RESULTS

CONTENTS

1. RESULTS: KIDDING

1.1 KIDDING OF GOATS

This section contains information about the fertility and fecundity of the goats:

* Parturition rate (number of parturitions per 100 females mated). This is important in a milk goat herd as it determines the number of goats in lactation.
* Reproductive rate (number of kids born per 100 females mated). This is important in a milk goat herd as it determines the number of replacement females in subsequent years, and the number of male goats for sale or slaughter.

Records of parturitions and kidding in the first three years of the experiment which were presented at the VI International Conference on Goats in Beijing (Donkin *et al.* 1996) are shown in Tables K1 and K2. Conception rates were high, except for first lactation Indigenous goats. The proportion of twinnings increased with age, but few goats had triplets. The numbers of kids born in the different categories are shown in Table K2. The lower proportion of twins among young Indigenous goats reduced their kidding percentage, but three-year old Indigenous goats had the same productivity as the Saanens (200 percent). The kidding percentage of Crossbred goats appeared to be intermediate, but fewer records were available for them in the first three years.

Details of the number of goats that were bred and subsequently kidded are shown in Tables K3 and K4. Conception rates were generally of a very high level, between 90% and 100%, except for the Indigenous goats in their first year, where many did not conceive during the first breeding season.

More detailed results are shown in the subsequent Tables K5 and K6, where information for all the years 1988 to 1994 are included. These data showed that Saanen goats achieved a high average kidding percentage of about 200% from the fourth kidding onwards, and that this was similar for Crossbreds and Three-quarter Saanens. However, the Indigenous goats did not achieve such high levels, and showed a decline after the third kidding. As a result, the average kidding percentage for Indigenous goats was 150%, compared to 165% for Saanens and Crossbreds. The apparently lower rates for Three-quarter Saanens was probably related to the

fewer animals recorded. Saanens and Crossbreds had more multiple births (about 60% of parturitions) than Indigenous goats (about 50%). Three-quarter Saanens had a particularly low level at (about 36%); but it is fair to note that most of the kiddings recorded for these goats were first kiddings, and there were relatively few animals. Perhaps these proportions would have been different if the number of kiddings recorded for this group had been similar to the other groups. Indigenous goats hardly ever had triplets, whereas these occurred in 6% of Saanen kiddings and 10% of Crossbred kiddings.

The gender of goat kids born from 1988 to 1994 are shown in Table K7. The proportion was very close to 50% for each sex, except that Indigenous goats had an overall proportion of females of 47%. It seems unlikely that this is an important difference.

In 1992 the previously uniform system of breeding in autumn was altered, and a proportion of goats were given light treatment in the winter according to the method developed by Chemineau *et al.*(1992). The Indigenous goats were not included in the treatment, so that from this time onwards, the comparisons between breeds were not valid. The results of two years of this breeding policy are shown in Table K8. It was successful in 1992, but because of a power failure which dislocated the timing of the light treatment, it was a failure in 1993.

The results of these trials, which were not part of the original crossbreeding experiments, have been reported elsewhere (Donkin *et al.*, 1996b), and are summarised in Table K9.

1.2 TABLES RELATED TO KIDDING

Table K1: Parturitions of Saanen, South African Indigenous and Crossbred goats (first three years) (Donkin, *et al.* 1996).

Breed	Age (yr)	Bred No.	Kidded No.	(%)	Singles No.	(%)	Twins No.	(%)	Triplets No.	(%)
Saanen	1	55	51	93	31	61	20	39	0	0
	2	33	31	94	8	26	21	68	2	6
	3	22	21	95	5	24	11	52	5	24
	All	110	103	95	44	43	52	50	7	7
Indigenous	1	64	42	66	38	90	4	10	0	0
	2	44	44	100	15	34	29	66	0	0
	3	20	19	95	1	5	17	90	1	5
	All	128	105	82	54	51	50	48	1	1
Crossbred	1	23	22	96	17	77	5	23	0	0
	2	9	9	100	2	22	6	67	1	11
	All	32	31	97	19	61	11	36	1	3

Table K2: Kids born to Saanen, South African Indigenous and Crossbred goats (first three years) (Donkin, *et al.* 1996).

Breed	Age (yr)	Kiddings	Males	Females	Singles	Twins	Triplets	Kids born Total	(%)
Saanen	1	51	35	36	31	40	0	71	139
	2	31	28	28	8	42	6	56	181
	3	21	21	21	5	22	15	42	200
	All	103	84	85	44	104	21	169	164
Indigenous	1	42	20	26	38	8	0	46	110
	2	44	35	38	15	58	0	73	166
	3	19	19	19	1	34	3	38	200
	All	105	74	83	54	100	3	157	150
Crossbred	1	22	17	10	17	10	0	27	123
	2	9	9	8	2	12	3	17	189
	All	31	26	18	19	22	3	44	142

Table K3: Numbers of goats bred and kidding (1988 to 1991)

	Age (years)	1988		1989		1990		1991	
		Bred	Kidded No. %	Bred	Kidded No. %	Bred	Kidded No. %	Bred	Kidded No. %
Saanen	1 2 3 4	24	23 96	10 24	10 100 21 88	22 10 24	18 82 10 100 21 88	12 16 3 12	10 83 16 100 3 100 12 100
Indigenous	1 2 3 4	33	25 76	25 20	11 44 20 100	7 24 19	6 86 24 100 19 100	5 4 19 14	2 40 3 75 14 74 14 100
Crossbred	1 2 3			10	9 90	14 9	13 93 8 89	12 8 2	10 83 8 100 2 100
Three-quarter Saaanen	1					2	2 100	8	8 100

Table K4: Numbers of goats bred and kidding (1988 to 1991): Consolidated.

Breed	Age (years)	1988 to 1991	
		Bred	Kidded No. %
Saanen	1 2 3 4 All	68 50 27 12 157	61 90 47 94 24 89 12 100 144 92
Indigenous	1 2 3 4 All	70 48 38 14 170	44 63 47 98 33 87 14 100 138 81
Crossbred	1 2 3 All	36 17 2 55	32 89 16 94 2 100 50 91
Three-quarter Saaanen	1	10	10 100

Table K5: Parturitions (1988 to 1994)

Breed	Lact.	Parturitions	Kids born	Kidding (%)
Saanen	1st	77	101	131
	2nd	61	100	164
	3rd	39	71	182
	4th	29	59	203
	5th	13	25	192
	6th	5	11	220
	7th	6	12	200
	All	**230**	**379**	**165**
Indigenous	1st	55	63	115
	2nd	51	82	161
	3rd	39	68	174
	4th	34	53	156
	5th	23	35	152
	6th	21	33	157
	7th	7	10	143
	All	**230**	**344**	**150**
Crossbred	1st	50	68	136
	2nd	36	62	172
	3rd	22	46	209
	4th	12	27	225
	5th	3	3	100
	All	**123**	**206**	**167**
Three-quarter Saanen	1st	19	21	111
	2nd	8	14	175
	3rd	7	10	143
	4th	2	4	200
	All	**36**	**49**	**136**

Table K6: Multiple births: Number of parturitions (1988 to 1994)

Breed	Lact.	Singles	Twins	Triplets	Total Parturitions
Saanen	1st	53	24	0	77
	2nd	24	35	2	61
	3rd	11	23	5	39
	4th	4	20	5	29
	5th	1	12	0	13
	6th	0	4	1	5
	7th	1	4	1	6
	All	**94**	**122**	**14**	**230**
Indigenous	1st	48	6	1	55
	2nd	19	32	0	51
	3rd	11	27	1	39
	4th	15	19	0	34
	5th	11	12	0	23
	6th	9	12	0	21
	7th	4	3	0	7
	All	**117**	**111**	**2**	**230**
Crossbred	1st	33	17	0	50
	2nd	12	22	2	36
	3rd	3	14	5	22
	4th	2	5	5	12
	5th	1	2	0	3
	All	**51**	**60**	**12**	**123**
Three-quarter Saanens	1st	17	2	0	19
	2nd	2	6	0	8
	3rd	4	3	0	7
	4th	0	2	0	2
	All	**23**	**13**	**0**	**36**

Table K7: Gender of kids born (1988 to 1994)

Breed of Dam	Male	Female	Totals
Saanen	190	189	379
Indigenous	162	182	344
Crossbred	103	103	206
Three-quarter Saanen	23	26	49
All goats	478	500	978

Table K8: Parturitions in autumn and spring (1993 and 1994): two seasons.

Breed	Lact.	Autumn 1993	Spring 1993	Autumn 1994	Spring 1994	Totals
Saanen	1st	0	2	0	13	15
	2nd	5	1	0	1	7
	3rd+	18	9	0	21	48
Indigenous	-	30	4	16	16	66
Crossbred	1st	0	3	1	14	18
	2nd	1	2	0	2	5
	3rd+	8	6	0	12	26
Three-quarter Saanen	1st	0	4	0	7	11
	2nd	1	0	0	1	2
	3rd+	5	1	0	3	9
Seven-eighths Saanen	1st	0	1	0	4	5
	2nd	0	0	0	1	1
All goats	-	68	33	17	95	213

Table K9: The effect of supplementary light on kidding of milk goats
(Donkin *et al.*, 1996b)

Breed and Year	Goats Bred	Goats Kidded	
	No.	No.	%
1992 - 1993			
Saanen	41	23	56
Crossbred	24	10	42
Three-quarter Saanen	9	6	67
All	**74**	**39**	**53**
1994 - 1995			
Saanen	39	24	62
Crossbred	27	19	70
Three-quarter Saanen	11	8	73
Seven-eighths Saanen	4	2	50
All	**81**	**53**	**65**

2. RESULTS: LACTATIONS

2.1 LACTATIONS OF GOATS

Information on the lactations is summarized in Tables L1 to L8, and selected lactation curves are illustrated in Figures L1 to L5.

Milk Production: All Goats, All Lactations (Table L1)

The data for mean milk production shown in Table L1 are not good examples of the average values because of the different proportions of lactation numbers in each group. Nevertheless, they show the broad differences between the breeds:

* Saanen goats had the highest yields, and lactation lengths of at least 300 days.

* Indigenous goats had very low yields and very short lactations.

* Crossbred goats produced less milk than Saanens, but considerably more than Indigenous goats; lactation lengths of Crossbreds were slightly shorter than those of Saanens.

* Three-quarter Saanens produced much the same amount of milk as Crossbreds. (However, there were too few lactations in the set of data to be sure that this would be generally true of all such goats.)

Lactation Yields: All Breeds and Lactations (Table L2)

Saanen Goats

The mean lactation yields as shown for each lactation number in this Table are more accurate indicators of the productivity of the Saanen goats than the averages in Table L1. These data show that the peak yield of Saanens occurred in the second lactation at a mean of 838 ± 177kg in 300 days. First lactation yields were 70% of second lactations; third lactation yields were reduced by 10%. Milk production declined slightly in the third and fourth lactations, but dropped to 60% in the fifth lactation, compared to yield in the second. Peak daily milk production was approximately 140% of average daily production per lactation, and the peak occurred at about 70 days. Peak daily milk production was approximately 0.5% of total lactation yield (i.e. a factor of 200 x peak daily milk yield).

Indigenous Goats

As stated previously, milk production from Indigenous goats was difficult to measure. Mean daily yield was only 250ml, and lactation length varied from two to four months. Only the first lactations were accurately measured. Intermittent measurements in subsequent years indicated similar production levels for second and third lactations.

Crossbred Goats

Milk production of Crossbred goats was highest also in the second lactation (466 ± 118kg). The higher yields shown for fourth lactation are not representative: this was a small and biased sample. The production of first lactation goats was approximately 70% of the yield in second lactation. Peak daily milk production was approximately 140% of average daily production per lactation, and the peak occurred at about 80 days. Peak daily milk production was approximately 0.57% of total lactation yield (i.e. a factor of 175 x peak daily milk yield).

Three-quarter Saanens

Milk production of Three-quarter Saanens was remarkably similar to that of Crossbred goats, but it is important to take note of the relatively small number of goats in the sample.

Dry periods (Table L3)

Mean lengths of dry periods were very similar for all goats (except Indigenous goats), and averaged about two months. In the case of Indigenous goats, the very short lactations meant that dry periods were very long.

Actual Lactation Lengths (Table L4)

Traditional analysis of lactations according to standard milk recording procedure makes comparisons only between lactations of 300 days or less. In fact many goats had lactations longer than this, as shown in Table L4. Where a goat was not bred during the normal breeding season of March to May (by intent), the better Saanen goat was capable of continuing milk production for twice as long as normal.

Milk Composition: All goats (Table L5)

The data for mean milk composition as measured by fat, protein and lactose percentage showed a high variability within breeds, apart from the distinctive differences between breeds. Although Indigenous goats had short and small lactations, their milk was extremely concentrated. Crossbred goats had milkfat and protein percentages approximately 1% higher than those of Saanens. The milk of Three-quarter Saanens was only slightly less rich in comparison to that of the Crossbred goats.

Kidding Intervals (Table L6)

Although not strictly a part of milk production *per se*, the interval between kiddings is an important measure for indicating continuity of milk production. Kidding interval averaged about 380 days for both Saanen and Indigenous goats, but with a greater range about the average for Indigenous goats. It is interesting that both Crossbred and Three-quarter Saanens had much shorter kidding intervals on average. It must of course be remembered that management decisions had a great influence on kidding interval. The breeding season was from March to May in all years until 1992. Even so, decisions about which group of goats should be bred at a particular time varied from year to year.

Milk Yields and Composition in the Early Years (Tables L7 and L8)

Milk production in the early years of the Milch Goat Project perhaps gave a better indication of breed and lactation number differences than did the means over all the years. Table L7 contains data presented at the VI International Conference on Goats in Beijing in 1996. It shows milk production from selected lactations, where the ages of goats were similar, and year effects were eliminated. Milk composition for these specific lactation comparisons are shown in Table L8. The variation between years is indicated, for example, in the comparison of milkfat and protein percent of first lactation Saanens in 1988 and 1989. Nevertheless, for both lactation yields and composition, the detailed analyses are similar to the breed averages shown in Tables L1 and L2.

2.1.1 Graphs of Lactations

Figure L1: Lactations: Saanen and Indigenous Goats: 1988/89: First Lactations
Figure L2: Lactations: Saanen and Crossbred Goats: 1989/90: First Lactations
Figure L3: Lactations: Saanen Goats: 1989/90: Second Lactations
Figure L4: Lactations: Saanen and Crossbred Goats: 1990/91: First Lactations
Figure L5: Lactations: Saanen and Crossbred Goats: 1990/91: Second Lactations

These graphs illustrate the actual lactation curves of goats. Examples are taken of the curve for the highest-yielding goat (total lactation), the lowest yielding goat (total lactation), and for the mean of the lactations in each particular group. [Thus it happened that the initial yield recorded for the highest yielding Indigenous goat (Table L1) was the same as for the average of all Indigenous goat lactations at that time. Other goats had higher yields initially, which raised the average yield, but they did not give as high a production measured over the whole lactation. A similar apparent anomaly is also shown in Figure L4.]
These graphs should be compared with those derived statistically using the linear Morant-4 model. (Figures G1 to G3).

Figure L1: Lactations: Saanen and Indigenous Goats: 1988/89
First Lactations: Mean daily milk production (kg)

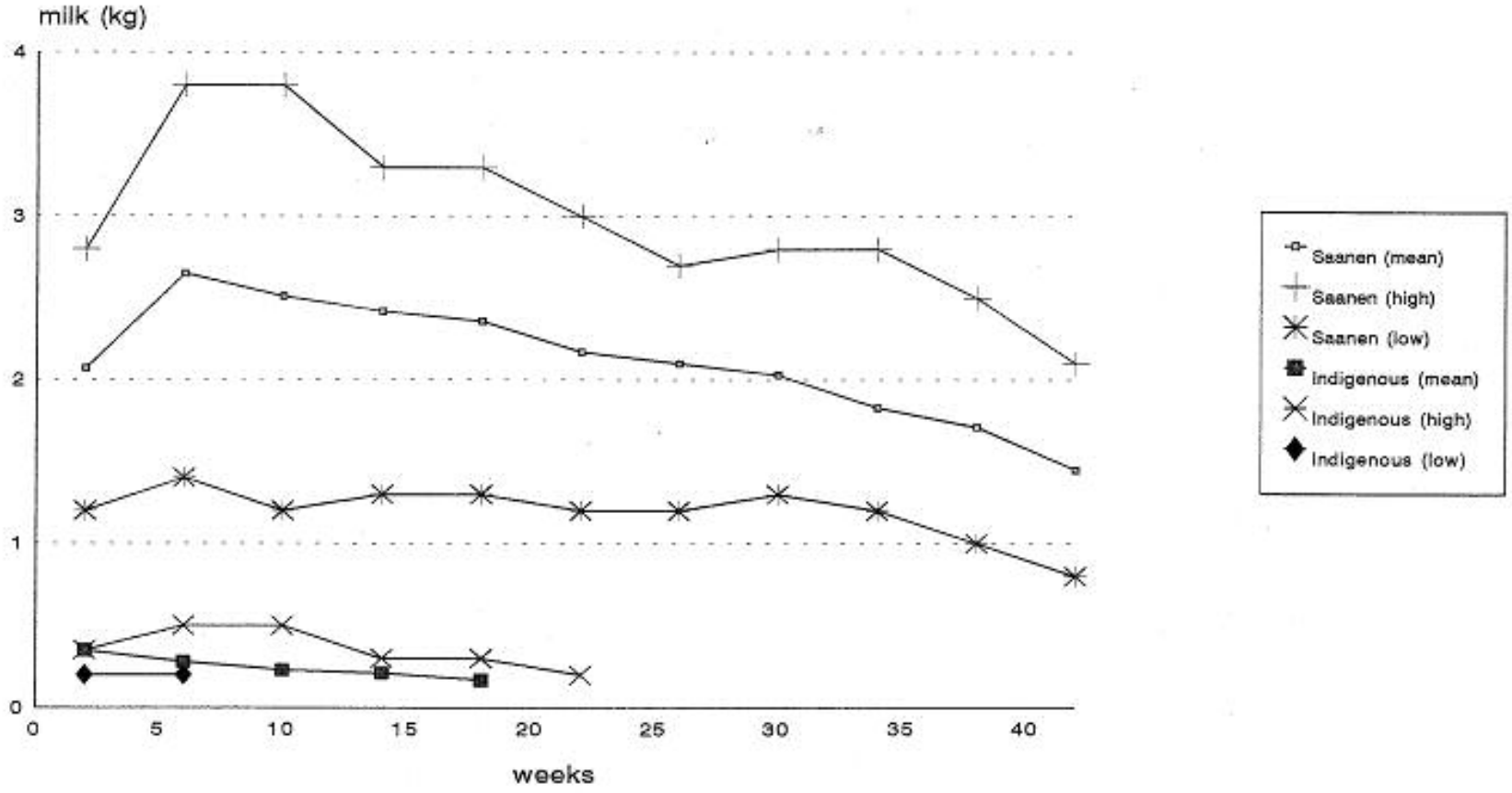


Figure L2: Lactations: Saanen and Crossbred goats: 1989/90
First Lactations: Mean daily milk production (kg)

