DISCUSSION OF RESULTS

1. CROSSBREEDING OF SAANEN AND INDIGENOUS GOATS: THE EFFECTS ON PRODUCTIVITY

2. CROSSBREEDING OF SAANEN AND INDIGENOUS GOATS: DISEASES (ESPECIALLY HEARTWATER)

DISCUSSION OF RESULTS

The results of this research project will be assessed in the context of the original objectives set; and in comparison with similar research done elsewhere. In addition, there are areas that require further research, which have been identified during the course of the project.

The project can be divided into two main categories:

* the effects of crossbreeding on productivity;
* the effect of crossbreeding on disease.

(The disease selected for specific study was heartwater).

1. CROSSBREEDING OF SAANEN AND INDIGENOUS GOATS: THE EFFECTS ON PRODUCTIVITY

The productivity of Crossbred goats was assessed in comparison to that of Saanen and Indigenous goats. The main categories considered in this section included:

* fertility
* multiple births
* milk production

1.1 Fertility

Reproductive rate is important in the context of crossbreeding of goats for milk production, in that sufficient female kids must be born from the Indigenous goats to supply Crossbreds for milk production as well as replacements for the Indigenous goat herd; and the Crossbreds themselves must reproduce in order to initiate new lactations. An additional source of income for the milk producer should also arise from the sale of surplus animals, and this too depends on an efficient reproductive rate.

The results from this research at MEDUNSA indicated that there were no major problems in regard to fertility for Saanen, Indigenous or for Crossbred goats. The proportion of goats that kidded was in excess of 90 percent, except for the first kiddings of Indigenous goats at the age of about 12 months (Table K8). This was related to the phenomenon of late maturity of Indigenous goats in comparison to the Saanens. No such limitation was apparent for the Crossbred goats, which were very similar to the Saanens in this respect. Kidding percentages in subsequent years were good for all breeds considered. Sands & McDowell (1978) reported kidding intervals of approximately 12 to 13 months across a wide range of breeds of goats, with in some cases a reduction of kidding interval for crossbreds. It must be remembered that in the first few years of the research at MEDUNSA, all goats were on the same diet, which supplied adequate quantites of nutrients. Nutritional limitations might well have an effect under normal circumstances if the goats were to rely only on natural vegetation. Little information seems to have been published about the reproductive rate of Indigenous goats subsisting on natural vegetation without supplementation in the developing areas of South Africa. However, Wilson *et al.*(1989) reported a high reproductive performance of Indigenous goats in Mozambique and Rwanda, which could be improved from existing levels on the farms by applying better management practices. Mrema (1996) in Botswana reported an average of 1.5 kids per female goat each year, which would indicate a good reproduction rate. At MEDUNSA in 1991, a reduction in adequacy of nutrition was probably the cause of the reduction in percentage of Indigenous goats that kidded (Table K7), by which time they had spent a portion of the year on the veld, and were not entirely dependent on the complete diet, as in the early years of the research. This aspect was not specifically assessed in this research.

1.2 Multiple Births

The percentage of kids born for each lactation number is shown in Table K3. In general, the Saanens were more prolific than the Indigenous goats, and Crossbred goats were similar to the Saanens. The Indigenous goats had very few triplets (Table K4). These results are similar to those summarized by Devendra & Burns (1983), ranging from 1.0 to 2.3 kids per parturition. This was in agreement with the data reported by Sands & McDowell (1978), with a range of 1.0 to 2.0. Small litters may be important for Indigenous goats to survive the rigours of climatic extremes in Southern Africa, where droughts occur frequently, and rainfall is often erratic within a rainy season.

