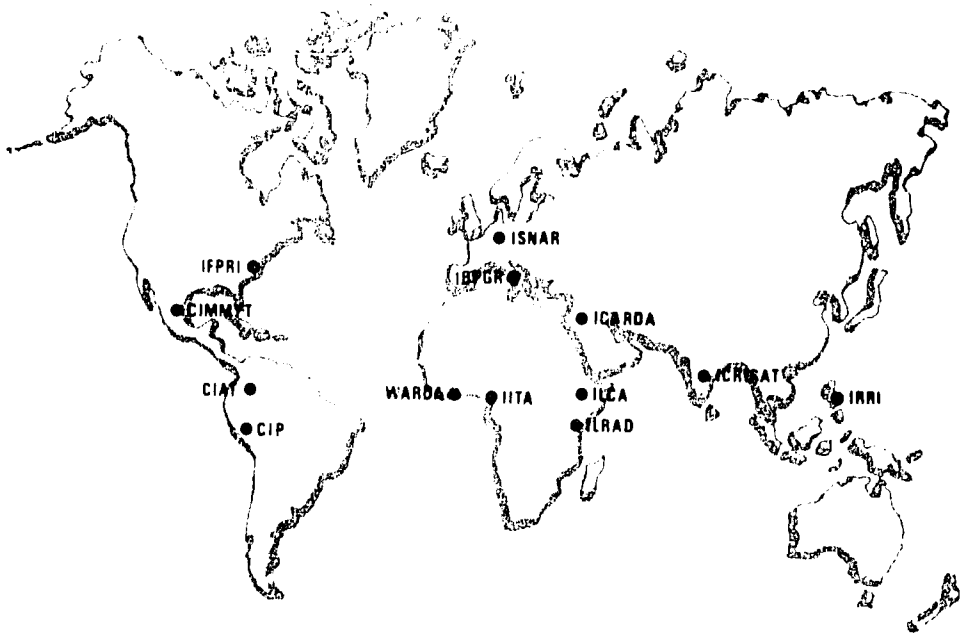
THE CONSULTATIVE GROUP ON INTERNATIONAL AGRICULTURAL RESEARCH

The International Livestock Centre for Africa (ILCA) is one of the 13 international agricultural research centres funded by the Consultative Group on International Agricultural Research (CGIAR). The 13 centres, located mostly within the tropics, have been set up by the CGIAR over the last decade to provide long-term support for agricultural development in the Third World. Their names, locations and research responsibilities are as follows :



Centro Internacional de Agricultura Tropical (CIAT), Colombia: cassava, field beans, rice and tropical pastures.

Centro Internacional de Mejoramiento de Maíz y Trigo (CIMMYT), Mexico: maize and wheat.

Centro Internacional de la Papa (CIP), Peru: potato.

International Centre for Agricultural Research in the Dry Areas (ICARDA), Lebanon: farming systems, cereals, food legumes (broad bean, lentil, chickpea), and forage crops.

International Board for Plant Genetic Resources (IBPGR), Italy.

International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), India: chickpea, pigeon pea, pearl millet, sorghum, groundnut, and farming systems.

International Livestock Centre for Africa (ILCA), Ethiopia: African livestock production.

International Rice Research Institute (IRRI), the Philippines: rice.

International Institute of Tropical Agriculture (IITA), Nigeria: farming systems, maize, rice, roots and tubers (sweet potatoes, cassava, yams), and food legumes (cowpea, lima bean, soybean).

International Laboratory for Research on Animal Disease (ILRAD), Kenya: trypanosomiasis and theileriosis of cattle.

West Africa Rice Development Association (WARDA), Liberia: rice.

International Service for National Agricultural Research (ISNAR), the Netherlands.

International Food Policy Research Institute (IFPRI), USA: analysis of world food problems.

Research Reports

1. *Trends and prospects for livestock and crop production in tropical Africa*, by C. de Montgolfier-Kouévi and A. Vlavonou. In press.
2. *Cattle herd dynamics: An integer and stochastic model for evaluating production alternatives*, by P. Konandreas and F.M. Anderson. 1982.
3. *Evaluation of the productivities of Djallonke sheep and N'Dama cattle at the Centre de Recherches Zootechniques, Kolda, Senegal*, by A. Fall, M. Diop, J. Sandford, Y.J. Wissocq, J. Durkin and J.C.M. Trail. 1982.
4. *Research on farm and livestock productivity in the central Ethiopian highlands: Initial results*, by G. Gryseels and F.M. Anderson. 1983.
5. *Systems research in the arid zones of Mali: Initial results*, eds P.N. de Leeuw, R.T. Wilson and C. de Haan. 1983.
6. *The water resource in tropical Africa and its exploitation*, by G.A. Classen, K.A. Edwards and E.H.J. Schroten. 1983.
7. *Livestock water needs in pastoral Africa in relation to climate and forage*, by J.M. King. 1983.
8. *Organisation and management of water supplies in tropical Africa*, by S.G. Sandford. 1983.
9. *Productivity of Boran cattle maintained by chemoprophylaxis under trypanosomiasis risk*, by J.C.M. Trail, K. Sones, J.M.C. Jibbo, J. Durkin, D.E. Light and Max Murray. 1985.
10. *Economic trade-offs between milk and meat production under various supplementation levels in Botswana*, by P.A. Konandreas, F.M. Anderson and J.C.M. Trail. 1983.
11. *Crossbred dairy cattle productivity in Arsi region, Ethiopia*, by Gabriel H. Kiwuwa, John C.M. Trail, Mohamed Y. Kurtu, Getachew Worku, Frank M. Anderson and Jeffrey Durkin. 1983.