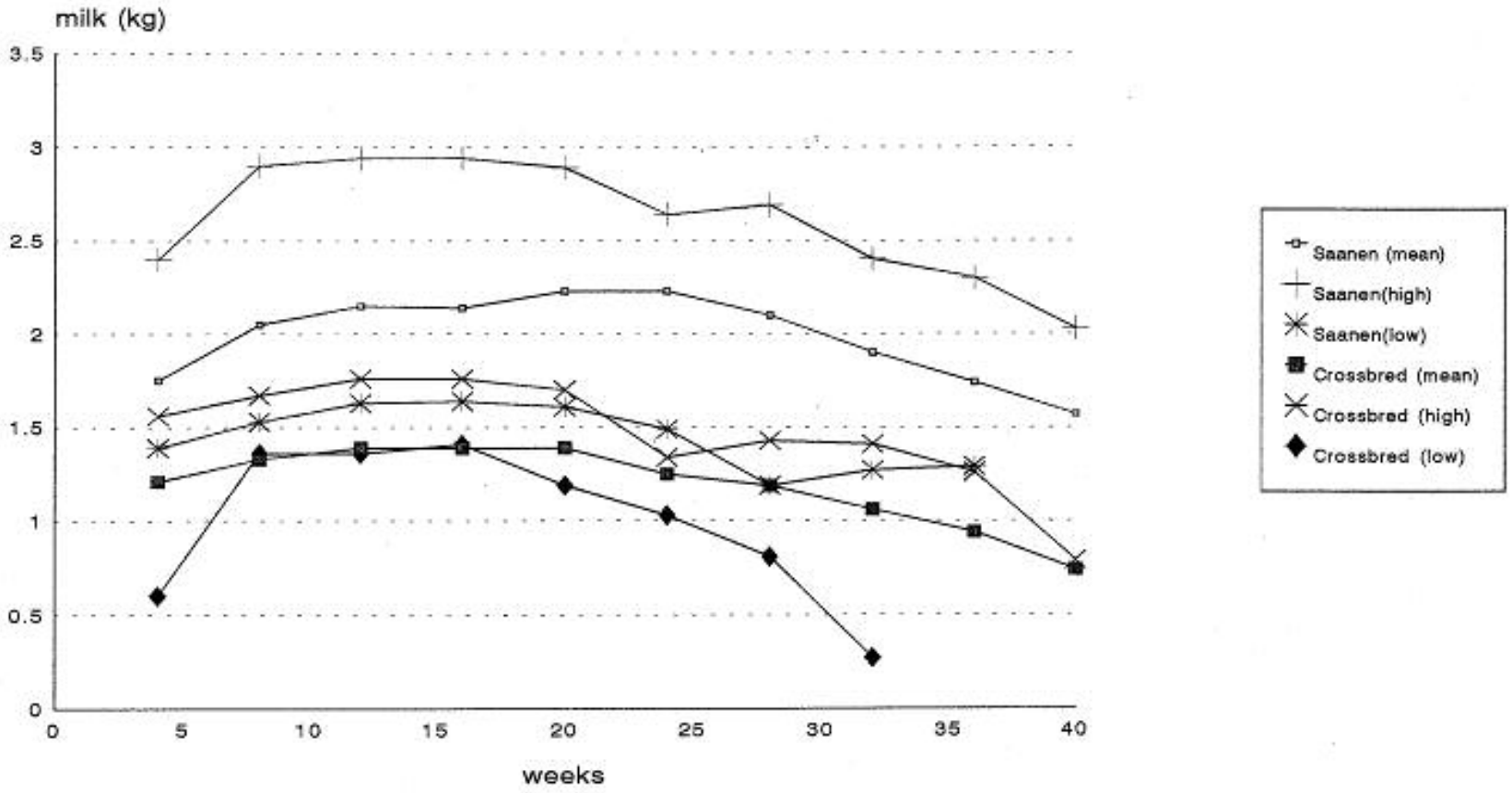


Figure L3: Lactations: Saanen goats: 1989/90
Second Lactations: Mean daily milk production (kg)

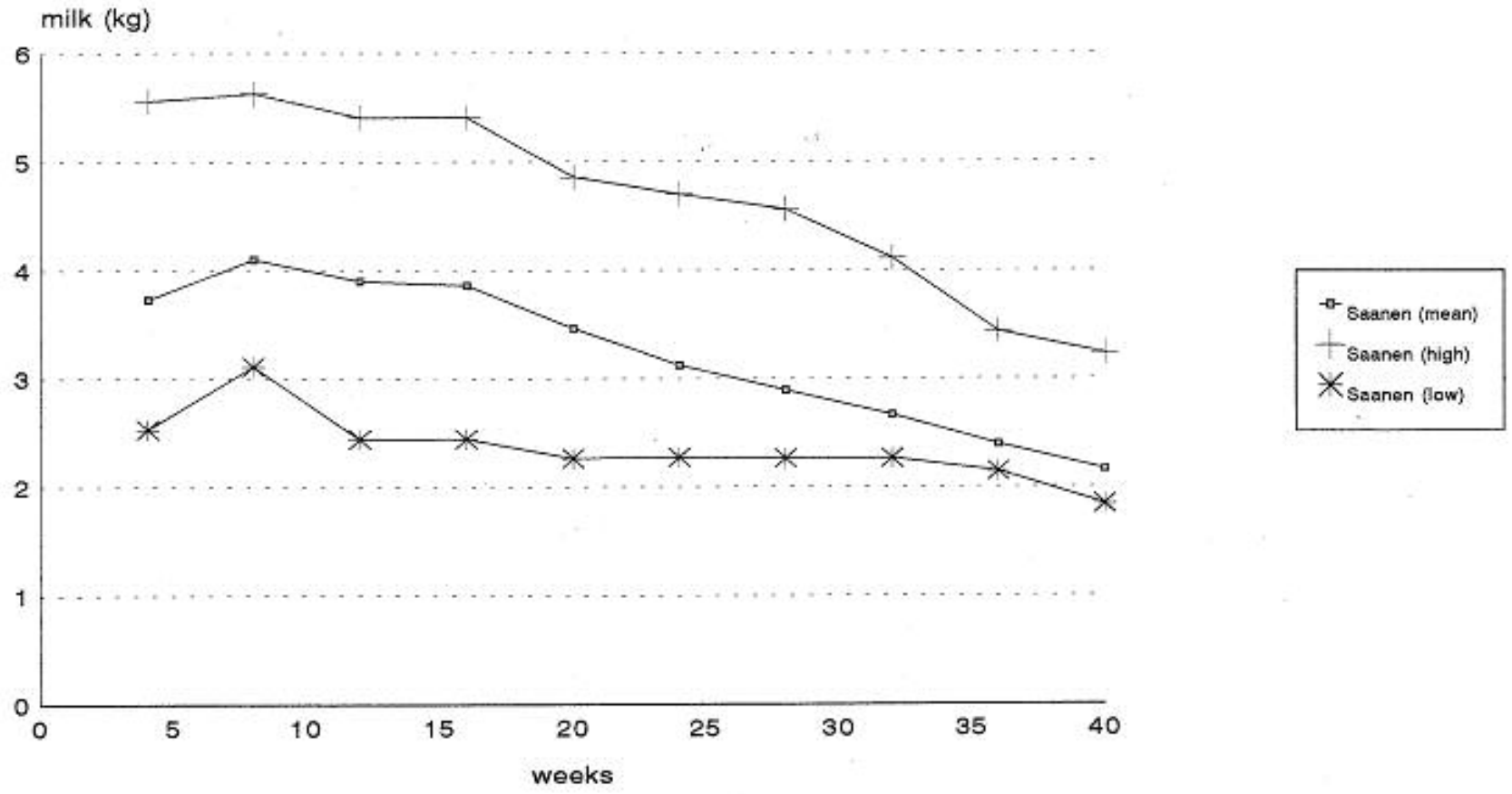


Figure L3: Lactations: Saanen goats: 1989/90
Second Lactations: Mean daily milk production (kg)

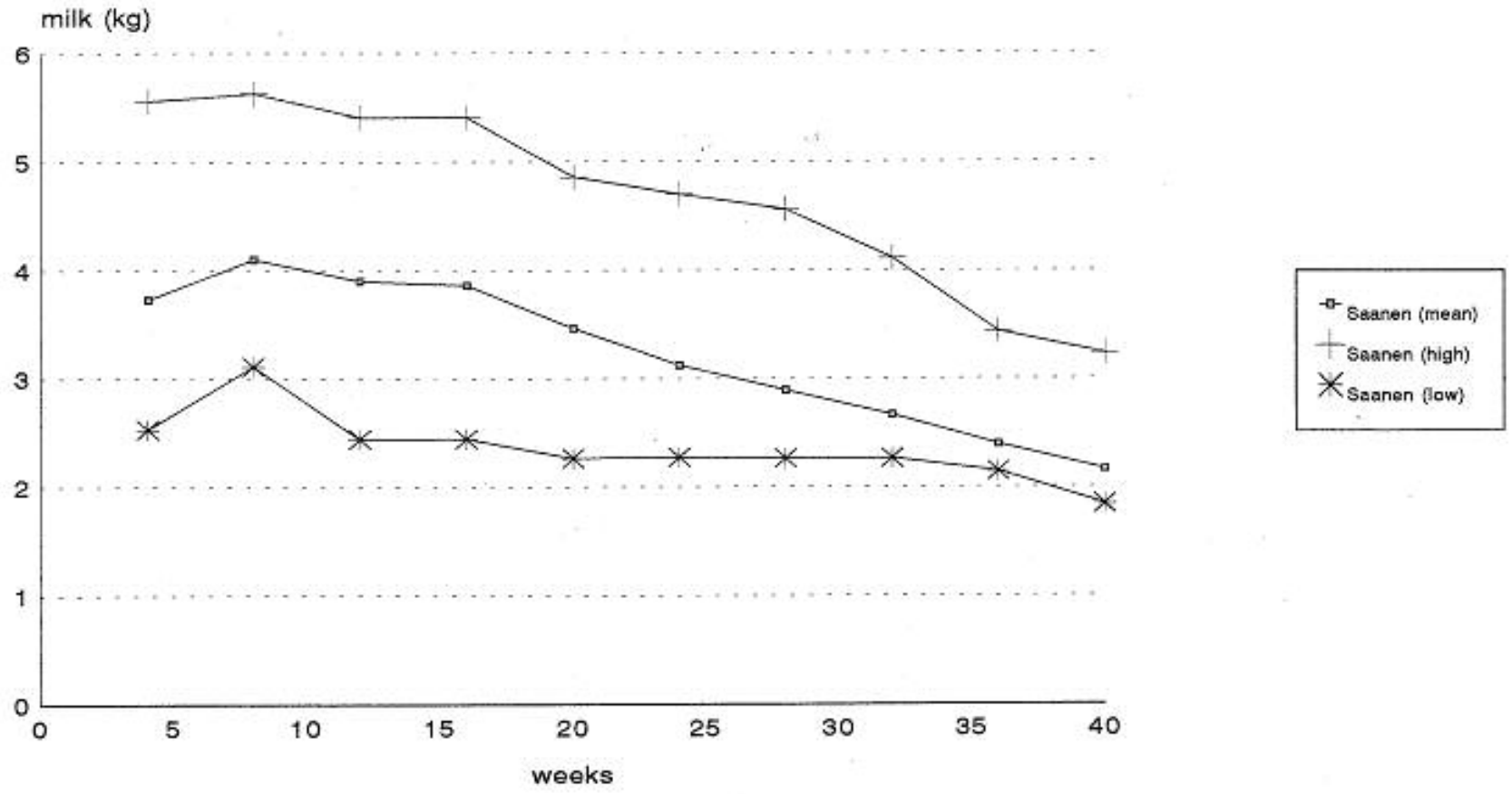


Figure L4: Lactations: Saanen and Crossbred Goats: 1990/91
First Lactations: Mean daily milk production (kg)

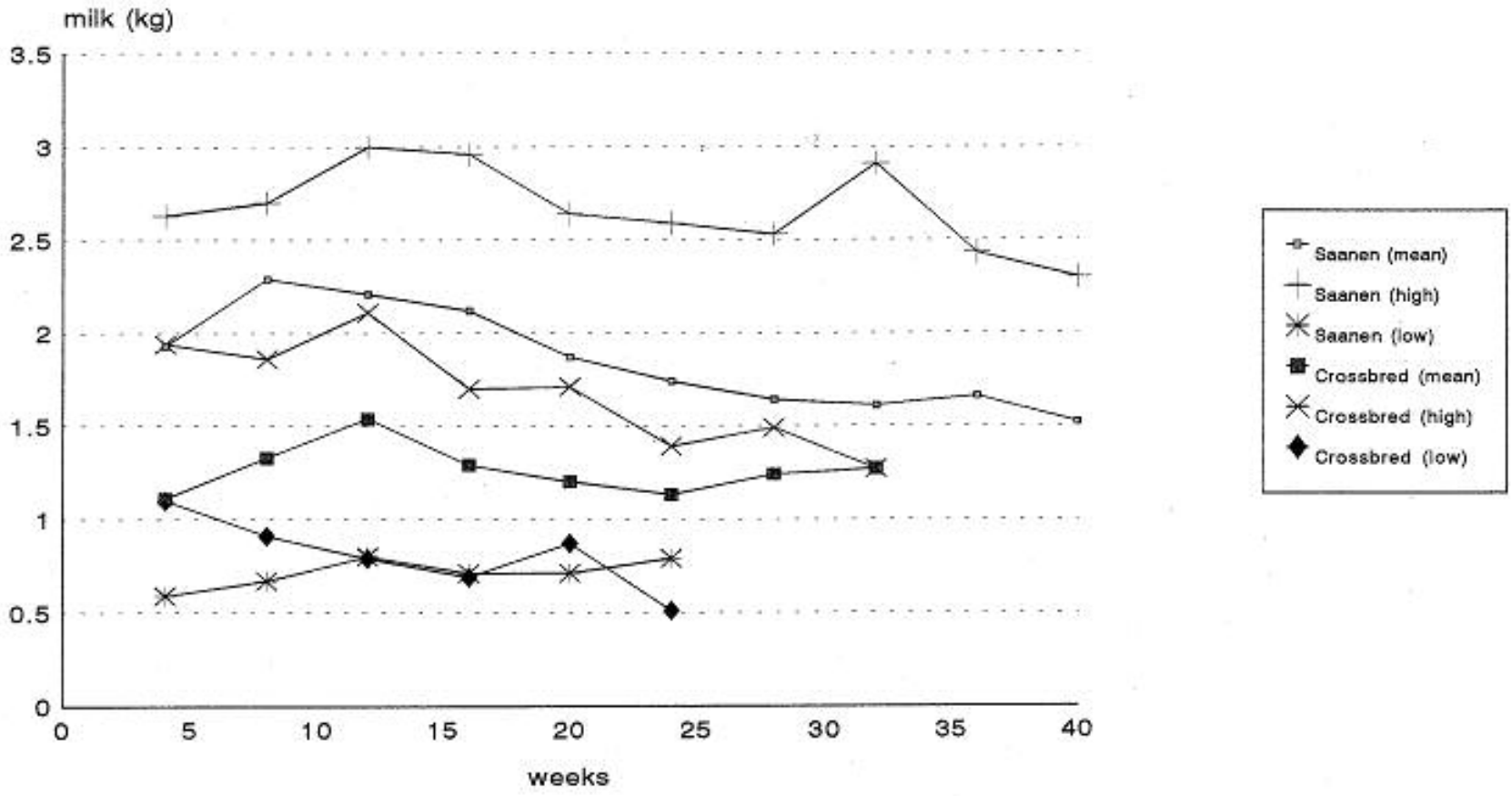
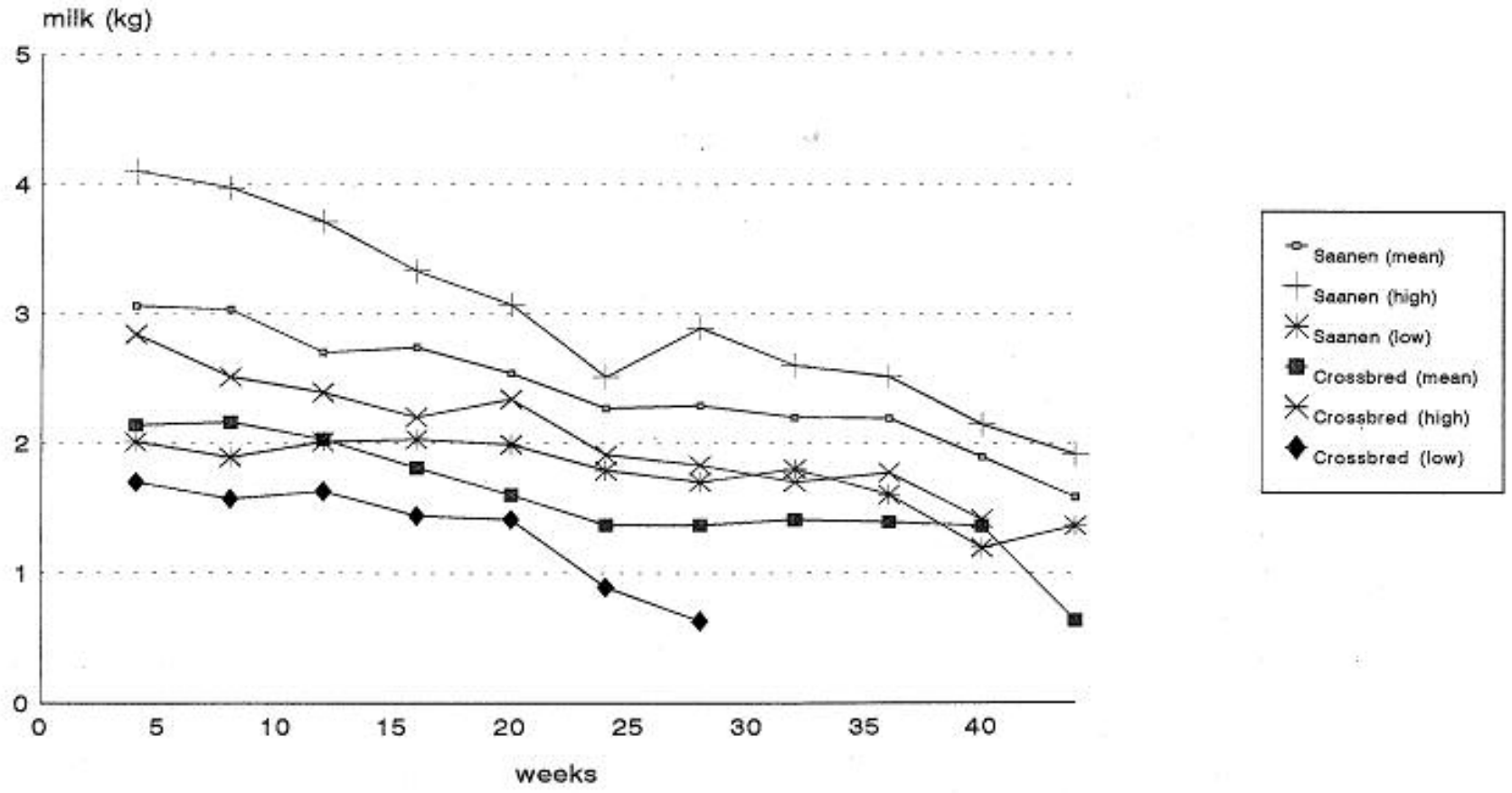


Figure L5: Lactations: Saanen and Crossbred Goats: 1990/91
Second Lactations: Mean daily milk production (kg)



2.1.2 Tables of Lactation Data

Table L1: Milk Production: All Goats, All Lactations

Breed	Lactation Yield (kg)*			Days of Lactation *		Mean Daily Milk (kg)
	No.	Mean ± SE	Min. Max.	Mean	Min. Max.	Mean ± SE
Saanen	156	706 ± 207	334 1404	288	164 300	2.45 ± 0.67
Indigenous	21	23 ± 13	6 57	94	30 155	0.25 ± 0.06
Crossbred	73	392 ± 13	56 828	245	69 300	1.58 ± 0.41
Three-quarter Saanen	22	390 ± 161	82 677	250	109 300	1.51 ± 0.41

[* Milk Production beyond 300 days not included]