1.3 Milk Production

1.3.1 Fitting Lactation Curves

The linear Morant-4 model proved to fit well to most Saanen and Crossbred lactations. (Tables G1, G2 and G3). The mean values for each group of goats were used to draw lactation curves shown in Figures G1 and G2. However, because the lactation curves for Indigenous goats were found to be so variable in shape, curves fitted to the average values of the parameters were unrealistic. Therefore, in Figure G3, curves have been plotted, using the Wood model (Wood 1969), for three typical lactations of Indigenous goats. These curves were very different from those of the Saanen and Crossbred goats (Tables G4, G5 and G6) and warrant further research, with greater numbers of lactations and more precise measurement of milk yields. Wahome *et al.* (1994) studied the lactation curves of Small East African goats using the Wood model. Their lactation curves were very similar to the one for Goat No. 8I17508 shown in Figure G3. They rose to a peak at about three weeks, but their lactation lengths were longer: up to 31 weeks. Montaldo *et al.* (1997) used the Wood model to document differences in lactation curves between various crossbreeds of Alpine, Saanen and Toggenburg goats crossed with local Mexican goats. These were compared to those for Granadina and Nubian crosses with local Mexican goats. The former group had greater values for maximum production and persistency. Young goats (2 and 3 years old) had flatter lactation curves and higher persistency. There were also seasonal effects. The production levels of the crossbred goats were of the same order as those in the MEDUNSA herd. Ruvuna *et al.* (1995) used the Wood model for lactations of straightbred East African and Galla goats and their crosses with Toggenburgs and Anglo Nubians. They documented many differences in the parameters of the lactation curves between all these combinations of breeds. Seasonal effects were significant for nearly all the lactation curve parameters, the season of kidding having a major effect on the shapes of the curves. The four-way cross (all breeds: the Kenyan Dual Purpose Goat) had a superior level of production. These levels of production appeared to be lower than those of the Crossbreds in the MEDUNSA herd. Some of this effect might be attributed to the generous feeding of the complete feed, compared to the feeding systems practised by smallholders in Kenya.

1.3.2 Milk Yields per Lactation

Milk yields of Saanen goats were on average less than those achieved by goats on the Milk Recording Scheme in South Africa. No details of the effect of parity have been published in the Milk Recording results in South Africa, but the mean lactation yield has varied between 900 and 1000 kg per lactation (RSA 1996). Average yields for Saanens in England and the USA have been quoted as 1188kg and 979kg respectively (Shelton 1978). [Although these results were reported a long time ago, it is likely that yields are still of the same order of magnitude, because sire selection is generally not carried out rigorously, as with dairy cattle.] A comparison of the milk yields of MEDUNSA Crossbred goats (Table L2) with those of crossbred goats from other breeds elsewhere in the world (see Review of Literature, page 13), shows that the yields of MEDUNSA Crossbred goats were higher. Mean yields were reported to have ranged from 164kg to 306kg (except for the Saanen x Kilis goats in Turkey). These results might have been because of less favourable nutrition than that provided for the goats at

MEDUNSA. In contrast, the same research reported *higher* milk yields for Three-quarter-bred goats than for the Crossbred goats. However, it seems probable that the relatively poor production of MEDUNSA Three-quarter Saanen goats may have been related to the small number of goats milked in this category.

The lower recorded milk yields of Saanens in the MEDUNSA herd compared to others in South Africa were probably because of a combination of factors:

*** Sires**

The sires used in the herd were not selected for exceptional production. Good average sires were used, from parents with good milk records. However, the sires were representative of average breed production, rather than the best.

*** Unselected Goats**

Goats were not culled from the herd. In the first few years, no goats were removed from the herd because of low milk production. This was to try to ensure that the experimental groups were representative of the real genetic worth of the goats studied, and not a biased sample. In a normal commercial or stud herd, the low yielding goats would not have been tolerated.

*** Complete Feed**

Goats show characteristics of grazing behaviour and diet selection which give them an advantage compared to other livestock. Most goat owners will make use of natural vegetation (Lu 1988), but more intensive feeding systems are needed to maximize milk production (Hadjipanayiotou & Morand-Fehr 1991). The goats at MEDUNSA were fed a complete feed, with a small supplement of dairy meal fed during milking. This was chosen to give a standard diet for all milking groups, to facilitate comparisons of genetic potential, with the minimum of variation resulting from feed differences. A complete feed was chosen also to be a reliable system of ensuring the goats would be adequately fed in spite of labour disruptions. The supplement of dairy meal might have been inadequate for the highest yielders resulting in a shortage of energy at peak milk production, with a consequent reduction in total lactation yield. This would be in spite of the fact that higher milk yields result in greater feed intake (Randy *et al.* 1988). Nevertheless, the complete feed diet chosen was of great value in ensuring that all goats had access to the same level of nutrition, eliminating feed effects as far as possible between breeds. In contrast, in a commercial or stud herd the economic incentive would have encouraged the farmer to feed a goat according to her individual needs and to maximize production.