Table L2: Goat Lactation Yields: Breeds and Lactation Numbers

Breed and Lactation	No.	Milk Yields (kg) Mean ± SE	Mean Lactation Lengths (days)*	Peak Daily Yields		Mean Daily Yields kg/d ± SE
				kg/d ± SE	Days ± SE	
Saanen						
1	59	579 ± 130	283	2.74 ± 0.55	78 ± 42	2.04 ± 0.42
2	48	838 ± 177	293	3.93 ± 0.85	69 ± 30	2.86 ± 0.57
3	28	758 ± 208	290	3.68 ± 0.58	68 ± 25	2.60 ± 0.66
4	15	764 ± 242	286	3.81 ± 1.10	67 ± 30	2.68 ± 0.78
5	6	503 ± 111	281	2.75 ± 0.56	55 ± 12	1.79 ± 0.37
Indigenous						
1	21	23 ± 13	94 ± 39	0.40 ± 0.11	16 ± 12	0.25 ± 0.06
Crossbred						
1	32	317 ± 102	236	1.83 ± 0.41	94 ± 38	1.33 ± 0.31
2	24	446 ± 118	248	2.55 ± 0.45	56 ± 21	1.80 ± 0.31
3	12	438 ± 120	257	2.39 ± 0.48	67 ± 18	1.69 ± 0.37
4	5	504 ± 227	265	2.76 ± 0.86	73 ± 31	1.85 ± 0.61
Three- 1	12	320 ± 166	232	1.75 ± 0.62	82 ± 28	1.33 ± 0.43
quarter 2	5	438 ± 115	260	2.49 ± 0.43	83 ± 20	1.67 ± 0.24
Saanen 3	5	509 ± 109	284	2.68 ± 0.35	59 ± 13	1.79 ± 0.27

[* Note: Milk production beyond 300d not included]

Table L3: Goat Lactations: Dry Periods: Days Dry Following Lactations

Breed	Previous Lactation	Number	Days Dry Mean ± SE
Saanen	1	49	73 ± 56
	2	29	62 ± 35
	3	15	55 ± 39
	4	6	65 ± 29
Indigenous	1	18	272 ± 190
	2	2	363 ± 236
	4	3	527 ± 328
Crossbred	1	23	95 ± 46
	2	12	58 ± 26
	3	5	52 ± 14
Three-quarter Saanen	1	5	75 ± 77
	2	4	37 ± 28

Table L4: Goat Lactations: Actual Lactation Lengths
[Including lactations >300 days]

Breed	Lactation	Number	Days Mean ± SE	Min.	Max.
Saanen	1	59	296 ± 58	231	662
	2	49	344 ± 98	108	574
	3	29	346 ± 108	174	717
	4	15	422 ± 146	220	673
	5	6	301 ± 51	230	359
Indigenous	1	21	98 ± 39	35	159
	2	2	46 ± 4	43	49
	4	3	54 ± 5	48	58
Crossbred	1	32	248 ± 62	73	412
	2	25	253 ± 51	137	336
	3	12	268 ± 53	203	333
	4	5	302 ± 66	235	406
Three-quarter Saanen	1	12	263 ± 95	118	424
	2	5	275 ± 60	194	339
	3	5	383 ± 132	224	574

Table L5: Milk Composition: All Breeds of Goats

Breed	Fat		Protein		Lactose	
	No.	Mean ± SE	No.	Mean ± SE	No.	Mean ± SE
Saanen	153	3.43 ± 0.53	153	2.88 ± 0.34	153	4.49 ± 0.20
Indigenous	26	9.33 ± 1.84	74	5.04 ± 0.82	74	5.12 ± 0.56
Crossbred	71	5.47 ± 0.67	71	3.88 ± 0.29	71	4.81 ± 0.18
Three-quarter Saanen	19	5.10 ± 0.64	19	3.50 ± 0.41	19	4.73 ± 0.17

Table L6: Kidding Intervals for Goats (days)

Breed	Number	Mean ± sd	Min.	Max.
Saanen	99	380 ± 88	174	693
Indigenous	148	384 ± 165	220	1276
Crossbred	42	329 ± 51	202	461
3/4 Saanen	9	304 ± 30	242	353

Table L7: Milk yields of Saanen, South African Indigenous and Crossbred goats [Donkin, *et al.*(1996)]

	No.	Lactation (kg)		Days[A]		Daily milk (kg/d)	
Category	mean	se	mean	se	mean	se	
First lactations 1988							
Saanen	23	614	142	285	-	2.16	0.48
Indigenous	21	23	13	94	39	0.25	0.07
First lactations 1989							
Saanen	10	558	87	290	-	1.92	0.30
Crossbred	9	337	63	282	-	1.19	0.16
Second lactations 1990							
Saanen	9	743	118	300	-	2.48	0.39
Crossbred	9	463	122	266	-	1.72	0.30

([A] milk production beyond 300 days not included)

Table L8: Milk composition analysis of Saanen, South African Indigenous and Crossbred goats [Donkin, *et al.*(1996)]

	No.	Milk fat (%)		Protein (%)		Lactose (%)	
Category	mean	se	mean	se	mean	se	
First lactations 1988							
Saanen	23	2.88	0.31	2.63	0.26	4.61	0.20
Indigenous	21	9.06	1.84	5.44	0.69	4.64	0.44
First lactations 1989							
Saanen	9	3.91	0.40	3.15	0.26	4.47	0.14
Crossbred	9	5.31	0.61	3.77	0.28	4.82	0.12
Second lactations 1990							
Saanen	9	3.73	0.40	3.12	0.28	4.47	0.16
Crossbred	9	5.13	0.63	3.77	0.26	4.82	0.12
All Saanens	41	3.29	0.58	2.85	0.37	4.55	0.19
All Crossbreds	18	5.22	0.61	3.77	0.27	4.82	0.12

2.2 FITTING LACTATION CURVES

The model chosen for the fitting of lactation curves was the linear Morant-4, as described in the section on Materials and Methods. These curves were fitted to lactation data for goats that kidded in 1988 and 1990.

The Parameters (A,B,C and D) for each lactation are shown in Tables G1, G2, and G3.

2.2.1 STATISTICAL ANALYSIS OF LACTATION CURVES

Comparison of Lactations: Saanen and Indigenous Goats in 1988 (First Lactations) [Table G4]

All Parameters were significantly different in the comparison between Saanen and Indigenous goats in first lactation: Parameters A and D ($P<0.001$); Parameters B and C ($P<0.05$). This analysis shows that the lactation curves were totally different in all aspects.

Comparison of First Lactation Saanens in 1988 and 1990 [Table G5]

The comparison of Saanen first lactations in 1988 and 1990 showed no significant effect of year on Parameters A and D, but a significant ($P<0.05$) difference in Parameters B and C. This means that there was no difference in the scale of the lactation curves, but that there were significant ($P<0.05$) differences in the rate of decline (persistency) for Saanen first lactations between the years 1988 and 1990.

Comparison of Lactations: Saanen and Crossbred Goats in 1990 [Table G6]

The comparison of Saanen and Crossbred lactations in 1990 showed a significant ($P<0.001$) difference in Parameter A (scale of lactation) for first lactations, and a lesser significance ($P<0.01$) for second lactations. This was the most important difference between groups. In contrast, there was little difference between groups in the "shape" parameters B and C. There were no significant differences in Parameter B. Parameter C showed a significant ($P<0.05$) difference only for second lactations. There were no significant differences for Parameter D in lactations 1 and 2, but a significant ($P<0.001$) breed x parity interaction. In Saanens the negative value of Parameter D decreased between parities 1 and 2, but the reverse was true for Crossbreds.

2.2 2 LACTATION CURVES: Figures G1, G2, G3.

*** Figure G1: Goat Lactation Curves 1990: Saanen and Crossbred: Lactations 1 and 2**.
These graphs relate to the data shown in Table G5.

*** Figure G2: Goat Lactation Curves: Saanens, First Lactations: 1988 and 1990**.
These graphs relate to the data shown in Table G4. The differences in persistency are clear, but the apparent difference of scale (at 150 days) was found to be not significant.

*** Figure G3: Goat Lactation Curves: Indigenous Goats: First Lactations**.
Lactation curves of Indigenous goats proved to be greatly variable in both scale and shape, and it was considered unrealistic to attempt to fit curves of average values. Therefore, three individual lactation curves were selected to illustrate the different types. The Wood model was used in these cases because it was more appropriate than the linear Morant-4 model.

Table G1: Morant Parameters for Lactation Curves of Goats: Saanens (1990)

Goat	Weeks	Parameter A	Parameter B	Parameter C	Parameter D	R-squared
1st Lact.						
0S1JO4	43	0.7139	-0.3459	0.0026	-9.3283	0.7009
0S1J06	42	0.7439	-1.1973	-0.0238	-8.6478	0.7514
0S1J11	42	0.8208	-0.2805	-0.0309	-9.0153	0.8621
0S1J21	41	0.7965	-0.2009	0.0315	-6.6768	0.6763
0S1J22	34	0.6123	-0.4139	-0.3107	-5.9161	0.7510
0S1J27	34	0.4421	-0.6216	-0.1929	-7.4457	0.7997
0S1J31	32	0.4279	-0.5026	-0.0638	-10.3434	0.8269
0S1J32	42	1.0067	-0.1271	-0.0652	-7.9446	0.7333
0S1J33	41	1.0437	-0.1197	-0.0136	-5.1633	0.5113
0S1J35	40	0.1742	-0.2521	-0.2668	-10.6366	0.3368
0S1J40	40	0.8309	-0.4318	-0.0459	-9.1974	0.8824
0S1J41	40	0.7374	-0.3594	0.0070	-7.1647	0.8469
0S1J44	41	0.7221	-0.3619	-0.0435	-8.7359	0.8827
0S1J46	35	0.8015	-0.4046	-0.1213	-8.7203	0.8638
2nd Lact.						
0S2K04	43	0.6950	-0.0999	-0.1295	0.9339	0.8689
0S2K23	46	0.8661	-0.2952	-0.0409	-11.6818	0.9131
0S2K30	46	0.9648	-0.0540	-0.0092	-0.8133	0.1185
0S2K31	44	0.9093	-0.2739	-0.1180	-9.9999	0.7103
0S2K35	43	1.1874	-0.2268	-0.1001	-5.0333	0.7345
0S2K40	44	0.8386	-0.2053	-0.0087	-3.6240	0.5954
0S2K43	47	1.0991	-0.3295	-0.0073	-7.4107	0.9167
0S2K45	46	1.1895	-0.2883	-0.0121	-6.0256	0.8921
0S2K50	43	0.9617	-0.2791	-0.0848	-10.4736	0.7372
0S2L276	42	1.1024	-0.1491	-0.0965	-0.5985	0.5606
3rd Lact.						
0S3L019	44	1.4498	-0.2356	-0.0008	-14.9629	0.7708
0S3L184	43	0.9268	-0.3806	-0.0360	-12.9887	0.8277
0S3L197	43	1.0524	-0.4112	0.0937	-11.5641	0.6057
0S3L199	43	1.0114	-0.2850	-0.0431	-10.8586	0.8674
0S3L205	46	0.9376	-0.2705	-0.1524	-8.2963	0.9446
0S3L217	36	1.0546	-0.5451	-0.4534	-3.5946	0.9167
0S3L314	38	0.7912	-0.4243	-1.0025	-7.7879	0.8497
0S3L341	46	1.5872	-0.1900	-0.1133	-3.6241	0.9278
0S3L410	15	1.6429	0.2933	0.2885	-6.9992	0.5453
0S3L429	47	1.2820	-0.1134	-0.0371	-6.8979	0.5842
0S3L436	32	0.9063	-1.0115	-0.8218	-1.9805	0.7230
0S3L449	45	1.1999	-0.4001	-0.3221	-4.5138	0.9058
0S3L454	45	0.8628	-0.1919	-0.0833	-5.0713	0.6989
0S3L466	47	1.4668	-0.1381	-0.0880	-9.0259	0.7652
0S3L481	45	0.9094	-0.4576	0.0290	-9.2677	0.8699
0S3L492	45	1.0909	-0.3597	-0.0291	-6.0572	0.8683
0S3L607	44	0.8457	-0.1911	-0.2120	-6.8036	0.8064
0S3L676	40	1.4478	-0.1614	-0.1476	-1.9844	0.7519

Table G2: Morant Parameters for Lactation Curves of Goats: Crossbreds (1990)

Goat	Weeks	Parameter A	Parameter B	Parameter C	Parameter D	R-squared
1st Lact.						
0C1J03	42	0.4949	-0.0175	-0.2345	-1.0253	0.5469
0C1J07	34	0.4858	-0.5465	-0.1650	-8.5388	0.8590
0C1J08	27	0.4057	-0.9702	-0.6327	4.6580	0.5206
0C1J12	34	0.3210	-0.3215	0.1178	-2.3898	0.6049
0C1J13	29	0.0599	-0.5249	-0.1470	-6.0280	0.6727
0C1J14	33	0.3615	-0.3195	0.1576	-9.0297	0.8223
0C1J18	29	0.0723	-0.4476	-0.4892	2.7099	0.5374
0C1J25	28	-0.0675	-0.1764	-0.1443	1.1638	0.0167
0C1J28	24	0.4530	-0.2932	0.0526	-7.9215	0.5773
0C1J39	12	-2.0772	-3.7680	-1.7882	2.3319	0.3298
2nd Lact.						
0C2K18	46	0.8571	-0.3694	0.0221	-12.5702	0.7139
0C2K28	33	0.3849	-0.2944	0.1657	-6.2509	0.7747
0C2K33	36	0.2880	-0.5345	0.1113	-10.4522	0.9002
0C2K44	32	0.4800	-0.3271	0.1476	-10.0944	0.8221
0C2K48	32	0.1834	-0.6652	-0.2013	-5.0700	0.8688
0C2K51	36	0.5142	-0.3054	0.1114	-3.3051	0.8885
0C2K53	45	0.8823	-0.3233	-0.0464	-8.7874	0.7661
0C2K57	43	0.4453	-0.2504	0.0130	-1.4311	0.7653
0C2K60	45	0.6448	-0.4610	0.0786	-11.3841	0.7868

Table G3: Morant Parameters for Lactation Curves of Goats: Saanen and Indigenous: First lactations (1988)

Goat	Weeks	Parameter A	Parameter B	Parameter C	Parameter D	R-squared
Saanen						
8S1L019	39	1.0513	-0.1847	-0.0464	-6.3470	0.7628
8S1L184	39	1.0639	-0.3178	-0.0399	-7.4547	0.9144
8S1L197	39	0.9164	-0.2147	-0.0815	-3.9781	0.4022
8S1L199	40	0.6019	-0.4010	-0.0228	-6.9475	0.8677
8S1L205	39	0.5785	-0.2360	-0.0812	-2.7201	0.7178
8S1L217	40	0.7821	-0.2507	-0.0032	-8.3467	0.8600
8S1L234	41	0.8068	-0.3418	0.0447	-9.2866	0.9005
8S1L257	39	1.0113	-0.3381	0.0490	-7.6988	0.9291
8S1L314	41	1.1548	-0.3153	0.1075	-12.1593	0.9144
8S1L341	40	1.1267	-0.2887	-0.0895	-6.7794	0.9295
8S1L410	41	0.9651	-0.2861	0.0486	-7.5197	0.6395
8S1L429	39	0.9635	-0.1022	-0.1151	-2.0917	0.7683
8S1L436	40	0.4130	-0.1708	0.0156	-4.9815	0.1561
8S1L449	38	0.8517	-0.2183	0.1171	-9.6178	0.4743
8S1L450	41	0.7045	-0.2601	-0.0224	-9.2969	0.8363
8S1L454	37	0.5594	-0.0530	-0.2001	-0.9158	0.6067
8S1L466	40	0.7051	-0.1618	-0.0814	-0.7622	0.7642
8S1L476	39	0.7329	-0.2324	-0.0901	-8.1727	0.8025
8S1L478	42	0.7960	-0.4888	0.0986	-13.1713	0.9035
8S1L481	42	0.7719	-0.3158	0.0819	-9.5331	0.8619
8S1L492	40	0.5937	-0.3095	0.0021	-4.1105	0.8932
8S1L607	42	0.2533	-0.2160	0.0088	-6.3893	0.6223
8S1L676	41	1.1978	-0.1746	-0.0453	-11.8381	0.9310
Indigenous						
8I17410	6	-1.7378	3.7699	1.0940	0.4761	0.9999
8I17313	15	-5.3367	-8.3127	-4.4559	11.7344	0.7614
8I17409	18	-1.7504	1.1008	0.9283	7.5253	0.2848
8I17410	16	-3.7568	3.9561	1.7867	9.0662	0.7284
8I17414	8	-5.8524	-7.7838	-3.5595	3.8036	0.0252
8I17416	9	-11.5113	-1.7392	-8.0416	9.6731	0.5694
8I17419	16	-1.7442	-1.9531	-1.5286	14.6419	0.0622
8I1746D	8	7.7034	15.6174	7.0711	-4.7555	-
8I17502	8	-2.1969	-1.6141	-1.1984	13.6993	0.7422
8I17503	7	-31.0701	-50.0363	-21.1264	13.5869	0.9675
8I17504	4	-	-	-	-	-
8I17506	22	-1.3427	-0.3427	0.5342	-14.7645	0.7085
8I17507	10	-1.9462	-0.4529	-0.1289	4.9155	0.8002
8I17508	16	-1.1311	4.8938	4.8888	-26.5440	0.7026
8I17509	-	-	-	-	-	-
8I17510	20	-1.5393	0.4245	-0.0606	13.5858	0.4826
8I17602	16	-3.4849	-4.5691	-2.4896	8.1851	0.6336
8I17603	10	-11.0127	-17.2253	-7.6174	9.2350	0.7114
8I17606	20	-3.4524	-3.1175	-1.0937	2.7330	0.8227
8I17613	8	-23.9691	-40.1356	-18.4570	21.3574	0.1025
8I1795D	12	-5.3480	-7.0191	-3.1293	6.8001	0.7709

Notes: 1. Goat No. 8I17504: No variance in yield.
2. Goat No. 8I17509: Too few observations.