Complete feeds are apparently not commonly used for milk goats, but have been used in some circumstances (Morand-Fehr *et al.* 1996; Reddy & Raghavan 1992). They were not mentioned in an review by Hadjipanayiotou & Morand-Fehr in 1991. Kawas *et al.* (1991) reported on the effects of different forage-to-concentrate ratios for diets of goats in Mexico, and found no effect of varying proportions. However, the milk yields for the Crossbred goats in the experiment were relatively low at about 0.5 litres per day.

*** Unequal Milking Intervals**

The large difference in the time between morning and afternoon milkings may well have had a depressing effect on lactations because of the build-up of milk overnight in high-yielding goats early in lactation (Wilde & Peaker 1990). Rischkowsky & Steinbach (1997) measured milk production of Crossbred goats (Saanen x Malawi Indigenous goats) at only 104 kg per lactation compared to a potential of 130 kg. Apart from feed inadequacies, one factor that suppressed milk production was the irregularity of milking. Initially the goats were milked once a day, but five years later, only a few were milked as often as four times a week.

*** Summary**

In summary, the broad differences between breeds in milk yield per lactation in the MEDUNSA herd were:

* Saanens had the highest yields, with lactation lengths of at least 300 days;

* Indigenous goats had very low yields, and very short lactations;

* Crossbred goats produced less milk than the Saanens, but far more than the Indigenous goats. Lactation length was slightly shorter than that of the Saanens. Strong hybrid vigour (heterosis) effects made milk production of Crossbred goats much closer to that of the Saanens than the Indigenous goats.

- Three-quarter Saanens produced a quantity of milk similar to that of the Crossbreds. Presumably any relative reduction in hybrid vigour was offset by the closer relationship to the pure Saanens.

1.3.3 Lactation Length and Dry Periods

The lactation lengths of Saanens were at least 300 days, and in many lactations milk production continued for a longer time than this. In one year a proportion of goats was left without being mated at the normal breeding season (March to May), and these goats continued in their lactations for up to double the normal length. However, not all goats were capable of continuing for the full length of these extended lactations. Lactation length and breeding policy determined the length of the dry period. Saanen and Crossbred goats had similar dry period lengths of about two months. The Indigenous goats had short lactations of two to four months, and therefore had very long dry periods, since they were also bred to kid every 12 months. Sands & McDowell (1978) reported mean lactation lengths of 270 to 300 days for most dairy breeds, but much shorter lactations for Indigenous breeds in India, Africa and Central America, ranging up to about 200 days. Crossbred goats had intermediate lactation lengths.

1.3.4 Milk Composition

Milk samples were analysed only for milkfat, protein and lactose percentages. It was not possible to analyse milk composition in more detail in this research herd. This is an area that warrants further research, particularly in the light of the beneficial nutritional and anti-allergenic properties reported about goat milk (Park 1994).

The mean analyses (Table L5) should be compared to the results reported by Jenness (1980). [See Review of Literature, page 9]. Saanen milk proved to have a broad compositional analysis similar to that of cows. Indigenous goats had milk that was very concentrated. No comparative information from this type of goat is available even though milk yields of similar goats have been measured (Cooper *et al.* 1994). The milk of Crossbred goats was approximately two percentage points higher for milk fat, and one percentage point higher for protein than that of Saanen goats. The analysis of milk from Three-quarter Saanens was similar to that of the Crossbred goats, rather than that of the pure Saanens. This means that although Crossbred and Three-quarter Saanens had lower total milk production per lactation than pure Saanens, the production of Total Solids in the milk was not as low, because of the higher percentages. This relationship was examined in the statistical analyses involving composition corrected milk (FCM,PCM, LCM, and FPLCM).

1.3.5 Composition Corrected Milk

Fat Corrected Milk has traditionally been a fairer means of comparison between lactations than straight milk yield, when the comparison is between cows producing milk of very different compositional analysis, such as between Holstein and Jersey cows (Schmidt & Van Vleck 1974). Since milkfat percent is susceptible to variations because of feeding and sampling, other criteria might be more reliable. Therefore, in this study, total milk production was corrected for fat, protein, lactose and also for all three criteria together (Fat-Protein-Lactose Corrected Milk).

Composition corrected yield estimates for Indigenous goats increased greatly because of the high percentage of nutrients in the milk. Those for Saanen goats decreased compared to the uncorrected milk yields, because Saanens generally had milk composition analyses lower than those used for the correction factors. In contrast, composition corrected yields for Crossbred and Three-quarter Saanen goats were increased, because their milk composition analyses were generally higher than those used for the correction factors. Nevertheless, even when milk production was corrected for these factors, the composition corrected yields of Saanens were still higher than those of Crossbreds and Three-quarter Saanens.

Fat-Protein-Lactose Corrected Milk yields of Crossbreds varied between 0.70 and 0.76 of the yields of Saanens of the same parity (Table L12). However, the mean bodyweights of Crossbreds was generally not much less than that of the Saanens, as is illustrated in Figure M1 (in the section "Materials and Methods"). It is unlikely that the differences of milk production between these breeds was affected significantly by differences in bodyweight. In contrast, the weights of Indigenous goats were considerably less (Figure M2), but their milk yields were dramatically lower that those of Saanens or Crossbreds, even when corrected for milk composition.

1.4 Factors Affecting Milk Production

Many of the factors that normally affect milk production, such as management differences, feeding systems and seasonal effects, were not relevant in this research because of the management systems that were applied. Until 1992, the breeding season was the same (autumn); natural breeding was practised, using a variety of billy goats; feeding was uniform, using one type of complete feed, with a small supplement of dairy meal in the milking parlour; and goats were bred to kid for the first time at about 12 months of age. Therefore, comparisons between breeds were more valid than they would have been in a less controlled situation.

Breed differences had the greatest influence on milk production and milk composition. Saanen goats had the highest yields, but the milk with the lowest concentration of nutrients. The Indigenous goats had very short lactations with low yields, but very high concentrations of nutrients in comparison. The Crossbred goats showed an effect of heterosis, not only in terms of milk yield, but also for milkfat and protein percentage.

Lactation number was significant ($P<0.05$), especially when first and subsequent lactations were compared. This result was similar to many other reports (e.g. Browning *et al.* 1995). Lactation length was significantly ($P<0.05$) different between breeds, and this was a major factor in determining the total lactation yield. The number of kids born was assessed as a significant ($P<0.05$) factor associated with lactation yield in a few of the comparisons. This was most likely because of breed differences in the incidence of multiple births, and due to the fact that the incidence of twinning increased with lactation number; and not because of an inherent effect of the number of kids born *per se*. However, Montaldo *et al.* (1991) reported in crossbred goats in Mexico that only 7% of variation in litter size was associated with parity: litter sizes increased from 1.5 to 1.8 (first to fourth kidding). No correlation was reported with milk production, although the milk yields were low (121kg in first lactation; 171kg in fourth lactation).

No attempt was made to assess the effect of disease on milk production. Direct effects were of course apparent, such as with mastitis, but indirect effects such as those arising from high kid mortality and the effects on replacement rate or sales of animals were not estimated.

1.5 Milk Production: The Benefits of Crossbreeding

Computations to estimate heterosis have not been done in this research, because of the limited data, and because information is not available on the performance of reciprocal crossbreds. Nevertheless, first lactation Crossbreds produced much more FPLCM than the average of the two parent breeds at this parity. This is a good indication of the benefit of heterosis. The lactations of Three-quarter Saanens were disappointing in comparison, but interpretation should be tempered by an awareness of the small number of lactations of these goats. They may well not be a representative sample. Table L12 (page 91) lists the mean standardized milk yields for Fat-Protein-Lactose Corrected Milk (FPLCM).