Table G4: Comparison of Lactations: Saanen and Indigenous Goats in 1988 (First Lactations)

	Breed	n	Means	SD	ANOVA	df	MS	F
Parameter A	Saanen Indigenous	23 18	0.80877 -6.56528	0.242895 8.297502	Breed Error	1 39	549.0701 30.0442	18.27 ***
Parameter B	Saanen Indigenous	23 18	-0.25557 -7.23089	0.096178 14.8415	Breed Error	1 39	491.2978 96.0201	5.1166 *
Parameter C	Saanen Indigenous	23 18	-0.01500 -3.53636	0.079692 6.719143	Breed Error	1 39	125.2096 19.6829	6.3613 *
Parameter D	Saanen Indigenous	23 18	-6.96166 6.09504	3.416135 11.10427	Breed Error	1 39	1721.405 60.331	28.532 ***

Table G5: Comparison of First Lactation Saanens in 1988 and 1990

	Year	n	Means	SD	ANOVA	df	MS	F
Parameter A	1988 1990	23 14	0.80877 0.70528	0.242895 0.230695	Year Error	1 35	0.09320 0.05685	1.6395NS
Parameter B	1988 1990	23 14	-0.25557 -0.40138	0.096178 0.267666	Year Error	1 35	0.18501 0.03242	5.7057*
Parameter C	1988 1990	23 14	-0.01500 -0.08124	0.079692 0.104634	Year Error	1 35	0.038180 0.008058	4.7380*
Parameter D	1988 1990	23 14	-6.96166 -8.20966	3.416135 1.585516	Year Error	1 35	13.35451 8.26913	1.6391NS

Table G6: Comparison of Lactations: Saanen and Crossbred Goats in 1990

	Parity	Saanen	Crossbred	Means	Source of Variation	df	MS	F
Parameter A	1 2 Means	0.7053 0.9814 0.8203	0.0515 0.5200 0.2734	0.4329 0.7628 0.5787	Breed Parity Breed x Parity Error	1 1 1 39	3.2510 1.4494 0.0968 0.1730	18.794*** 8.379 ** 0.559 NS
Parameter B	1 2 Means	-0.4014 -0.2201 -0.3259	-0.7385 -0.3923 -0.5745	-0.5419 -0.3017 -0.4357	Breed Parity Breed x Parity Error	1 1 1 39	0.6782 0.7274 0.0711 0.3060	2.216 NS 2.376 NS 0.232 NS
Parameter C	1 2 Means	-0.0812 -0.0607 -0.0727	-0.3273 0.0447 -0.1511	-0.1838 -0.0108 -0.1073	Breed Parity Breed x Parity Error	1 1 1 39	0.0517 0.4027 0.3229 0.0821	0.630 NS 4.9038 * 3.932 NS
Parameter D	1 2 Means	-8.2097 -5.4725 -7.0692	-2.4069 -7.7049 -4.9165	-5.7919 -6.5300 -6.1180	Breed Parity Breed x Parity Error	1 1 1 39	33.3222 17.1436 168.7747 14.5771	2.286 NS 1.176 NS 11.578**

[Note: The means are unadjusted]

Figure G1: Goat Lactation Curves 1990: Saanen and Crossbred: Lactations 1 and 2
Mean curves derived from the linear Morant-4 Model

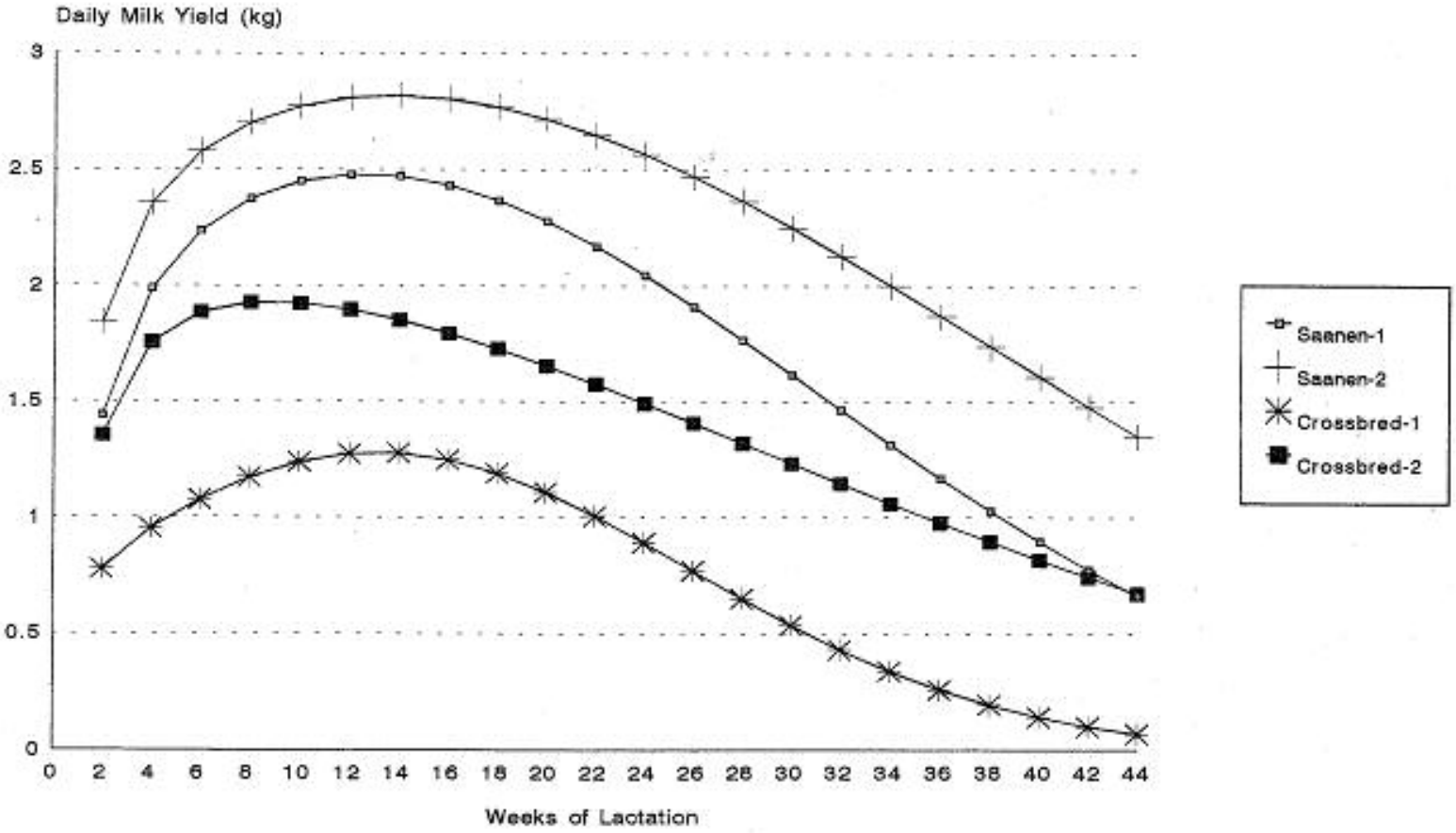


Figure G2: Goat Lactation Curves: Saanens, First Lactations:1988 and 1990
Mean curves derived from the linear Morant-4 Model

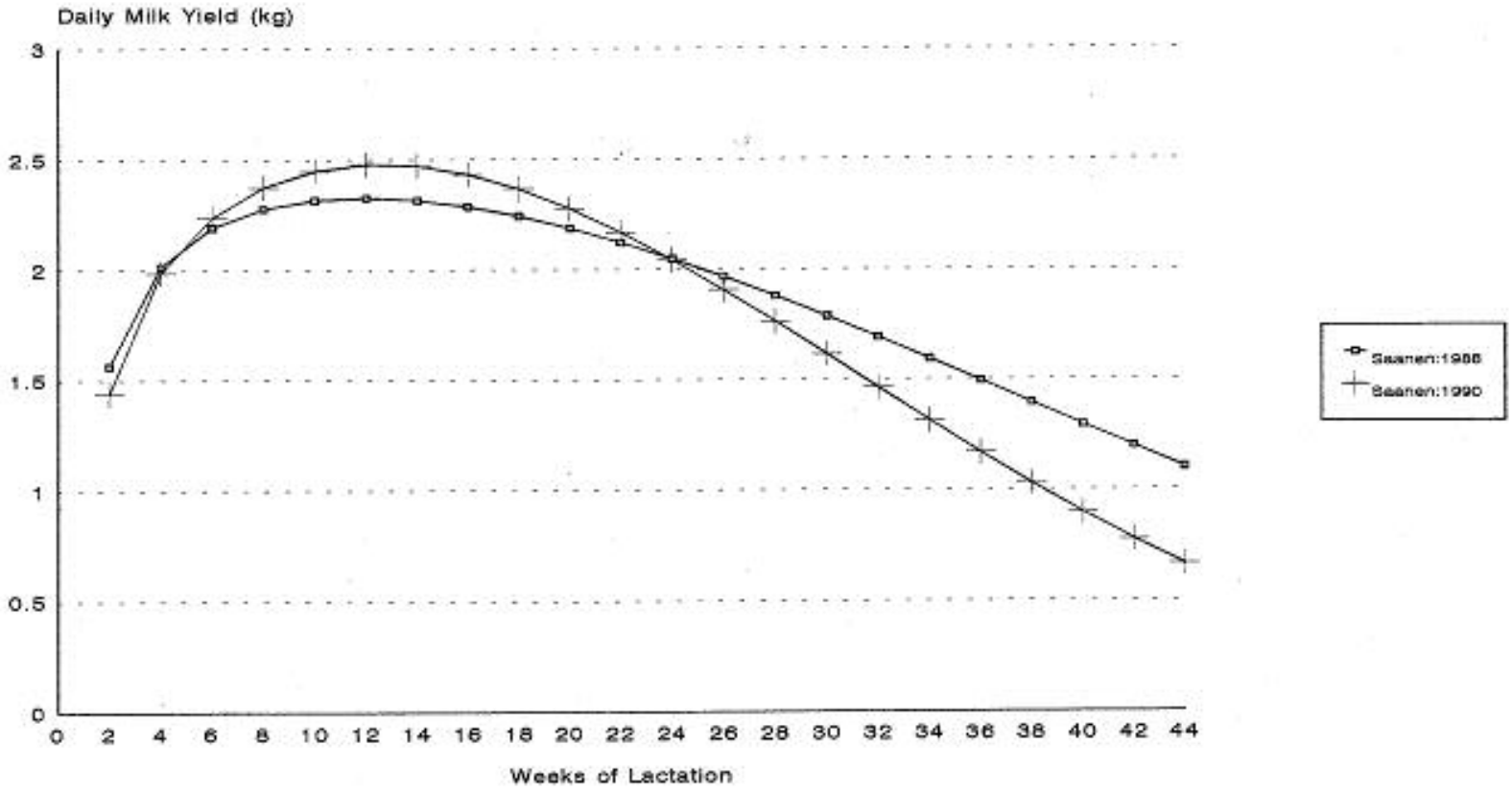
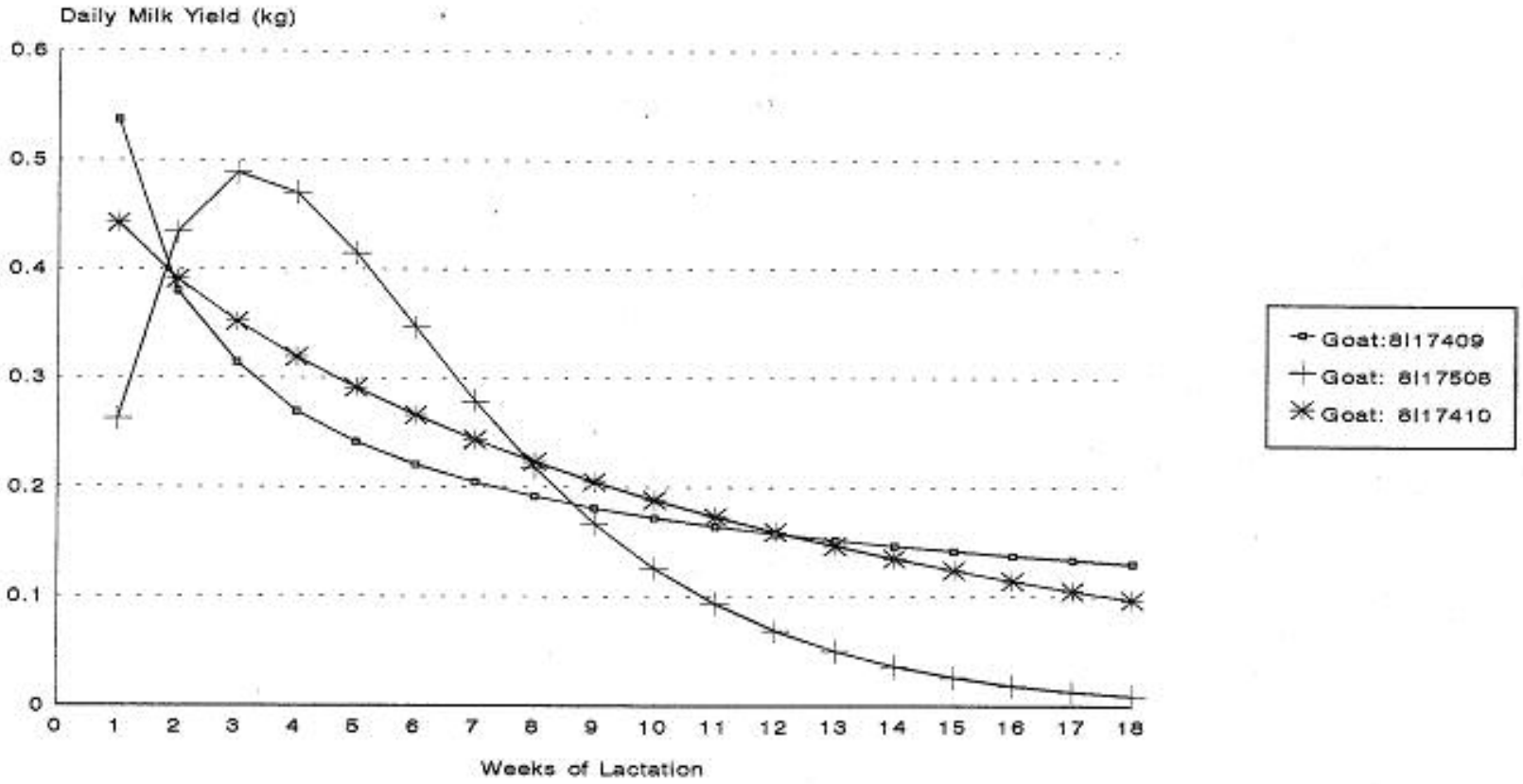


Figure G3: Goat Lactation Curves: Indigenous Goats: First Lactations
Curves derived from Wood Model



2.3 COMPOSITION CORRECTED MILK

The wide variation of milk composition analysis (as shown for example in Table L2) raised the question of the adequacy of comparing milk yields on the basis of litres of milk alone. The traditional system of correcting milk yields to a standard equivalent of 4% Fat Corrected Milk was originally used because milkfat was the only criterion measured at that time. Since routine milk recording analyses now also include protein and lactose percentages, additional composition corrected milk estimates were added to the list of criteria to be assessed in the analyses:

* Fat Corrected Milk (FCM) [corrected to 4%]
* Protein Corrected Milk (PCM) [corrected to 3%]
* Lactose Corrected Milk (LCM) [corrected to 4.5%]
* Fat, Protein, Lactose Corrected Milk (FPLCM) [corrected to 11.5%]

Summaries of these for lactation number and for breed are shown in Tables L9 to L12.
Full details of the corrected lactation yields are listed in Tables L13 to L31 (Appendix A).
Probably the most meaningful Tables are those which included data for the first three lactations for each breed: Tables L14 to L17 (Appendix A). 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 after correction for composition, yields of Saanens were still higher than those of Crossbreds and Three-quarter Saanens. Further details of statistical analyses of these lactations are shown in the subsequent Tables in the sections concerning correlations and multiple regression analyses.

2.3.1 COMPOSITION-CORRECTED MILK: Tables L9 to L12

Table L9: Fat Corrected Milk Yields of Goats: All Breeds; All Lactations
Table L10: Protein Corrected Milk Yields of Goats: All Breeds; All Lactations
Table L11: Lactose Corrected Milk Yields of Goats: All Breeds; All Lactations
Table L12: Fat-Protein-Lactose Corrected Milk Yields of Goats: All Breeds; All Lactations

[Note: Detailed Tables of Composition Corrected Milk Yields are shown in Appendix A].

Table L9: Fat Corrected Milk Yields of Goats (kg):
All Breeds: All Lactations.

Breed and Lactation		No.	Mean ± SE	Min.	Max.
Saanen	1	56	487 ± 116	215	770
	2	48	716 ± 148	375	1130
	3	28	644 ± 158	425	1030
	4	15	643 ± 191	382	966
	5	6	427 ± 115	254	558
Indigenous	1	19	53 ± 22	24	107
Crossbred	1	30	452 ± 133	256	923
	2	24	612 ± 159	339	1022
	3	12	593 ± 141	353	850
	4	5	658 ± 208	495	913
Three-	1	9	476 ± 147	291	730
quarter	2	5	542 ± 114	391	648
Saanen	3	5	649 ± 198	407	894

Table L10: Protein Corrected Milk Yields of Goats (kg):
All Breeds: All Lactations.

Breed and Lactation		No.	Mean ± SE	Min.	Max.
Saanen	1	56	548 ± 127	297	850
	2	48	801 ± 165	404	1284
	3	28	721 ± 163	498	1166
	4	15	717 ± 179	445	999
	5	6	483 ± 107	282	602
Indigenous	1	19	43 ± 20	20	97
Crossbred	1	30	434 ± 111	261	826
	2	24	573 ± 160	373	1086
	3	12	559 ± 149	291	770
	4	5	649 ± 295	398	1071
Three-	1	9	461 ± 168	268	749
quarter	2	5	476 ± 103	333	560
Saanen	3	5	570 ± 154	406	774

Table L11: Lactose Corrected Milk Yields of Goats (kg):
All Breeds: All Lactations.

Breed and Lactation		No.	Mean ± SE	Min.	Max.
Saanen	1	56	585 ± 132	334	883
	2	48	836 ± 182	488	1376
	3	28	745 ± 203	501	1278
	4	15	743 ± 228	440	1129
	5	6	489 ± 107	329	596
Indigenous	1	19	26 ± 15	9	63
Crossbred	1	30	357 ± 86	154	617
	2	24	476 ± 128	287	810
	3	12	467 ± 124	244	631
	4	5	528 ± 229	337	865
Three-	1	9	402 ± 149	214	613
quarter	2	5	455 ± 114	314	578
Saanen	3	5	527 ± 123	378	707

Table L12: Fat-Protein-Lactose Corrected Milk Yields of Goats (kg):
All Breeds: All Lactations.

Breed and Lactation		No.	Mean ± SE	Min.	Max.
Saanen	1	56	541 ± 117	301	823
	2	48	785 ± 156	454	1254
	3	28	704 ± 169	482	1162
	4	15	701 ± 197	421	1030
	5	6	466 ± 103	290	584
Indigenous	1	19	40 ± 18	17	87
Crossbred	1	30	410 ± 106	220	778
	2	24	549 ± 143	339	956
	3	12	535 ± 134	294	714
	4	5	605 ± 238	408	935
Three-	1	9	444 ± 152	255	689
quarter	2	5	491 ± 108	367	589
Saanen	3	5	581 ± 153	395	789

2.4 CORRELATIONS: LACTATION DATA

2.4.1 CORRELATIONS: Lactation Yields and Milk Composition

Tables C1.1 to C1.19 (See Appendix B) summarize the results of analyses carried out to assess the correlations between milk production per lactation and milk composition analysis for each breed and lactation number.

All Goats; All Breeds (Tables C1.1, C1.2)

Fat percent, protein percent and lactose percent were all highly significantly ($P<0.0001$) negatively related to milk yield, when all goats and breeds were included in the analyses. Fat percent was also significantly ($P<0.0001$) related to protein percent; and lactose percent was significantly ($P<0.0001$) related to protein percent, but less so ($P<0.05$) to fat percent. However, more detailed analyses within breeds showed that not all these broad relationships held true for all the analyses. For example, lactose percent was not significantly related to fat percent, when *only the first three lactations* of all goats were considered (Table C1.2). ***Saanen Goats*** (Tables C1.3 to C1.8)

Protein percent was significantly ($P<0.0001$) related to fat percent for first and second lactations of Saanens, was less significantly related in third and fourth lactations ($P<0.01$ and $P<0.05$ respectively), but not significantly for the small group of fifth lactations (six goats; Table C1.7). Milk fat percent was significantly ($P<0.0001$) negatively related to milk yield per lactation for the first lactations, was less significantly negatively related($P<0.05$) for second and third lactations, but was not significantly related for fourth and fifth lactations. However, when the first three lactations were considered together, there was a significantly ($P<0.01$) negative relation between milkfat percent and lactation yield (Table C1.8). Protein percent was only significantly negatively related to milk yield per lactation for third and fourth lactations ($P<0.01$ and $P<0.05$ respectively) (Tables C1.5 and C1.6), but was clearly so ($P<0.01$) when the first three lactations were considered (Table C1.8).

Indigenous Goats (Tables C1.9 and C1.10)

The results of this group must be interpreted carefully, because of the short lactations and therefore the relatively small number of analyses carried out. Lactations were closely monitored in the first year, but in subsequent years they were sampled for yield and compositional quality at intervals. In addition, many of these further samplings gave distorted results for milkfat analyses, because the samples were frozen before analysis. The milkfat analyses were therefore

excluded; but the protein and lactose percentages did not appear to be affected, and were included in the analyses.

Milkfat and protein percent were significantly ($P<0.05$) negatively related to milk yield per lactation, but lactose percent was positively related ($P<0.01$). Lactose percent was negatively related to fat and protein percent ($P<0.05$ and $P<0.001$ respectively). Fat and protein percent were significantly positively related to each other ($P<0.01$).

Crossbred Goats (Tables C1.11 to C1.15)

In contrast, Crossbred goats in first and second lactations had no significant correlations between the criteria considered, except for the positive correlation ($P<0.01$) between fat and protein percent in first lactations (Table C1.11). However, significant ($P<0.05$) negative correlations were observed in third and fourth lactations (Tables C1.13 and C1.14) between fat percent and milk production per lactation. The only significant ($P<0.0001$) correlation observed when the first three lactations were considered (Table C1.15) was between fat percent and protein percent. I have no explanation for the lower number of correlations between these criteria for Crossbred goats in comparison to those for Saanen goats.