The benefits of crossbreeding among these goats are comparable to those reported by Rege *et al.* (1994) in cattle crossed with Jerseys. They found a strong effect of heterosis in terms of milk yields with the F1 Crossbred cows, but there was no benefit of back-crossing to produce a Three-quarter Jersey cow. This agreed with the results reported by Syrstad (1990). These results indicate that the option of crossbreeding is probably the most suitable method for introducing milk production potential to local goat breeds (Sands & McDowell 1978): using local breeds to produce Crossbred females; and to repeat the process for replacement animals. The suggested alternative of up-grading may show little benefit; and the development of a new (adapted) breed would be a solution only with a long-term programme of development (Shelton 1986). A few studies have shown an equal or improved performance of the Three-quarter (up-graded) breeds of goat for milk production (Sahni & Chawla 1982); but this was not shown in the research herd at MEDUNSA.

Other researchers have reported similar benefits of crossbreeding to form "new" or "synthetic" breeds. Horst (1997) reported that the Jermasia synthetic breed improved milk production to 250kg per lactation compared to 45kg for Kambing Katjang goats in Malaysia.

Baker & de Souza Neto (1989) reported low productivity of dual-purpose goats in Brazil, which gave a total of only 107kg in a lactation of 134 days. The main reasons suggested for the low milk yields were inbreeding and poor nutrition.

The most thoroughly studied programme in Africa has been in Kenya, where a dual-purpose goat has been developed (Semenye *et al.* 1989). This research was carried out thoroughly, has been accepted, and is part of the lives of many people: the report by Miller & Mwangi 1996 concerned 1300 milk goat owners. In contrast, a crossbreeding project in Malawi has not proved to be sustainable (Rischkowsky & Steinbach 1997), although the reasons were not due to the goats, but were socio-economic. Among these were the design and administration of the project: goats were "loaned" to people, and many were subsequently sold; the programme was not sustained for a long enough duration; and "the motivation for the acceptance or rejection of goat milk production was hard to clarify, as the farmers were never completely frank when giving their reasons."

2. CROSSBREEDING OF SAANEN AND INDIGENOUS GOATS: DISEASES (ESPECIALLY HEARTWATER)

The occurrence of diseases in the goat herd was monitored; and a large number of goats that died were evaluated by post-mortem examination. In addition, heartwater, the widespread and devastating tick-borne disease in South Africa, was assessed for its effects on the different breeds of goats.

2.1 Occurrence of Diseases

Record-keeping of the incidence of diseases in the herd was not consistent or satisfactory, so that a complete record is not available. A detailed analysis of post-mortems examinations was carried out, which represents a good sample of the incidence of fatal diseases. However, there were other diseases, which though not fatal, were also important in the herd.

2.1.1 Kid Mortality

In the MEDUNSA herd, no breed effects were apparent in the ability of goat kids to survive. This was similar to the finding of Rischkowsky & Steinbach (1997) who reported losses of 24.0% and 22.8% of local Malawi goats and F1 crossbreds (with Saanens) on smallholder farms. Kid mortality can be much higher, as for example reported among West African Dwarf goats in Ghana, where 55 percent of kids died within three months, mainly as a result of starvation and pneumonia (Oppong & Yebuah 1981). Losses can be severe even for animals kept under extensive management systems, as reported by Ndlovu & Sibanda (1991) in

Zimbabwe. The reasons for kid mortality have been reported to be usually respiratory and gastrointestinal diseases (Nagy *et al.* 1987). This was true for the MEDUNSA goat herd. The mortality of kids was unacceptably high at 29 percent on average (Table D8.2, page 141).

The major disease problem among goat kids at MEDUNSA was, without doubt, the loss of goat kids as a result of coccidiosis. This has been described as a disease of intensification (Vihan 1992b). A proportion of goat kids was lost soon after being born, related to inadequate colostrum intake, poor mothering ability, and overcrowding. It is well known (O'Brien & Sherman 1993a,b) that immunoglobulin levels are important for the survival of neanatal goat kids. Vihan (1988) reported a loss of 20 percent mainly arising from this reason. However, the great losses at MEDUNSA occurred later in the lives of the kids, at about the age of two to four months. Diarrhoea quickly spread through the group of kids. A timely treatment with Vecoxan® was usually effective in stopping the diarrhoea, but by then the damage had been done. Affected goat kids usually died, if not from diarrhoea, then from pneumonia. The few kids that were saved often took months to recover, and some remained stunted and had to be culled. In addition to treatment with Vecoxan®, preventative measures included the addition of an ionophore to the feed, either Romensin® or Taurotec®. Such compounds have a coccidiostatic effect. This was at first thought to be ineffective, because kids with coccidiosis stopped eating anyway, which reduced the intake of coccidiostat. However, in one year the feed mill supervisor, for no apparent reason, omitted the ionophore, and a devastating outbreak of coccidiosis occurred, even though the kids had been born in autumn (a better time of the year). This unintended and undesirable change in the feeding policy illustrated clearly the importance of including the ionophore in the kids' diet. Monensin has been shown to reduce the effects of coccidiosis in lambs (Muwulla *et al.* 1994). In the first three years, kids were taken from their mothers and kept in groups of up to ten in nursery pens with slatted floors. They were there fed 0.5 litre milk twice a day, and had free access to the complete feed. Research by Greenwood (1993) has indicated that a high protein diet (18.7% Crude Protein in the Dry Matter) resulted in a higher growth rate of kids compared to those fed a diet containing 14.4% CP in the DM. The complete feed given the the goat kids at MEDUNSA was at the level of approximately 14% CP. Further research is warranted to determine not only if a high protein diet would result in better growth rates, but also improve survival rates of goat kids. Systems of kid rearing have been well documented by researchers in France (Simon *et al.* 1986), but techniques need to be adapted to South African conditions.

The system of kid rearing that was initially used had to be abandoned because of labour difficulties, and the uncertainty whether there would be anyone available to feed the kids.

Therefore, in subsequent years, the kids were allowed to run with their mothers until about six weeks of age. This system, although more similar to the method likely to be used by farmers in the developing areas, was inefficient. It meant that less milk was available for sale, and inevitably resulted in poorer control and management. It cannot be recommended, but the use of it in the MEDUNSA herd should be seen in the context of the turbulent political situation in South Africa at that time. An improvement in hygiene and in careful husbandry of the kids in recent years has made a great difference in reducing the effects of coccidiosis in the kids, but it is still the most important problem in the herd, and warrants further research.

2.1.2 Mortality of Adult Goats

A wide range of diseases resulted in the deaths of adult goats. The most important of these identified from post-mortem examinations were mastitis, ketosis and pneumonia. Both mastitis and ketosis are management related diseases; and pneumonia was probably the end result of other diseases or general debilitation. Few cases of dystocia were recorded, but some goats were lost as a result of uterine infections and peritonitis, sometimes following dystocia. Some goats suffered from pregnancy toxaemia, and some of the cases of ketosis were clearly related to the increased demand for energy late in gestation. In this regard, it is important to supply a diet with sufficient energy, especially where there are multiple births. Some goats suffered from ketosis when they had gained too much weight; these were usually Crossbred goats. There is therefore a need to supply a complete feed or diet for dry goats that is different from that fed to lactating goats, particularly if the dry period is expected to be longer than two months. Indigenous goats, in later years when they were not fed a complete feed continuously, showed a good ability to survive severe changes in the quality and quantity of feed. However, in general, the incidence of diseases causing deaths of adult goats could not be said to differ between breeds.

2.1.3 Mastitis

Kalogridou-Vassiliadou (1991) reported high levels of mastitis organisms in goat herds in Greece, but stated:

> *"no mastitis control measures ... have been adopted by farmers"*
>
> (Kalogridou-Vassiliadou *et al.* 1991).

The basic control measures for mastitis prevention and control are well established (Dodd & Neave 1970; Kingwill *et al.* 1979) and include hygienic practices in the milking routine (washing and drying the udder; stripping foremilk to test for mastitis; teat disinfection after milking); prompt antibiotic treatment of clinical cases; intramammary therapy in the dry period to control sub-clinical infections; and strategic culling of chronically infected animals. These procedures were carried out routinely in the MEDUNSA goat herd, except that intramammary dry period therapy was discontinued after the third year because of management difficulties. Further research should be carried out to determine the need for and the potential benefits of dry period intramammary therapy in goats. Subclinical mastitis appeared to be low, but a full survey was carried out in only one year. Losses from peracute mastitis have been quantified (Tables D1 and P1). A few goats lost half udders as a consequence. The recording of only 28 cases of clinical mastitis in a period of six years indicated a relatively moderate level of infection in the herd.