Three-quarter Saanens (Tables C1.16 to C1.17)

Goat numbers were small for all three lactations. The only significant ($P<0.05$) negative correlation observed was between fat percent and milk production per lactation for first lactation goats; and a positive correlation ($P<0.01$) between fat percent and protein percent for the same group. This latter relationship ($P<0.01$) was also observed when data were analysed for all Three-quarter Saanens together (Table C1.19).

Summary

Most lactations showed a significant correlation (at least $P<0.05$) between fat percent and protein percent. A significantly (at least $P<0.05$) negative correlation between fat percent (and sometimes also between protein percent), and milk production per lactation was observed for Saanen goats and Indigenous goats; but not for Crossbreds and Three-quarter Saanens. There were no significant correlations between lactose percent and milk production per lactation, except for a positive ($P<0.01$) correlation for the Indigenous goats.

TABLES: CORRELATIONS: Lactation Yield and Milk Composition

(SEE APPENDIX B)

2.4.2 CORRELATIONS:

Composition Corrected Yield: Lactation Yield and Milk Composition

Tables C2.1 to C2.18 summarize the results of analyses carried out to assess the correlations between composition corrected milk and milk production per lactation and milk composition analysis for each breed and lactation number.

All Goats; All Breeds (Tables C2.1 and C2.2)

When all lactations, and the fat, protein and lactose percentages were grouped, then all measures of composition corrected milk were significantly ($P<0.001$) related to them, except for the relation between lactose percent and Fat Corrected Milk. The correlations were positive with milk production per lactation, and negative with fat, protein and lactose percent. The highest correlation (99%), was between milk yield per lactation and Lactose Corrected Milk (LCM), presumably because lactose was the component that varied the least. Fat Corrected Milk (FCM) had the lowest correlation with milk yield per lactation (84%), since fat percent was more variable than protein or lactose percent. The correlations with Protein Corrected Milk (PCM) were intermediate. Lactose percent had a negative correlation with composition-corrected milk, but it was not significant for FCM. However, more detailed analyses within breeds showed that not all these broad relationships held true for all the analyses.

Saanen Goats (Tables C2.3 to C2.8)

Milk Yield per lactation was significantly ($P<0.001$) positively related to all categories of composition corrected milk, except for the small sample of goats in fifth lactation (Table C2.7). Fat percent was significantly ($P<0.05$) correlated with FCM in the first and second lactation (Tables C2.3 and C2.4), but not in subsequent lactations. It was negatively correlated ($P<0.05$) with LCM in first lactations. Protein percent was significantly ($P<0.05$) positively correlated with FCM and PCM but only in first lactations (Table C2.3). It was negatively correlated ($P<0.05$) with LCM in third and fourth lactations, and in all three lactations when the data were grouped together (Table C2.8).

Indigenous Goats (Table C2.9)

Milk yield per lactation was significantly ($P<0.001$) positively correlated with all measures of composition corrected milk for Indigenous goats. Correlations ranged from 99% for LCM to 88% for FCM; a similar pattern to that observed for Saanen goats. Fat percent and protein percent were negatively ($P<0.05$) related to LCM. Lactose percent was positively ($P<0.05$) correlated to PCM, LCM and FPLCM.

Crossbred Goats (Tables C2.10 to C2.14)

Milk yield per lactation was significantly (P<0.0001) correlated with all categories of composition corrected milk in a similar way to the correlations for Saanen goats, but with a higher range of correlations (89% to 99%). Fat percent was significantly (P<0.01) correlated (*positively)*, with FCM, but only for first lactations (Table C2.10), although the same trend was apparent when the first three lactations were considered as a group. It was negatively (P<0.05) correlated to LCM, but only in the third and fourth lactations (Tables C2.12 and C2.13); and to PCM (P<0.05), but only for fourth lactations (Table C2.13). Protein percent and lactose percent were not significantly correlated with any of the composition corrected milk parameters.

Three-quarter Saanens (Tables C2.15 to C2.18)

Goat numbers were small for all three lactations, which may have affected the reliablilty of the estimates as representing Three-quarter Saanens in general. Milk yield per lactation was significantly (P<0.05) correlated with all composition corrected milk parameters, except for FCM in second lactations. The only significant (P<0.05) negative correlation observed was between fat percent and LCM, but only for first lactations (Table C2.15). Protein percent and lactose percent were not significantly correlated with any of the composition corrected milk parameters.

Summary

Milk yield per lactation was significantly (P<0.05) positively correlated with all measures of composition corrected milk for all but a few of the comparisons (which had a small number of goats in the group). Fat percent was significantly (P<0.05) correlated with FCM for some, but not all of the analyses. Fat percent was also correlated (negatively) (P<0.05) with LCM for some of the analyses. Protein percent was significantly (P<0.05)positively correlated with FCM and PCM but only in first lactations, and only for Saanen goats. It was negatively (P<0.05) correlated with LCM in third and fourth lactations, and in all three lactations when the data were grouped together, but again, only for Saanens.

TABLES: CORRELATIONS (C2):(SEE APPENDIX B)

2.4.3 CORRELATIONS: Composition Corrected Yield: Breed and Lactation Number

Tables C3.1 to C3.18 (see Appendix B) summarize the results of analyses carried out to assess the correlations between the different criteria of composition corrected milk; for the goat breeds and lactation numbers.

The correlations between different criteria of composition corrected milk (i.e. FCM; PCM; LCM; and FPLCM) were all significantly ($P<0.05$) correlated. The only exception was the small group of Saanen goats (five goats) in their fifth lactation.

The correlations varied from a low of 71.8% between LCM and FCM for Saanen goats in their first lactations (Table C3.3); to a high of 99.9% between PCM and LCM for Crossbred goats in their fourth lactations (five goats) (Table C3.13). Most correlations were over 90%. This would seem to imply that there were not many differences between the composition corrected milk criteria. However, there were some differences that were apparent from other analyses carried out. (See later: Multiple Regression Analyses).

TABLES: CORRELATIONS (C3)

(SEE APPENDIX B)

2.5 RESULTS: ANALYSIS OF LACTATION DATA:

2.5.1. Multiple Regression Analyses

INTRODUCTION

The SAS General Linear Models Procedure (SAS Institute 1989) was used to carry out Multiple Regression Analysis, and Analysis of Variance and Covariance. Analyses were carried out for the different sets of data:

* Total milk production per 300-day lactation
* Fat percent
* Protein percent
* Lactose percent
* Fat Corrected Milk (FCM)
* Protein Corrected Milk (PCM)
* Lactose Corrected Milk (LCM)
* Fat-Protein-Lactose Corrected Milk (FPLCM)

Within each item, analyses were done comparing selected criteria between breeds.
In general, comparisons were only made between first lactations; or between the data from Lactations 1,2 and 3.

First lactations were compared for two reasons:

* Indigenous goats had effective milk records only for the first lactation;
* First lactations are usually the primary standard of comparison between cows, such as for progeny testing, because other potentially complicating factors such as fertility management are avoided. Nevertheless, second and third lactations were also used in comparisons, to assess longer-term effects than those shown for first lactations only. The number of goats with records of the first three lactations was adequate for the tests, whereas records of fourth and fifth lactations were relatively few.

Multiple Regression Analysis is a technique where a mathematical model is derived to fit the data of the particular comparison. The Least-Square Means (LSM) calculated are specific to that particular comparison. (LSM tables have been included for some of the comparisons.) The model is then used to perform an Analysis of Variance and Covariance. A summary of the

salient facts relating to the Analysis of Variance is included in the Table for each test. Details of the significance of interactions have also been tabulated for some of the comparisons.

The Analysis of Variance was done in two forms: Type I SS and Type III SS (Sum of Squares). The effects of Breed were significant ($P<0.05$) in nearly all cases of Type I SS tests. Type I SS analysis was the appropriate method for this test. The Type III SS tests were found to be unreliable when compared to the Type I tests, and often gave contradictory results.

Terminology

One aspect of the terminology used in the Tables requires clarification:

* "**Days**" refers to the number of days in a lactation, within the limitation of a 300-day lactation.

* "**Lactation Length**" refers to the actual lactation length, which may or may not be more than 300 days.

THE ANALYSES

The analyses carried out are listed in the Contents page for the Tables of this section, and are summarized in Tables A1.1 to A8.4.
Comments on the results follow according to the sub-headings listed above.

TOTAL MILK PRODUCTION (Tables A1.1 to A1.5)
These tests refer to total milk production per standard lactation.
Indigenous Goats: Lactation 1 (Table A1.1)
The only factor shown to affect total milk production per lactation for Indigenous goats in Lactation 1 was lactation length. The longer the lactation, the more milk was produced! (This was identical to Days of lactation for Indigenous goats, since all Indigenous goat lactations were short, and considerably less than 300 days).

Saanen and Indigenous Goats: Lactation 1 (Table A1.2)
The main factor was breed differences, but after that, Days of lactation was significant ($P<0.0001$), and there was a significant ($P<0.01$) interaction with breed. In other words, total milk production was dependant mostly upon breed, and length of the lactation; but Indigenous goats had much shorter lactations than Saanens.

Saanen and Crossbred Goats: Lactation 1 (Table A1.3)
The main factor was breed differences, but after that, Days of lactation was significant ($P<0.0001$), and there was a significant ($P<0.01$) interaction with breed. In other words, total milk production was dependant mostly upon breed, and length of the lactation; but Crossbred goats had shorter lactations than Saanens.

Saanen and Crossbred Goats: Lactations 1,2,3.
(Tables A1.4.1, A1.4.2)
Table A1.4.1 shows the Analysis of Variance. Table A1.4.2 shows the Least Square Means for the model used in analysis, and the significance of interactions. Note that the 5% level of significance for Table 1.4.2 (as shown beneath the Table) is different from the usual levels of probability because of the nature of the tests carried out.
Table A1.4.1 indicates that, in addition to breed effects, total milk production per lactation was significantly affected by lactation number, (with the highest yield in Lactation 2, as shown in

Table 1.4.2). There was a significant interaction between breed and lactation number. These relations are shown in detail in Table A1.4.2. Saanen first lactations were significantly less than second ($P<0.01$) and third ($P<0.05$) lactations. Saanen second lactations were not significantly different from third lactations (Table 1.4.2).

The only other interactions found ***not*** to be significant were between Saanen first lactation and second and third Crossbred lactations; and between Crossbred third lactations and Crossbred first and second lactations. This is probably due to the relatively low number of Crossbred third lactations included in this analysis.

Considering the results shown in Table A1.4.1, total milk production per lactation was dependant upon Days of lactation (i.e. within the standard 300 days length), but not upon actual lactation length (including production beyond the standard of 300 days). This is an anomaly that is difficult to explain. However, for each of these factors, there was a significant ($P<0.01$) interaction with breed. The number of kids was not significantly related to total milk production per lactation.

Saanen, Crossbred and Three-quarter Saanens: Lactation 1,2,3

(Tables A1.5.1 and A1.5.2)

The analyses shown in these Tables are similar to those of Tables A1.4.1 and A1.4.2 discussed above for Saanen and Crossbred goats. Table A1.5.1 shows the Analysis of Variance. In addition to the breed differences shown, total milk production per lactation was significantly related to lactation number, to lactation length and the number of kids born. It is not clear why the association between number of kids and total milk production should be significant ($P<0.001$) in this test, whereas it was not significant for the test reported in Table A1.4.1. The only suggestion could be that first lactations (lower yields) were associated with a lower rate of twinning when compared to subsequent lactations.

Table A1.5.2 shows the Least Square Means for the sample of data fitted to the mathematical model, and interactions between breed and lactation number. The significant ($P<0.05$) interactions between lactations of Saanen and Crossbred goats was the same as reported in Table A1.4.1 (but the size of the Table has meant that the level of significance was not measured as precisely). Apart from these interactions between Saanen and Crossbred goats, these results show that, although first lactations of pure Saanens were not significantly different from Three-quarter Saanen first, second or third lactations; second and third lactations of Saanens were significantly different ($P<0.05$) from all of them. No Crossbred lactations were found to be significantly ($P<0.05$) different from those of any of the groups of Three-quarter Saanens.

FAT PERCENT

These tests refer to the weighted mean fat percentage per lactation.

Indigenous Goats: Lactation 1 (Table A2.1)

Fat percent was found not to be significantly related to the factors considered (of which four are shown).

Saanen and Indigenous Goats: Lactation 1 (Table A2.2)

The difference in fat percent between Saanens and Indigenous goats in first lactation was highly significant ($P<0.001$).

Saanen and Crossbred Goats: Lactations 1,2,3. (Table A2.3)

Fat percent was significantly different ($P<0.001$) between Saanen and Crossbred goats. It is difficult to see how fat percent was related to lactation length itself, except that Crossbreds had shorter lactations than Saanens. The non-significance of the interaction between Days of lactation (within 300 days) is in contrast to the significance ($P<0.01$) when the actual length of lactations (i.e. beyond 300 days) was considered.

All Goats: Lactations 1,2,3. (Tables A2.4.1, A2.4.2 and A.2.4.3)

These Tables show the significant breed differences in fat percent. The Analysis of Variance result is shown in Table A2.4.1 and the Least Square Means are listed in Table A2.4.2 with the interactions between breeds. These indicate that all breeds were found to be significantly different ($P<0.01$); except that the fat percent of Crossbred goats was found ***not*** to be significantly different from that of Three-quarter Saanens. The significance ($P<0.01$) of lactation number shown in Table A2.4.1 is not a fair indication as a general statement, because of the varying numbers of lactations in each category for each breed. A further test (Table A2.4.3) showed no significant effect of lactation number when all lactations were considered.

PROTEIN PERCENT

These tests refer to the weighted mean protein percentage per lactation. Least Square Means for the model used in analysis are shown in Table A3.5.2.

Indigenous Goats: Lactation 1 (Table A3.1)

Protein percent was significantly ($P<0.05$) related to lactation length. It is difficult to explain this finding. The finding that there was a significant relation between protein percent and days to peak daily yield is also of dubious value. The sample of Indigenous goats was relatively small, the lactations were short, and the variation from day to day was small. In fact it was probably not valid to assign a particular day as representing the peak of lactation, because of the variable nature of the lactation curves for Indigenous goats in comparison to that shown by the milk goats: daily milk yield did not change much during the lactation. In addition, the opportunity for obtaining milk samples (at the usual interval of once a month) was limited because the lactations were short.

Saanen and Indigenous Goats: Lactation 1 (Table A3.2)

Breed differences in protein percent were found to be highly significant ($P<0.001$), as was expected. The significance with days to peak of lactation is again hard to explain, but the reasons discussed above are presumed to apply here as well.

Saanen and Crossbred Goats: Lactation 1 (Table A3.3)

Breed was the only factor found to influence protein percent ($P<0.001$) in this comparison.

Saanen and Crossbred Goats: Lactations 1,2,3. (Table A3.4)

This analysis also showed the significance ($P<0.001$) of breed differences in protein percent.

All Goats: Lactations 1,2,3. (Tables A3.5.1 and A3.5.2)

Again, breed difference was the main factor identified as being significant ($P<0.001$). The marginal level of significance ($P<0.05$) shown for days to peak yield should be interpreted as for the test reported in Table A3.1. The interaction analysis in Table A3.5.2 shows that the differences were significant ($P<0.01$) between all breeds.

LACTOSE PERCENT

These tests refer to the weighted mean lactose percentage per lactation.

Indigenous Goats: Lactation 1 (Table A4.1)

Lactose percent was significantly (P<0.01) related to length of lactation. As with protein percent, it is difficult to explain this finding. The same reasons as those proposed above apply in this case as well.

Saanen and Indigenous Goats: Lactation 1

(Tables A4.2.1 and A4.2.2)

Breed differences were not shown to be significant according to the Type I SS analysis. This was even though Saanen lactations were much longer than those of Indigenous goats, and a significant (P<0.01) relation was found between lactose percent and lactation length for Indigenous goats. There was also a significant (P<0.05) breed x lactation length interaction. It is difficult to explain such findings. Perhaps an error was made. Table A4.2.2 shows the Least Square Means for the model used in this comparison.

Saanen and Crossbred Goats: Lactation 1

(Tables A4.3.1 and A4.3.2)

These analyses show the significant (P<0.001) breed differences in lactose percent between Saanen and Crossbred goats for the first lactation.

Saanen and Crossbred Goats: Lactations 1,2,3.

(Tables A 4.4.1 and A4.4.2)

Breed differences were highly significant (P<0.001) in this comparison. The analysis of the interactions in Table A4.3.2 shows *no* significant differences between lactose percent of Saanen lactations 1, 2 or 3. However they were significantly (P<0.01) different with those of all Crossbred lactations. Similarly, the differences between Crossbred lactations were not significant.

Saanen, Crossbred and Three-quarter Saanens: Lactations 1,2,3.

(Tables A4.5.1 and A4.5.2)

Breed differences were the main factors found to be significant (P<0.001) in affecting lactose percent in this larger group of lactations. No significant interaction was shown between Days of lactation (within 300 days) and Breed; but there was a significant (P<0.05) interaction between breed and days dry. Lactose percent of Saanen goats was significantly (P<0.001) different from that of Crossbreds and Three-quarter Saanens. However, no significant difference was apparent between Crossbreds and Three-quarter Saanens (Table A4.5.2).

FAT CORRECTED MILK (FCM)

FCM refers to 4% Fat Corrected Milk per lactation.

Indigenous Goats: Lactation 1 (Table A5.1)

FCM was significantly (P<0.01) related to lactation length. As with total milk production, the longer the lactation, the more FCM was produced. These lactations were short in comparison to those of all other breeds of goats studied.

Saanen and Indigenous Goats: Lactation 1 (Tables A5.2.1 and A5.2.2)

In this comparison, FCM was significantly (P<0.001) related to breed and lactation length.

The Least Square Means for the model used in this analysis are shown in Table A5.2.2.

Saanen and Crossbred Goats: Lactations 1,2,3. (Tables A5.3.1 and A5.3.2)

FCM was significantly different according to breed (P<0.01), lactation number (P<0.001), number of kids born (P<0.05), and lactation length (P<0.01). In addition, there was a significant (P<0.05) interaction between breed and lactation length. The Least Square Means for the model used in this analysis are shown in Table A5.3.2.

Saanen, Crossbred and Three-quarter Saanens: Lactations 1,2,3.

(Tables A5.4.1 and A5.4.2)

This test was similar to that shown in Table A5.3.1, but with the addition of Three-quarter Saanens. FCM was significantly affected by breed (P<0.05), lactation number (P<0.001) and lactation length (P<0.01). There was a significant (P<0.001) interaction between breed and lactation length. The Least Square Means for the model used in this analysis are shown in Table A5.4.2.

PROTEIN CORRECTED MILK (PCM)

PCM refers to 3% Protein Corrected Milk per lactation.

Indigenous Goats: Lactation 1(Table A6.1)

PCM was significantly (P<0.001) related to lactation length.

Saanen and Indigenous Goats: Lactation 1 (Tables A6.2.1 and A6.2.2)

In this comparison, PCM was significantly (P<0.001) affected by breed, and related (P<0.001) to Days of lactation (within 300 days), but not to lactation length. However, there was a significant (P<0.01) interaction between breed and lactation length. Least Square Means for the model used in this analysis are shown in Table A6.2.2.

Saanen and Crossbred Goats: Lactation 1 (Tables A6.3.1 and A6.3.2)

In this analysis, PCM was shown to be significantly (P<0.001) affected by breed. The other factor having a significant effect was Days of lactation (within the 300 day standard lactation length); but actual lactation length was not significant.

Saanen and Crossbred Goats: Lactation 1,2,3

(Tables A6.4.1, A6.4.2 and A6.4.3)

The results reported in Table A6.4.1 showed significant (P<0.001) differences of PCM according to breed, lactation number and lactation length. There was a significant (P<0.001) interaction of breed and lactation length, related to the fact that Crossbreds had shorter lactations than Saanens. When the lactations were considered across all parities (lactation number), the Saanens were not shown to be significantly different from the Crossbreds. (This is an apparent contradiction of the result in Table A6.4.1, but may have arisen because of the unequal numbers of goats in in the first, second or third lactation groups for each breed. The interactions of lactation number are shown in Table A6.4.3 (without taking breed into account). First lactations were significantly (P<0.05) different from second and third lactations; but second lactations were not significantly different from third lactations.