2.1.4 Internal Parasites

Internal parasites were not a problem in the Milch Goat Project, but might well be in other circumstances especially where goats are kept on pastures (Cabaret *et al.* 1989). Some work on resistance to haemonchosis in Saanen goats has been reported from New Zealand (Gill *et al.* 1991). Dosing with anthelmintics may lead to resistance (Pomroy 1996), as demonstrated with *Haemonchus contortus* in goats in Sri Lanka (Van Aken *et al.* 1989). This is an area that warrants further research, particularly as Indigenous goats appear to show some resistance.

2.1.5 External Parasites

Lice were the only external parasites of note among the goats kept in the pens or shed. Ticks occurred on the Indigenous goats (which were kept in the veld after the first few years on zero grazing), but did not seem to cause major problems. Tick resistance was not studied in this research project, and is an area that warrants further study, particularly as Indigenous goats appeared to be more resistant than the other breeds. The report of the FAO First Expert Consultation (FAO 1994) indicated that although tick-borne diseases were of great significance in Africa,

> *" tick control was of little value, because of the complexity of most situations, the expense and the experience of many failures."*

2.2 Heartwater

The FAO (1994) report stated:

> *" Heartwater is one of the major constraints to ruminant livestock industries in most of Sub-Saharan Africa, and has spread to the Caribbean where it is a severe threat to the livestock industries of America."*

Matheron *et al.* (1987) reported low levels (25%) of genetic resistance to heartwater in Guadeloupe native goats. The value of genetic resistance to disease has been recognized as a general principle, especially for trypanotolerance, where it has been reported to be higher in Indigenous breeds of sheep and goats compared to exotic breeds (Griffin & Allonby 1979). No research has been reported on genetic resistance to heartwater in goats in South Africa, apart from the preliminary report on the MEDUNSA research (Donkin *et al.* 1992). After the goats had been given heartwater blood, they all showed the same temperature reaction, which indicated that none was completely resistant. This was in contrast to research on cattle, where some showed no reaction at all (Du Plessis & Bezuidenhout, 1979; Du Plessis, 1985). The temperature reactions also confirmed that the goats had not been previously exposed to heartwater. The similarity of temperature reaction between breeds was not reflected in the incidence of clinical signs, which were more severe in Saanens and in the Crossbred goats. Mortality was highest in the Saanens, and less in Crossbred goats, apparently in proportion to the contribution of Saanen genes. The Indigenous goats had a resistance to heartwater, but still showed a typical temperature reaction and some clinical signs, though less than shown by the Saanens. They appeared to be able to transfer this resistance to a good proportion of Crossbred goats (approximately half).

No effect of gender was apparent in resistance to heartwater, in contrast to that found in Guadeloupe (Matheron *et al.* 1987). The male goats were all castrated, but it seems unlikely that this would have made a difference. No differences were noted in temperature reactions or the incidence of clinical signs (except for those directly associated with death) between those goats that survived or those that died, even though there were substantial differences between genotypes in the proportions that survived or died.

Serum conglutinin levels were no apparent indication of potential resistance. This was in contrast to the findings reported for cattle (Du Plessis 1985; Du Plessis & Malan 1987). Therefore, at this stage, the only indicator of the ability to survive heartwater is the positive result to a direct challenge with the disease. This would make any attempt to select for resistance an expensive procedure, involving considerable suffering by both resistant and susceptible goats. However, as the resistance to heartwater shown by these Indigenous goats can be incorporated in goats that are kept for milk production, then it is possible to use these goats as a source of milk to alleviate human malnutrition in areas affected by heartwater.

2.3 Diseases: The Benefits of Crossbreeding

This research has demonstrated a benefit of crossbreeding in transferring genetic resistance to heartwater from Indigenous to Crossbred goats. In any situation it is difficult to separate genetic from other influences, especially managerial and environmental effects. For example, no clear benefit of crossbreeding was apparent in reducing kid mortality in this herd. Nevertheless, further research should be carried out to assess benefits of crossbreeding for resistance to other diseases and against internal and external parasites.