Saanen, Crossbred and Three-quarter Saanens: Lactations 1,2,3.

(Tables A6.5.1 and A6.5.2)

The Analysis of Variance in Table A6.5.1 shows that breed, lactation number, days in milk and lactation length were all significantly (P<0.001) related to PCM. There were significant (P<0.001) interactions between breed and lactation number, breed and lactation length, but not breed and days of lactation (within 300 days). The interactions between breed and lactation number are shown in Table A6.5.2, with the Least Square Means calculated for the model used in the analysis. This Table should be compared to Table A1.5.2, the comparison for total milk production per lactation (uncorrected). The correction to PCM had a number of effects in the significant relations identified.

Saanen first lactations were significantly (P<0.05) different from second and third lactations. Saanen second lactations were not significantly different from Saanen third lactations. (These results were no different from the tests in Table A1.5.2). In contrast, whereas Saanen first lactations were significantly different from Crossbred first lactations in Table A1.5.2, this was not the case in this comparison; instead the difference here was with Crossbred second lactations. Similarly, in this Table comparing PCM, Saanen second lactations were significantly (P<0.05) different from Crossbred first lactations, and from all Three-quarter Saanen lactations, but not from Crossbred second and third lactations. Saanen third lactations were shown to be significantly different from Crossbred and Three-quarter Saanen first lactations, but not from the second or third lactations of these other breeds. (This was a change from the data shown in Table A1.5.2). Crossbred first lactations were significantly different (P<0.05) from Crossbred second lactations, but not from Crossbred third lactations.

LACTOSE CORRECTED MILK (LCM)

LCM refers to 4.5% Lactose Corrected Milk per lactation.

Indigenous Goats: Lactation 1 (Table A7.1)

LCM was significantly (P<0.001) related to lactation length. LCM increased significantly (P<0.001) as the length of lactation increased.

Saanen and Indigenous Goats: Lactation 1 (Table A7.2)

LCM was shown to be significantly (P<0.001) affected by breed and Days in milk (within the standard 300 day lactation), and there was a significant (P<0.01) interaction between Days and breed.

Saanen and Crossbred Goats: Lactations 1,2,3 (Table A7.3)

This analysis showed a significant (P<0.001) effect of breed, lactation number and Days of lactation, with significant (P<0.001) breed interactions for these factors.

Saanen, Crossbred and Three-quarter Saanens: Lactations 1,2,3.

(Tables A7.4.1 and A7.4.2)

Significant (P<0.001) effects were identified for all the parameters included (Table A7.4.1). This analysis should be compared to that for total milk production per lactation (uncorrected) (Table A1.5.2). The only *difference* in the factors found to be significant were in the relation between Saanen third lactations and Crossbred second and third lactations. For these factors, the relationship was significantly different (P<0.05; Table A1.5.2) in the case of uncorrected lactation yield, whereas the differences were not significantly different for LCM. In addition, no significant difference was found between first and third lactation LCM yields for Saanens. The fact that there were very few differences as shown in these two Tables, is probably because lactose did not vary as much as the other milk composition components analysed.

FAT-PROTEIN-LACTOSE CORRECTED MILK (FPLCM)

FPLCM refers to milk production per lactation corrected to 4% for fat, 3% for protein and 4.5% for lactose.

Indigenous Goats: Lactation 1(Table A8.1)

FPLCM was significantly (P<0.001) related to lactation length. As with the other measures of milk production per lactation, the longer the lactation, the more milk produced.

Saanen and Indigenous Goats: Lactation 1 (Table A8.2)

FPLCM was shown to be significantly (P<0.001) affected by breed, and Days in milk (within the standard 300 day lactation), and there was a significant (P<0.01) interaction between lactation length and breed. Indigenous goats had much shorter lactations than Saanens. Why the test should show the relation of FPLCM to lactation length (actual) to be non-significant is inexplicable, since the lactations of all Indigenous goats were short and therefore identical with Days of lactation (shown to be significantly (P<0.001) different between the breeds). Perhaps there was an error in the analysis.

Saanen and Crossbred Goats: Lactations 1,2,3 (Table A8.3)

This analysis showed a significant (P<0.001) effect of breed, lactation number and Days of lactation, with no significant breed interaction identified.

Saanen, Crossbred and Three-quarter Saanens: Lactations 1,2,3.

(Tables A8.4.1 and A8.4.2)

Significant ($P<0.001$) effects were identified for breed, lactation number, Days of lactation, and Number of kids ($P<0.01$). The interaction between breed and lactation number was significant ($P<0.01$), as was the interaction between breed and lactation length ($P<0.001$). The anomaly of a non-significant effect of lactation length, whereas the effect of Days of lactation was significant ($P<0.001$) was apparent in this test also. (See comments above concerning Table 8.1). This analysis should be compared to that for total milk production per lactation (uncorrected) (Table A1.5.2).

The process of correcting milk yield for all three factors (to FPLCM) changed the significance of relationships for many parameters. Saanen first lactations were significantly different from Saanen second ($P<0.01$) and third ($P<0.05$) lactations (as before), but were not found to be significantly different from any of the Crossbred or Three-quarter Saanen lactations. Saanen second lactations were only significantly ($P<0.01$) different from Crossbred first lactations, and from Three-quarter Saanen first and second lactations. Saanen third lactations were only significantly ($P<0.01$) different from Crossbred first lactations. Crossbred first lactations were only significantly ($P<0.01$) different from Crossbred second lactations. It must be borne in mind that there were relatively few third Crossbred lactations, and relatively few Three-quarter Saanen lactations compared to the other categories, and this could have had an effect on the results of the analyses.

2.5.2 Tables of Multiple Regression Analyses

CONTENTS

Tables of Multiple Regression Analyses

A1. TOTAL MILK PRODUCTION

Table A1.1: Total Milk Production: Indigenous Goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lact. Length	1	82.1776	82.1776	257.11	0.0001	***

Table A1.2 Total Milk Production: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	1058.1109	1058.1109	1480.64	0.0001	***
Days	1	15.6827	15.6827	21.95	0.0001	***
Days x Breed	1	8.0054	8.0054	11.20	0.0013	**

Table A1.3: Total Milk production: Saanen and Crossbred: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	228.9042	228.9042	210.18	0.0001	***
Days	1	64.3106	64.3106	59.05	0.0001	***
Days x Breed	1	7.6996	7.6996	7.07	0.0085	**

Table A1.4.1: Total Milk Production: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	228.9042	228.9042	340.02	0.0001	***
Lactation No.	2	79.8478	39.9239	59.30	0.0001	***
Breed x Lact. No.	2	10.6443	5.3222	7.91	0.0005	***
Days	1	10.3639	10.3639	15.39	0.0001	***
Days x Breed	1	43.4600	43.4600	64.56	0.0001	***
No. of Kids	1	2.5961	2.5961	3.86	0.0511	NS
Lact. Length	1	0.1782	0.1782	0.26	0.6075	NS
Lact. Length x Breed	1	6.5715	6.5715	9.76	0.0021	**

Table A1.4.2: Total Milk Production: Saanen and Crossbred: Lactations 1,2,3
Interaction between breed and lactation number:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	559.7	-7.852 0.0001 **	-3.221 0.0015 *	6.216 0.0001 **	2.111 0.0362 NS	2.159 0.0322 NS
	2	779.0	-	2.024 0.0445 NS	11.901 0.0001 **	8.169 0.0001 **	7.404 0.0001 **
	3	691.7	-	-	6.677 0.0001 **	4.313 0.0001 **	4.240 0.0001 **
Cross-bred	1	406.8	-	-	-	-3.419 0.0008 *	-2.126 0.0349 NS
	2	496.9	-	-	-	-	0.427 0.6697 NS
	3	481.1	-	-	-	-	-

[Note: 5% level of significance is at P <0.05 ÷ (5x6) = 0.0017]

Table A1.5.1: Total Milk Production: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	238.7049	119.3525	183.67	0.0001	***
Lactation No.	2	85.6438	42.8219	65.90	0.0001	***
Breed x Lact. No.	4	12.6557	3.1639	4.87	0.0009	***
No. of Kids	1	10.4789	10.4789	16.13	0.0001	***
Days	1	55.0484	55.0484	84.71	0.0001	***
Days x Breed	2	2.7943	1.3971	2.15	0.1192	NS
Lact. Length	1	0.2722	0.2722	0.42	0.5183	NS
Breed x Lact. Length	2	6.6902	3.3451	5.15	0.0066	**

Table A1.5.2: Total Milk Production: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
Interaction between breed and lactation number:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred			Three-quarter Saanen		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	551.6	-8.050 0.0001 *	-3.308 0.0005 *	5.941 0.0001 *	1.870 0.0629 NS	1.967 0.0507 NS	2.936 0.0037 NS	2.308 0.0220 NS	1.763 0.0795 NS
	2	772.1	-	2.062 0.0405 NS	11.761 0.0001 *	8.006 0.0001 *	7.282 0.0001 *	7.018 0.0001 *	6.691 0.0001 *	5.836 0.0001 *
	3	684.7	-	-	6.637 0.0001 *	4.224 0.0001 *	4.160 0.0001 *	4.627 0.0001 *	4.228 0.0001 *	3.674 0.0003 *
Cross-bred	1	404.8	-	-	-	-3.523 0.0005 *	-2.202 0.0289 NS	-0.234 0.8153 NS	-0.896 0.3715 NS	-1.211 0.2273 NS
	2	496.0	-	-	-	-	0.429 0.6684 NS	1.576 0.1167 NS	1.026 0.3060 NS	0.584 0.5597 NS
	3	480.3	-	-	-	-	-	1.172 0.2426 NS	0.648 0.5176 NS	0.266 0.7904 NS
Three-quarter Saanen	1	416.0	-	-	-	-	-	-	-0.501 0.6168 NS	-0.784 0.4341 NS
	2	446.4	-	-	-	-	-	-	-	-0.292 0.7705 NS
	3	465.3	-	-	-	-	-	-	-	-

[Note: 5% significance level is at P <0.05 ÷ (9x8) = 0.0006]

A2. FAT PERCENT

Table A2.1: Fat percent: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Days	1	3.8305	3.8305	4.49	0.0525	NS
Days to Peak Yield	1	0.3677	0.3677	0.43	0.5222	NS
Lact. Length	1	0.7137	0.7137	0.84	0.3759	NS
Age at Kidding	1	1.1411	1.1411	1.34	0.2669	NS

Table A2.2: Fat percent: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	173.1589	173.1589	173.16	0.0001	***

Table A2.3: Fat percent: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	405.1691	405.1691	428.82	0.0001	***
Days	1	0.7488	0.7488	0.79	0.3745	NS
Lact. Length	1	8.3467	8.3467	8.83	0.0034	**

Table A2.4.1: Fat Percent: All Goats: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	3	661.9027	220.6342	222.58	0.0001	***
Lactation No.	2	13.6740	6.8370	6.90	0.0012	**

Table A2.4.2: Fat Percent: All Goats: Lactations 1,2,3
Breed Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	LSM (fat %)	Indigenous	Crossbred	Three-quarter Saanen
Saanen	3.46	-16.0151 0.0001 **	-20.1248 0.0001 **	-10.6505 0.0001 **
Indigenous	9.45	-	10.4667 0.0001 **	10.8353 0.0001 **
Crossbred	5.47	-	-	1.9787 0.0491 NS
Three-quarter Saanen	5.13	-	-	-

[Note: 5% level of significance is at P < 0.05 ÷ (4x3) = 0.004]

Table A2.4.3: Fat Percent: All Goats: Lactations 1,2,3
Interactions of Lactation No.:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	Lact. 2	Lact. 3
Lact. 1	-0.5089 0.6113 NS	-1.1618 0.2466 NS
Lact. 2		-0.7253 0.4690 NS

[Note: 5% level of significance is at P < 0.05 ÷ (3x2) = 0.008]

A3. PROTEIN PERCENT

Table A3.1 Protein Percent: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lact. Length	1	3.7547	3.7547	6.34	0.0228	*
Days to Peak Yield	1	2.9949	2.9949	5.06	0.0390	*

Table A3.2: Protein Percent: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	224.5461	224.5461	282.05	0.0001	***
Lact. Length	1	0.0174	0.0174	0.02	0.8828	NS
Breed x Lact. Length	1	3.9336	3.9336	4.94	0.0295	*
Days to Peak Yield	1	10.0946	10.0946	12.68	0.0007	***
Breed x Days to Peak	1	2.2462	2.2462	2.82	0.0975	NS

Table A3.3: Protein Percent: Saanen and Crossbred: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	427.3342	427.3342	436.73	0.0001	***
Lact. Length	1	0.8924	0.8924	0.91	0.3409	NS
Breed x Lact. Length	1	0.8138	0.8138	0.19	0.6653	NS
Days to Peak Yield	1	2.7545	2.7545	2.81	0.0951	NS
Breed x Days to peak	1	2.5996	2.5966	2.66	0.1049	NS

Table A3.4: Protein Percent: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	427.3342	427.3342	430.64	0.0001	***

Table A3.5.1: Protein Percent: All Goats: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	3	592.1899	197.3966	204.37	0.0001	***
Days to peak Yield	1	3.8385	3.8385	3.97	0.0475	*
Breed x Days to Peak	3	6.2741	2.0914	2.17	0.0931	NS

Table A3.5.2: Protein Percent: All Goats: Lactations 1,2,3
Breed Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	LSM (%)	Indigenous	Crossbred	Three-quarter Saanen
Saanen	2.88	-5.2272 0.0001 **	-21.1506 0.0001 **	-6.1887 0.0001 **
Indigenous	6.90	-	3.9531 0.0001 **	4.5681 0.0001 **
Crossbred	3.85	-	-	5.9383 0.0001 **
Three-quarter Saanen	3.37	-	-	-

[Note: 5% level of significance is at $P < 0.05 \div (4x3) = 0.004$]

A4. LACTOSE PERCENT

Table A4.1: Lactose Percent: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lact. Length	1	1.6619	1.6619	15.05	0.0012	**

Table A4.2.1: Lactose Percent: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	0.4969	0.4969	0.57	0.4519	NS
Days	1	0.1844	0.1844	0.21	0.6464	NS
Breed x Days	1	6.0162	6.0162	6.93	0.0104	*

Table A4.2.2: Lactose Percent: Saanen and Indigenous: Lactation 1: Least-square Means

	Least-square Means (Lactose %)
Saanen	4.52
Indigenous	4.80

Table A4.3.1: Lactose Percent: Saanen and Crossbred: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	100.4007	100.4007	97.46	0.0001	***
Days	1	0.3180	0.3180	0.31	0.5792	NS
Breed x Days	1	0.0001	0.0001	0.00	0.9921	NS

Table A4.3.2: Lactose Percent: Saanen and Crossbred: Lactation 1
Breed Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	Lactose LSMEAN (milkfat %)	TEST
Saanen	4.52	-8.203 0.0001 ***
Crossbred	4.80	-

Table A4.4.1: Lactose Percent: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	100.4007	100.4007	98.38	0.0001	***

Table A4.4.2: Lactose Percent: Saanen and Crossbred: Lactations 1,2,3
Breed and Lactation Number Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	4.54	1.103 0.2715 NS	1.969 0.0506 NS	-4.494 0.0001 **	-4.393 0.0001 **	-4.415 0.0001 **
	2	4.49	-	0.921 0.3585 NS	-5.217 0.0001 **	-4.562 0.0001 **	-4.921 0.0001 **
	3	4.43	-	-	-5.671 0.0001 **	-5.383 0.0001 **	-5.253 0.0001 **
Cross-bred	1	4.82	-	-	-	-0.095 0.9242 NS	0.109 0.9134 NS
	2	4.83	-	-	-	-	0.219 0.8272 NS
	3	4.81	-	-	-	-	-

[Note: 5% level of significance is at P < 0.05 ÷ (5x6) = 0.0017]

Table A4.5.1: Lactose Percent: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	77.1371	38.5685	41.88	0.0001	***
Days x Breed	3	4.3148	1.4383	1.56	2.2037	NS
Dry Days x Breed	3	10.7065	3.5689	3.88	0.0116	*

Table A4.5.2: Lactose Percent: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
Breed Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	LSM	Crossbred	Three-quarter Saanen
Saanen	4.47	-7.1167 0.0001 ***	-6.1723 0.0001 ***
Crossbred	4.78	-	0.2030 0.8396 NS
Three-quarter Saanen	4.77	-	-

[Note: 5% level of significance is at P < 0.05 ÷ (2x3) = 0.008]

A5. FAT CORRECTED MILK (FCM)

Table A5.1: Fat Corrected Milk: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Days in milk	1	57971.4199	57971.4199	314.72	0.0012	**

Table A5.2.1: Fat Corrected Milk: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	714.4844	714.4844	869.15	0.0001	***
Days	1	13.8125	13.8125	16.80	0.0001	***

Table A5.2.2: Fat Corrected Milk: Saanen and Indigenous: Lactation 1: Least Square Means
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

	Least Square Means (FCM)
Saanen	462.4
Indigenous	124.9

Table A5.3.1: Fat Corrected Milk: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	5.9734	5.9734	7.78	0.0059	**
Lactation No.	2	89.6040	44.8020	58.36	0.0001	***
No. of Kids	1	4.0163	4.0163	5.23	0.0234	*
Days	1	34.3268	34.3268	44.72	0.0001	***
Lact. Length	1	5.3485	5.3485	6.97	0.0090	**
Breed x Lact Length	1	3.2936	3.2936	4.29	0.0398	*

Table A5.3.2: Fat Corrected Milk: Saanen and Crossbred: Lactations 1,2,3: Least Square Means
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

	Least Square Means (FCM)
Saanen	588.3
Crossbred	627.8
Lactation 1	515.6
2	685.3
3	623.3

Table A5.4.1: Fat Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	6.6599	3.3299	4.59	0.0113	*
Lactation No.	2	88.5714	44.2857	61.03	0.0001	***
Breed x Days	3	46.7543	15.5848	21.48	0.0001	***
Lact. Length	1	5.2088	5.2088	7.18	0.0080	**
Breed x Lact. Length	2	10.9012	5.4506	7.51	0.0007	***

Table A5.4.2: Fat Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3:
Least Square Means
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

	Least Square Means (FCM)
Saanen	579.8
Crossbred	654.7
Three-quarter Saanen	553.1
Lactation 1	495.0
2	671.8
3	620.8

A6. PROTEIN CORRECTED MILK (PCM)

Table A6.1: Protein Corrected Milk: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lact. Length	1	4458.2768	4456.2768	31.22	0.0001	***

Table A6.2.1: Protein Corrected Milk: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	824.7700	824.7700	1107.46	0.0001	***
Days	1	14.5208	14.5208	19.50	0.0001	***
Lact. Length	1	0.1638	0.1638	0.22	0.6405	NS
Breed x Lact. Length	1	6.1833	6.1833	8.30	0.0053	**

Table A6.2.2: Protein Corrected Milk: Saanen and Indigenous: Lactation 1: Least Square Means
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

	Least Square Means (PCM)
Saanen Indigenous	428.3 92.0

Table A6.3.1: Protein Corrected Milk: Saanen and Crossbred: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	59.1757	59.1757	51.54	0.0001	***
Days	1	52.4052	52.4052	45.64	0.0001	***
Lact.Length	1	8.1056	8.1056	7.06	0.0086	**
Breed x Lact.Length	1	0.4196	0.4196	0.37	0.5463	NS

Table A6.3.2: Protein Corrected Milk: Saanen and Crossbred: Lactation 1
Breed Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

	PCM LSMEAN (kg)	TEST
Saanen	612.9	1.92723 0.0555 NS
Crossbred	558.1	-

Table A6.4.1: Protein Corrected Milk: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	59.1757	59.1757	71.04	0.0001	***
Lactation No.	2	81.7335	40.8668	49.06	0.0001	***
Lact. Length	1	18.4164	18.4164	22.11	0.0001	***
Breed x Lact Length	1	18.0354	18.0354	21.65	0.0001	***

Table A6.4.2: Protein Corrected Milk: Saanen and Crossbred: Lactations 1,2,3
Breed Interactions: [Test: Ho: LSMEAN(i)=LSMEAN(j)]

	LSM (PCM) (kg)	Crossbred
Saanen	668.2	2.1831 0.0303 NS
Crossbred	615.4	-

[Note: 5% level of significance is at P < 0.05 ÷ (1x2) = 0.025]

Table A6.4.3: Protein Corrected Milk: Saanen and Crossbred: Lactations 1,2,3
Lactation Number Interactions: [Test: Ho: LSMEAN(i)=LSMEAN(j)]

	LSM (PCM)(kg)	Lact. 2	Lact. 3
Lact. 1	536.9	-8.732 0.0001 *	-4.070 0.0001 *
Lact. 2	734.8	-	2.570 0.0110 NS
Lact. 3	653.8	-	-

[Note: 5% level of significance is at P < 0.05 ÷ (2x3) = 0.008]

Table A6.5.1: Protein Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	66.0152	33.0076	47.07	0.0001	***
Lactation No.	2	76.2043	38.1022	54.34	0.0001	***
Breed x Lact. No.	4	13.9458	3.4865	4.97	0.0008	***
Days	1	45.9906	45.9906	65.59	0.0001	***
Breed x Days	2	1.2089	0.6044	0.86	0.4240	NS
Lact. Length	1	1.0847	1.0847	1.55	0.2151	NS
Breed x Lact. Length	2	13.8906	6.9453	9.90	0.0001	***

Table A6.5.2: Protein Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
Breed and Lactation Number Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred			Three-quarter Saanen		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	524.0	-8.672 0.0001 *	-4.290 0.0001 *	-0.393 0.6948 NS	-3.865 0.0002 *	-2.643 0.0089 NS	1.049 0.2955 NS	0.027 0.9787 NS	0.592 0.5548 NS
	2	752.8	-	2.413 0.0168 NS	6.740 0.0001 *	2.066 0.0402 NS	2.333 0.0207 NS	5.334 0.0001 *	4.972 0.0001 *	3.803 0.0002 *
	3	666.7	-	-	3.519 0.0005 *	-0.033 0.9739 NS	0.488 0.6264 NS	3.481 0.0006 *	2.878 0.0045 NS	2.499 0.0133 NS
Cross-bred	1	534.8	-	-	-	-3.904 0.0001 *	-2.436 0.0158 NS	1.201 0.2314 NS	0.259 0.7958 NS	0.728 0.4678 NS
	2	668.1	-	-	-	-	0.529 0.5977 NS	3.370 0.0009 NS	2.766 0.0062 *	2.460 0.0148 NS
	3	641.7	-	-	-	-	-	2.691 0.0078 NS	2.052 0.0415 NS	2.005 0.0464 NS
Three-quarter Saanen	1	471.8	-	-	-	-	-	-	-0.830 0.4073 NS	-0.144 0.8856 NS
	2	522.9	-	-	-	-	-	-	-	0.487 0.6268 NS
	3	483.4	-	-	-	-	-	-	-	-

[Note: 5% level of significance is at P < 0.05 ÷ (9x8) = 0.0006]

A7. LACTOSE CORRECTED MILK (LCM)

Table A7.1: Lactose Corrected Milk: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lact. Length	1	2465.6726	2465.6726	28.13	0.0001	***

Table A7.2: Lactose Corrected Milk: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	972.6140	972.6140	1322.87	0.0001	***
Days	1	13.4043	13.4043	18.23	0.0001	***
Lact. Length	1	0.0898	0.0898	0.12	0.7277	NS
Breed x Lact. Length	1	8.0398	8.0398	10.94	0.0015	**

Table A7.3: Lactose Corrected Milk: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	204.2540	204.2540	271.81	0.0001	***
Lactation No.	2	69.0132	34.5066	45.92	0.0001	***
Breed x Lact. No.	2	10.7274	5.3637	7.14	0.0010	***
Days	1	33.5399	33.5399	44.63	0.0001	***
Breed x Days	1	2.1525	2.1525	2.86	0.0923	NS
Lact. Length	1	0.0580	0.0580	0.08	0.7816	NS
Breed x Lact. Length	1	11.4962	11.4962	15.30	0.0001	***

Table A7.4.1: Lactose Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	208.0199	104.0099	150.83	0.0001	***
Lactation No.	2	68.4380	34.2190	49.62	0.0001	***
Breed x Lact. No.	4	14.1524	3.5381	5.13	0.0006	***
Days	1	41.9466	41.9466	60.82	0.0001	***
Breed x Days	2	3.1230	1.5615	2.26	0.1067	NS
No. of Kids	1	9.5432	9.5432	13.84	0.0003	***
Lact. Length	1	0.5921	0.5921	0.86	0.3553	NS
Breed x Lact Length	2	9.8414	4.9207	7.14	0.0010	***

Table A7.4.2: Lactose Corrected Milk: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
Breed and Lactation Number Interactions:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred			Three-quarter Saanen		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	569.5	-7.446 0.0001 *	-2.872 0.0045 NS	5.473 0.0001 *	1.025 0.3065 NS	1.345 0.1801 NS	2.845 0.0049 NS	1.854 0.0652 NS	1.683 0.0941 NS
	2	784.8	-	2.343 0.0202 NS	11.214 0.0001 *	6.774 0.0001 *	6.388 0.0001 *	6.896 0.0001 *	6.006 0.0001 *	5.238 0.0001 *
	3	685.0	-	-	6.007 0.0001 *	3.259 0.0013 NS	3.352 0.0010 NS	4.307 0.0001 *	3.552 0.0005 *	3.227 0.0015 NS
Cross-bred	1	439.5	-	-	-	-3.592 0.0004 *	-2.245 0.0259 NS	-0.040 0.9680 NS	-0.893 0.3727 NS	-0.649 0.5171 NS
	2	536.9	-	-	-	-	0.458 0.6476 NS	1.883 0.0612 NS	1.075 0.2836 NS	1.023 0.3077 NS
	3	518.7	-	-	-	-	-	1.411 0.1598 NS	0.671 0.5028 NS	0.680 0.4975 NS
Three-quarter Saanen	1	441.3	-	-	-	-	-	-	-0.664 0.5076 NS	-0.517 0.6060 NS
	2	481.9	-	-	-	-	-	-	-	0.084 0.9329 NS
	3	475.9	-	-	-	-	-	-	-	-

[Note: 5% level of significance is at P <0.05 ÷ (9x8) = 0.0006]

A8. FAT-PROTEIN-LACTOSE CORRECTED MILK (FPLCM)

Table A8.1: FPLCM: Indigenous goats: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Lactation Length	1	34199.9358	34199.9358	317.96	0.0001	***

Table A8.2: FPLCM: Saanen and Indigenous: Lactation 1
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	963.0428	963.0428	1312.00	0.0001	***
Days	1	14.9418	14.9418	20.36	0.0001	***
Lact. Length	1	0.0348	0.0348	0.05	0.8282	NS
Breed x Lact. Length	1	6.6415	6.6415	9.05	0.0037	**

Table A8.3: FPLCM: Saanen and Crossbred: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	1	72.0733	72.0733	90.17	0.0001	***
Lactation No.	2	88.6339	44.3169	55.44	0.0001	***
Days	1	40.1048	40.1048	50.17	0.0001	***
Lact. Length	1	1.6536	1.6536	2.07	0.1521	NS
Breed x Lact. Length	1	2.2527	2.2527	2.82	0.0950	NS

Table A8.4.1: FPLCM: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
(SAS General Linear Models Procedure: Multiple Regression Analysis: Analysis of Variance and Covariance)

Source of Variation	DF	Type I SS	Mean Square	F Value	P > F	Signif.
Breed	2	76.5089	38.2544	56.45	0.0001	***
Lactation No.	2	86.2294	43.1147	63.63	0.0001	***
Breed x Lact. No.	4	12.4965	3.1241	4.61	0.0014	**
Days	1	46.5895	46.5895	68.75	0.0001	***
Breed x Days	2	1.5092	0.7546	1.11	0.3305	NS
No. of Kids	1	6.6012	6.6012	9.74	0.0021	**
Lact. Length	1	1.9342	1.9342	2.85	0.0928	NS
Breed x Lact. Length	2	10.6510	5.3255	7.86	0.0005	***

Table A8.4.2: FPLCM: Saanen, Crossbred, Three-quarter Saanen: Lactations 1,2,3
Breed and Lactation Number Interactons:[Test: Ho: LSMEAN(i)=LSMEAN(j)]

			Saanen		Crossbred			Three-quarter Saanen		
Breed	Lact	LSM	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3	Lact 1	Lact 2	Lact 3
Saanen	1	529.7	-8.181 0.0001 **	-3.524 0.0005 *	0.818 0.4143 NS	-2.867 0.0046 NS	-1.847 0.0663 NS	1.143 0.2543 NS	0.125 0.9007 NS	0.241 0.8098 NS
	2	733.9	-	2.411 0.0169 NS	7.455 0.0001 **	2.940 0.0037 NS	3.086 0.0023 NS	5.280 0.0001 **	4.489 0.0001 **	3.214 0.0015 NS
	3	648.5	-	-	3.756 0.0002 **	0.524 0.6012 NS	0.947 0.3451 NS	3.208 0.0016 NS	2.411 0.0168 NS	1.876 0.0623 NS
Cross-bred	1	508.9	-	-	-	-3.837 0.0002 **	-2.422 0.0164 NS	0.637 0.5246 NS	-0.324 0.7461 NS	-0.069 0.9448 NS
	2	626.2	-	-	-	-	0.522 0.6023 NS	2.793 0.0058 NS	1.996 0.0474 NS	1.569 0.1182 NS
	3	603.5	-	-	-	-	-	2.185 0.0301 NS	1.437 0.1525 NS	1.201 0.2313 NS
Three-quarter Saanen	1	478.6	-	-	-	-	-	-	-0.761 0.4477 NS	-0.460 0.6460 NS
	2	524.1	-	-	-	-	-	-	-	0.131 0.8962 NS
	3	513.7	-	-	-	-	-	-	-	-

[Note: 5% level of significance is at P <0.05 ÷ (6x5) = 0.0016]

3. RESULTS: DISEASES OF GOATS

3.1 DISEASES

3.2 MORTALITIES AND POST-MORTEMS

3.1 DISEASES

In the routine management of the Milch Goat Project, many goats developed diseases and were treated for them. Goats that died were sent to the Pathology Department, and post-mortems were carried out. No accurate statistics of disease incidence are available, because the required records were not kept fully, and are therefore incomplete and inadequate. Mortalities of adult goats are shown in Table D4, and mortalities of goat kids for the first three years are shown in Tables D5 to D9. Accurate and complete information about kid mortality in subsequent years is not available. The results of post-mortems are accurate and are discussed separately (Tables P1 to P3). Although this is also not a complete record, it is a representative sample.These diseases which were recorded as post-mortem reports were the most important, and had the greatest impact on the productivity of the goat herd. Neither of the two sets of data (mortalities and post mortem records) is complete, and they contain some data which is duplicated, because it is not possible to identify all individual goats. The data sets should therefore be seen as complementary. Other diseases occurred which did not result in death, and it is important to record observations about them also. A summary of the incidence of these diseases from the inadequate information available is recorded in Table D1. This gives some idea of the relative importance of the main disease problems.

3.1.1 DISEASES OF GOAT KIDS

1.1 Coccidiosis

Most of the disease problems relating to the kids were not recorded, as the diarrhoea/coccidiosis/pneumonia complex was the main and overriding problem.

1.2 Rotavirus

Rotavirus was isolated from the faeces of goat kids in 1990, and reported in 1994 (DaCosta Mendes *et al.*,1994). This was believed to be the first report of rotavirus in goats in southern Africa. Further attempts to isolate the virus in other years have been unsuccessful.

1.3 Pasteurella

No outbreaks of *Pasteurella* were recorded, but the herd is now routinely vaccinated.

1.4 Broken legs

In the early years, broken legs were a problem with young kids; but the incidence was generally low. Exact statistics were not recorded, but were of the order of two to four kids a year (Table D1).

1.5 Orf (Vuilbek)

In the early years of the Milch Goat Project, orf did not appear. However, since then outbreaks occurred in kids of about three months of age, most recently in 1996. The lesions contributed to mortality, by making the drinking of milk or eating of other food difficult. Generally the problem cleared up after a few weeks. It was not a major problem.

3.1.2 DISEASES OF ADULT GOATS

2.1 Mastitis

2.1.1 Clinical Mastitis

The goats were subject to a normal milking routine, involving standard hygiene and mastitis control practices, and mastitis occurred in the herd periodically. The problem on occasions reached alarming proportions with outbreaks of peracute cases. On one occasion in 1991 this was traced specifically to a *Pseudomonas* infection that was transmitted by the milking machine. The peracute cases ("blue udder") resulted in deaths, or in the loss of one half of the udder. The recording of 28 cases of clinical mastitis (including the peracute outbreaks) in a period of six years indicated a relatively moderate level of infection.

2.1.2 Subclinical Mastitis

In the years 1990/91 milk samples were taken regularly to monitor subclinical infections.

The results are presented in Tables D2 and D3. The incidence of subclinical mastitis as indicated by growth of bacterial colonies was generally low, and infections identified did not often persist. The main organism identified was *Staphylococcus epidermidis*, infecting 109 of the 1032 udder halves sampled (10.6%). It is likely that this organism was an environmental contaminant, and not a true mastitis-causing organism. The other bacteria were few in comparison (27 of 1032 udder halfsamples = 2.6%), and consisted primarily of *Staphylococcus aureus* (23 of 27 colonies = 85%). *Pasteurella haemolytica* and *Streptococcus sp.* were each identified once, and *Escherichia coli* twice.

As was expected, the Somatic Cell Counts (SCC) were an unreliable indication of subclinical mastitis (Table D3). These values would be considered to indicate severe infections if they were measured in samples of cow milk.

2.2 Dystocia

Dystocia, and the resultant metritis, occurred in a surprisingly low number of goats: only 11 of these cases were identified in the six year period.

2.3 Abscesses (Caseous lymphadenitis)

Abscesses occurred in the herd every year, but generally without any deleterious effects. The characteristic group was the dry goat group, and the abscesses developed in the winter months. When the abscess was swollen, it was opened, the caseous matter was cleaned out, the wound was treated with wound spray, and an antibiotic given. Healing occurred in a short time. The incidence was low enough (up to ten cases a year; see Table D1) that the disease was not perceived as a major problem, and no attempt was made at vaccination.

2.4 Eye Infections

Serious eye infections were generally not a problem, and seldom occurred (Table D1).

2.5 Pneumonia

Six cases of adult goats with pneumonia were recorded. (See Table D1 and Table P1). This was relatively low, compared with the high incidence in kids.

2.6 Squamous Cell Carcinoma

Approximately half of the original herd of pure Saanens (out of 24) developed squamous cell carcinoma on the skin of the udder from the fourth lactation onwards. This condition proved to be uncurable, and these goats were culled. No cases were reported in the Crossbred goats. The new goat shed was constructed which provided more complete shelter from the sun than the original pens, and the problem has abated.

2.7 "Sore Feet"

Foot problems occurred only occasionally in goats where the hoofs had not been trimmed regularly. Hoof trimming should have been done every three months, but this procedure was often treated as a low priority. Some goats' hoofs grew so long that the feet became deformed; although it appeared that a small proportion of goats had a genetic weakness, making them susceptible to foot deformities, especially if they became overweight. A few showed what appeared to be laminitis, and spent a proportion of their time kneeling. This may have resulted from the high energy diet that was fed even when the goats were not lactating.

2.8 Caprine Arthritis Encephalitis Virus (CAEV)

This disease was not recorded, and appears **not** to exist in South Africa. On two occasions, samples were collected from goats that had swollen joints, but the laboratory tests were negative.

2.9 Internal Parasites

Apart from the problem with coccidiosis in the kids discussed above, internal parasites did not cause much of a problem in the adult goat herd. The goats kept in the goat pens or shed seldom showed any evidence of internal parasites. Levamisole was included with the vaccination Ovivax® given annually to adult goats during the dry period. Indigenous goats were dosed with various anthelmintics once or twice a year. A small trial to assess resistance against *Haemonchus* was attempted with the first group of male goat kids born. However, the number of goats was too small to be able to draw general conclusions.

2.10 External Parasites

The only external parasites that caused any problems were lice. These became apparent at various times, about twice a year. The goats would rub themselves against fences or walls. In general they were only of nuisance value, but may occasionally have contributed to kid debility. A simple dipping of the goats (a synthetic pyrethroid was used) solved the problem; at least for a time. The goats that spent some time outside the goat pens in the veld paddocks ran a high risk of tick infestation. Saanen or Crossbred goats generally were not left in the veld because they deteriorated in body condition and were at risk of tick-borne diseases. In contrast, Indigenous goats appeared to be resistant to tick infestation. Tick populations on the Indigenous goats were generally low, affecting areas under the tail and between the hoofs. The latter sometimes caused lameness.

3.1.3 TABLES OF GOAT DISEASES

Table D1: Records of Goat Diseases
(In addition to those reported as post-mortems: See Table P3).

	1989	1990	1991	1992	1993	1994
Kids						
Diarrhoea	2	21	15	-	2	-
Respiratory	1	4	-	-	-	-
Broken legs	4	2	2	-	1	-
Adults						
Mastitis	1	7	4	2	2	4
Dystocia, etc.	-	2	1	-	1	4
Abscesses	-	7	10	-	1	-
Eye infections	-	-	3	-	-	-
Pneumonia	-	-	1	-	-	-

Table D2: Subclinical Mastitis Survey: 1990/91: Bacterial growth.

Date	Udder halves sampled	No growth	Growth of bacterial colonies				% Growth	% Growth*
			Totals	*Staph. epidermidis*	*Staph. aureus*	Other		
18/9/90	76	73	3	2	1	0	3.9	1.3
2/10/90	114	106	8	5	2	1	7.0	2.6
16/10/90	140	129	11	10	1	0	7.9	0.7
6/11/90	132	113	19	14	4	1	14.4	3.0
27/11/90	126	106	20	11	9	0	15.9	7.1
5/2/91	118	99	19	17	1	1	16.1	1.7
12/3/91	120	100	20	18	1	1	16.7	1.7
16/4/91	121	98	23	19	4	0	19.0	3.3
14/5/91	85	72	13	13	0	0	15.3	0.0
Totals	1032	896	136	109	23	4	13.2	2.6

[* Excluding *Staph. epidermidis*]

Table D3: Subclinical Mastitis Survey: 1990/91: Mean Somatic Cell Counts (SCC)

Date	Somatic Cell Counts (cells x 1000/ml)	
	No growth mean SCC ± SE	**Growth** mean SCC ± SE
18/9/90	1687 ± 2866	1222 ± 1080
2/10/90	1042 ± 1712	2334 ± 3989
16/10/90	1194 ± 2500	1022 ± 1100
6/11/90	508 ± 614	670 ± 696
27/11/90	527 ± 1020	1344 ± 2214
5/2/91	864 ± 1171	696 ± 525
12/3/91	825 ± 1362	671 ± 726
16/4/91	831 ± 1242	954 ± 590
14/5/91	839 ± 1795	1313 ± 855

3.2 MORTALITIES AND POST-MORTEMS

3.2.1 MORTALITIES

3.2.1.1 Mortality of Adult Female Goats

Records of deaths of adult femle goats are summarized in Table D4 for the years 1988 to 1993. There were few deaths in the early years, but the incidence increased as the animals became older, and as the size of the herd increased. The overall rates of 10% for Saanens and 15% for Crossbreds was surprisingly high, compared with equivalent percentages for a dairy cow herd of about 3%. Perhaps the "turn-over" in a goat milk herd is higher than a dairy cow herd, not only because of the more rapid reproductive rate. The data for Three-quarter Saanens are unrepresentative, because of the small number of animals of this type. In contrast, the overall percentage for Indigenous goats was much lower at 4%.

3.2.1.2 Mortality of Goat Kids

Mortality of goat kids is shown in Tables D5.1 to D9. Little effect of gender was apparent (Table D8.1); nor was there any obvious effect of whether the kids were from multiple births (Table D8.2). About one third of kid deaths occurred within the first month, but deaths continued until past the age of four months (Table D9).

The reasons are discussed in the section about post-mortems.

3.2.2 TABLES OF MORTALITY OF GOATS

3.2.2.1 MORTALITY OF ADULT GOATS

Table D4: Mortality of adult female goats: 1988 - 1993.

Year	Saanen		Crossbred		Three-quarter Saanen		Indigenous	
	No.	%	No.	%	No.	%	No.	%
1988:	25		-		-		33	
deaths	1	4.0	-	-	-	-	-	-
1989:	24		-		-		33	
deaths	-	-	-	-	-	-	1	3.0
1990:	34		9		-		44	
deaths	5	14.7	-	-	-	-	6	13.6
1991:	48		21		2		40	
deaths	4	8.3	7	33.3	-	-	1	2.5
1992:	41		22		8		48	
deaths	4	9.8	2	9.1	4	50.0	2	4.2
1993:	41		21		9		49	
deaths	9	22.0	2	9.5	1	11.1	1	2.0
Averages:								
1988 - 1993:	35.5		18.2		6.3		41.2	
deaths	3.8	10.7	2.7	15.1	1.7	27.0	1.8	4.4

3.2.2.2 MORTALITY OF GOAT KIDS

Table D5.1: Mortality of Goat Kids Born 1988: Gender

	Male		Female		Totals	
	No.	%	No.	%	No.	%
Saanen	2	11.1	6	37.5	8	23.5
Crossbred	3	25.0	5	35.7	8	30.8
Totals	5	16.6	11	36.7	16	26.7

Table D5.2: Mortality of Goat Kids Born 1988: Multiple Births

	Singles		Twins and Triplets		Totals	
	No.	%	No.	%	No.	%
Saanen	4	28.6	4	20.0	8	23.5
Crossbred	6	27.3	2	50.0	8	30.8
Totals	10	27.8	6	25.0	16	26.7

Table D6.1: Mortality of Goat Kids Born 1989: Gender

	Male		Female		Totals	
	No.	%	No.	%	No.	%
Saanen	11	39.3	6	21.4	17	30.4
Crossbred	7	30.4	9	39.1	16	34.8
Three-quarter Saanens	5	71.4	2	50.0	7	63.6
Totals	23	39.7	17	30.9	40	35.4

Table D6.2: Mortality of Goat Kids Born 1989: Multiple Births

	Singles		Twins and Triplets		Totals	
	No.	%	No.	%	No.	%
Saanen	2	20.0	15	32.6	17	30.4
Crossbred	8	50.0	8	26.7	16	34.8
Three-quarter Saanen	4	57.1	3	75.0	7	63.6
Totals	14	39.7	26	30.9	40	35.4

Table D7.1: Mortality of Goat Kids Born 1990: Gender

	Male		Female		Totals	
	No.	%	No.	%	No.	%
Saanen	12	40.0	1	33.3	23	36.5
Crossbred	4	11.8	6	17.1	10	14.5
Three-quarter Saanens	5	26.3	5	35.7	10	30.3
Indigenous	4	28.6	5	27.7	9	28.1
Totals	25	25.5	27	26.7	52	26.1

Table D7.2: Mortality of Goat Kids Born 1990: Multiple Births

	Singles		Twins and Triplets		Totals	
	No.	%	No.	%	No.	%
Saanen	6	46.1	17	34.0	23	36.5
Crossbred	8	50.0	8	26.7	16	34.8
Three-quarter Saanen	3	17.6	7	13.5	10	14.5
Indigenous	7	63.6	3	13.6	9	28.1
Totals	14	39.7	26	30.9	40	35.4

Table D8.1: Mortality of Goat Kids Born: Three Years (1988 to 1990): Gender

	Male		Female		Totals	
	No.	%	No.	%	No.	%
Saanen	25	32.9	23	29.9	48	31.4
Crossbred	14	20.3	20	27.8	34	24.1
Three-quarter Saanens	10	38.5	7	38.9	17	38.6
Indigenous	4	28.6	5	27.8	9	28.1
Totals	53	28.5	55	29.6	108	29.0

Table D8.2: Mortality of Goat Kids Born: Three Years (1988 to 1990): Multiple Births

	Singles		Twins and Triplets		Totals	
	No.	%	No.	%	No.	%
Saanen	12	32.4	36	31.0	48	31.4
Crossbred	17	30.9	17	19.8	34	24.1
Three-quarter Saanen	11	61.1	6	23.1	17	38.6
Indigenous	2	28.6	7	28.0	9	28.1
Totals	42	35.3	66	26.1	108	29.0

Table D9: Age of Goat Kids at Death: Three Years (1988 to 1990)

Age at death (days)	1988	1989	1990	Three Years		
				10-day	30-day	%
0 to 10	3	8	17	28		
11 to 20	1		4	5		
21 to 30	4			4	37	36.3
31 to 40	2	1	1	4		
41 to 50	5	2		7		
51 to 60		4		4	15	14.7
61 to 70		4		4		
71 to 80		4	4	8		
81 to 90		3	1	4	16	15.7
91 to 100		2	5	7		
101 to 110	1	5	4	10		
111 to 120		3	2	5	22	21.6
121 to 130		2	3	5		
131 to 140		1	1	2		
141 to 150		1	1	2	9	8.8
151 to 160			1	1		
161 to 170			2	2		
171 to 180					3	2.9
Totals	16	40	46	102	102	100

3.2.3 POST-MORTEMS OF GOATS

Since the start of the Milch Goat Project, it was a standing instruction that all goats that died should be sent to the Department of Veterinary Pathology. This was to ensure that the reasons for death were correctly identified, and to provide teaching material for the students. However, because of management and labour difficulties, not all dead animals were delivered to the Department; some arrived too late for post-mortems to be done; and others were not done because there were too many with the same problem, as happened when many kids were dying from coccidiosis at the same time.

Nevertheless, records are available for 182 post-mortems, from 1988 to 1994. These probably represent a good sample of the animals that died within this period. The details are shown in Table P3 (Appendix C), and the results are summarized in Table P1.

*** GOAT KIDS**:

The overwhelming reasons for the death of goat kids were coccidiosis and pneumonia, usually occurring together. If the diagnosis "enteritis" is also taken to be indicative of coccidiosis, and "cachexia" is the logical consequence before death, then there is no doubt that this was the major problem in the herd. Pneumonia also occurred separately from coccidiosis, and this was probably the final reason for death of goat kids that had not received enough colostrum.

An important proportion of kids were lost in the early days after being born, probably as a result of poor mothering ability, pendulous udders, overcrowding, and lack of close attendance by the staff responsible.

In the list of goats in Table P3 (Appendix C), two distinct groups were discerned:

* Kids that died soon after being born. In this group, those that died from pneumonia before 35 days after being born, on average died at two to three weeks (range: 1 to 33 days).

* Kids that died from coccidiosis and its complications, at about two to four months of age. The different groups distinguished are shown in Table P2. In most cases, the pneumonia diagnosed as the cause of death was a complication arising from the debilitating effects of earlier coccidiosis.

*** ADULT GOATS**:

The 32 post-mortems recorded are summarized in Table P1. Few deaths of adult goats (older than six months) occurred in the first years. Some of the reasons for death that warrant specific comment are as follows:

*** Mastitis**

Mastitis was not perceived to be a problem generally in the herd, but on specific occasions there were a few goats that died from acute mastitis ("blue udder"), usually caused by *Staphylococcus aureus*. On one occasion the causative organism was identified as *Pseudomonas*, spread as a result of inadequate cleaning of the milking machine.

*** Pneumonia**

Pneumonia was diagnosed as the cause of death for five adult goats, but this may have been the final complication to other disease problems.

*** Hepatic cirrhosis**

The two cases recorded here occurred in Indigenous goats that were brought into the herd from elsewhere.

*** Plastic bags in the rumen**

This was seldom a problem with the goats kept in the goat pens. However, it was a hazard for the Indigenous goats that spent time in the veld paddocks elsewhere on campus. Littering is endemic, and the older goats, when slaughtered often had tangled masses in the rumen. These obstructions restricted the flow of ingesta, and contributed to deaths by weakening the animals.

*** Squamous cell carcinoma**

Approximately one half of the foundation Saanen goats developed squamous cell carcinoma on the skin of their udders from the fourth lactation onwards (more than five years of age). This progressed to unhealable wounds, and would have led to death, except that in most cases the goats were culled before the problem became extreme. In later years this was not a problem, probably because the new goat shed provided adequate shade. No cases of squamous cell carcinoma were recorded in Crossbred or Indigenous goats.

*** Ketosis**

Ketosis developed in a few goats that were grossly overweight and were put on a low energy diet of roughage and a lick. The majority of overweight goats were Crossbred goats that had dried off, but had been left on the complete feed designed for the goats in milk. A shortage of energy that was associated with later pregnancy was usually the cause of the ketosis. In this regard, goats should be treated like sheep, rather than like dry cows, because of the energy demand for multiple pregnancies.

*** Heartwater**

Only two cases of heartwater were recorded during this period (1988 to 1994), one of which was from a goat kept in the goat pens. How the tick managed to reach the goat is difficult to imagine, but it could have been transported via guinea fowl that fly in to eat spilled goat feed in the pens, or it could have been carried in by an Indigenous goat that had been in the veld. Because of the risk of heartwater, Saanen and Crossbred goats were seldom sent out to the veld paddocks.

3.2.4 TABLES OF POST-MORTEMS OF GOATS

Table P1: Goat post-mortems: 1988 to 1994: Summary (n = 182)

Aetiology	Number
Adult goats (32 post-mortems):	
mastitis	8
ketosis	5
pregnancy toxaemia	1
pneumonia	5
peritonitis	3
metritis	2
dystocia	1
uterine prolapse	1
hepatic cirrhosis	2
heart failure	1
Heartwater (cowdriosis)	1
plastic bags in rumen	1
squamous cell carcinoma	1
nephrosis/renal calculi	1
Corynebacterium abscesses	1
Goat kids (150 post-mortems):	
pneumonia	54
coccidiosis	53
enteritis/diarrhoea	9
cachexia	15
septicaemia	8
E.coli	3
born dead	4
born weak	5
hypothermia	1
cerebrocortical necrosis	1
Vitamin E/ selenium deficiency	1
myocarditis	1
pericarditis	1
ataxia	1
renal dysplasia	1
arthritis	1
pyogenic bacterial embolism	1
Monezia	1
"concentrate overload"	2
asphyxiation (stuck in feed bin)	2

Table P2: Goat kid mortality: age at death

Group	No.	Days (mean ± SE)
Coccidiosis	53	86 ± 79
Coccidiosis with pneumonia	14	94 ± 28
Pneumonia (<35 days)	18	13 ± 11
Pneumonia (>35 days)	13	102 ± 30
Pneumonia (> 35 days; incl. coccidiosis)	27	95 ± 31

4. RESULTS OF HEARTWATER EXPERIMENT

4.1 RESULTS OF HEARTWATER EXPERIMENT

4.1 RESULTS OF HEARTWATER EXPERIMENT

Preliminary results for the first year of the experiment have already been reported at the Fifth International Conference on Goats (Donkin *et al.* 1992). These have been consolidated in this report with the information from the second year.

4.1.1 TEMPERATURE REACTIONS

Temperature reactions are illustrated in Figures H1 to H4. The similarity is readily apparent. The detailed analyses of these reactions are given below.

4.1.1.1 Pre-febrile temperatures

Morning and afternoon mean pre-febrile temperatures are listed in Table H1. It is apparent that any differences between groups are small. On average, afternoon temperatures were approximately 0.5°C higher than morning temperatures. As the morning temperatures were taken at a more consistent time than for those in the afternoon, the morning temperatures were used in all further analyses.

4.1.1.2 Temperature reactions:

Temperature reactions are shown in Tables H2 to H6. On average, the pre-febrile temperature was 39°C (Table H2). The characteristic rise in temperature above 40°C occurred on Day 10, with a mean temperature of 40.6°C. Peak temperature occurred on Day 12, at a mean of 41.7°C; and for those goats that survived, temperature fell below 40°C again on Day 16. The mean temperature rise was 2.7°C. The mean time from temperature rise to drop was 5.3 days, and the mean time from peak to drop was 3.6 days. Death, if it occurred was on average on Day 15.

4.1.1.3 Breed Differences

Breed difference effects were analysed, and the results are shown in Tables H7 to H18 :

* H7: Mean temperatures before heartwater reaction
* H8: Mean temperatures at day of rise in temperature
* H9: Day of temperature rise above 40°C
* H10: Peak temperatures
* H11: Peak temperatures for goats that died
* H12: Day of peak temperature
* H13: Degrees rise in temperature
* H14: Degrees rise in temperature for 1992 only
* H15: Day of temperature drop

* H16: Days from peak to temperature drop
* H17: Days from temperature rise to drop
* H18: Day of death

All these tests were not significant, except for the three shown in Tables H7, H10 and H13.

** Table H7: Mean temperature before heartwater reaction:*

The mean temperature before temperature rise was significantly ($P<0.05$) different only between Saanen (39.87°C) and Three-quarter Saanen goats (39.19°C). This is difficult to interpret, as the temperatures are very similar; it seems likely that the difference would not have been significant if there had been more Three-quarter Saanen goats.

** Table H10: Peak temperatures:*

Peak temperatures did not differ significantly between the breeds Saanen, Indigenous and Crossbred. However, the peak temperature of the Three-quarter Saanens was significantly ($P<0.05$) higher than those of goats of the three other breeds. This is difficult to account for, and the mean difference was approximately 0.5°C. It is possible that the small number of goats might have contributed to the significance, and the fact that the Three-quarter Saanens were only included in the experiment in Year 2.

** Table H13: Degrees rise in temperature:*

The difference in degrees rise in temperature was not significant between Saanen goats and Three-quarter Saanens. However, it was significantly ($P<0.05$) different when Indigenous and Crossbred goats were compared to Three-quarter Saanens. This difference was not significant when the test was done again (Table H14), including only goats in Year 2. This suggests that there might have been a year effect, or that the difference in the number of goats could have caused the effect. This influence would not have been apparent if there had been more Three-quarter Saanen goats in the experiment, and if they had been in both years.

4.1.1.4 Differences between survivors and those that died:

Temperature reactions in terms of rising and peak temperatures are shown in Tables H19 to H22. The relatively low number of male goats that died was related to the fact that most of the Saanen goats were females, and this group had the highest mortality. In spite of this discrepancy, there were no significant differences between the parameters measured.

4.1.1.5 Year effects

The only groups that could be compared between years were the Crossbred and Indigenous groups (Table H23). There were no significant differences.

4.1.1.6 Saanens treated or not treated with tetracycline

These data are shown in Table H24 to H29. The only nearly-significant difference was in the slightly later timing of the rising temperatures of treated goats. No explanation can be given of this, and it was unrelated to whether goats were treated or not, as it occurred before treatment was given.

4.1.2 CLINICAL SIGNS

Clinical signs have been grouped into four categories, relating to general behaviour, the effects of fluid accumulation, nervous signs, and those associated with collapse and death. Observation periods consisted of about one hour each morning and afternoon. Some signs might therefore have been missed, such as convulsions, if they did not occur during the specific observation periods. Other signs, such as anorexia, might have not been noted because they were a negative occurrence. Observation periods were generally shared by two people, and four observers were involved altogether. Death was not often observed, and when it was seen, the progression through lateral recumbency and convulsions was mercifully swift. In the first year, goats in lateral recumbency were used for an experiment on emergency resuscitation procedures, but very few goats survived long enough for a drip to be inserted. Because of the uncertainties concerning the validity of incidence of observed signs, it was not considered appropriate to attempt to carry out statistical analyses of these data.

4.1.2.1 Breed differences:

The incidence of clinical signs noted for the different breeds is indicated in Table H30. All Saanens, approximately half of the Crossbreds, and approximately three-quarters of the Three-quarter Saanens died. Although all breeds showed a range of clinical signs, the incidence and severity appeared to increase with the increasing proportion of Saanen genetic influence.

The general impression was that Indigenous goats showed less clinical signs, and those signs that were noted appeared to be less severe than in the other groups.

4.1.2.2 Gender differences:

These are shown in Table H31. The relatively low proportion of males that died is a breed effect, resulting from the low number of male Saanens included. It would be difficult to attempt to distinguish any differences in the incidence of clinical signs between males and females, for the reasons discussed above. For example, more male goats showed diarrhoea, but a higher proportion of female goats died.

4.1.2.3 Differences between Saanen goats that were treated or not:

These are shown in Table H32. The small number of goats in this comparison make it difficult to draw any general conclusions. However, the treated goats did not show many of the more severe nervous signs that were shown by the untreated goats in the final stages of the disease.

4.1.2.4 Differences between those goats that survived or died:

These are shown in Table H33. *No apparent differences* were obvious between these groups in regard to general behavioural signs and those associated with fluid accumulation. Apparently these goats could survive in spite of showing the same clinical signs. Although more nervous signs were shown by goats that died compared to those that survived, nevertheless many of the survivors showed licking of lips, grinding of teeth, and tremors.

4.1.3 CONGLUTININS

Serum conglutinin titres are listed in Tables H34 to H37.

In Year 1, conglutinins were only measured after the experiment, and as all the Saanens had died, samples were taken from a group of other Saanens in the herd. These few results seemed to indicate that there might be a difference between breeds.

Therefore, in Year 2, conglutinin levels were measured before and after the experiments. The data shown in Tables H34 and H36 were not numerous enough in each cell to ensure the validity of the Chi-squared tests. Therefore the data were consolidated into Tables H35 and H37 respectively, to ensure validity of the Chi-squared tests. No significant effect was evident of the level of conglutinin before heartwater on survival of the goats (Table H35). Although conglutinins were at a lower level before than after heartwater, there was no significant relationship between the levels before and after.

These results gave no indication that conglutinin titres were a predictor of the goats' ability to survive heartwater.

4.1.4 DEATH OR SURVIVAL

The incidence of deaths from heartwater among goats, from animals treated or untreated is shown in Table H38. A more detailed summary including the differences between Year 1 and Year 2, is shown in Table H39. The deaths recorded in untreated goats are shown in Table H40. It can be seen that all ten Saanens died, only one of the twenty Indigenous goats died, 55% of Crossbred goats survived, and 22% of Three-quarter Saanens survived. The proportion of goats that survived from the different breed groups was similar to the proportion of genetic inheritance from the Indigenous goats.

The statistical analysis is shown in Tables H41.1, H41.2 and H41.3. The Fisher Exact Chi-squared Test showed that the death rate between the different breeds was significantly ($P<0.05$) different, except between Three-quarter Saanens and pure Saanens. It was also not significantly different between Three-quarter Saanens and the Crossbred goats. This was probably because of the small number of goats in the Three-quarter Saanen group.

The relation between gender and survival from heartwater is shown in Table H42. No significant effect of gender was determined.

4.1.5 WEIGHTS

Weights and ages of goats are shown in Table H43. The differences in weights between the Indigenous goats and those of the other breeds are apparent. A reduction in weight was not always observed, and no general trend was discernible. It was concluded that weight change was not a reliable parameter in these experiments.

4.2 GRAPHS OF TEMPERATURE REACTIONS

Figure H1: Heartwater in Goats: 1991: Saanen, Indigenous and Crossbred Goats

Figure H2: Heartwater in Goats: 1992: Phase 1: Indigenous and Crossbred Goats

Figure H3: Heartwater in Goats: 1992: Phase 2: Saanen and Three-quarter Saanen Goats

Figure H4: Heartwater in Goats: 1992: All Goats

Figure H1: Heartwater in Goats
1991: Saanen, Indigenous and Crossbred Goats

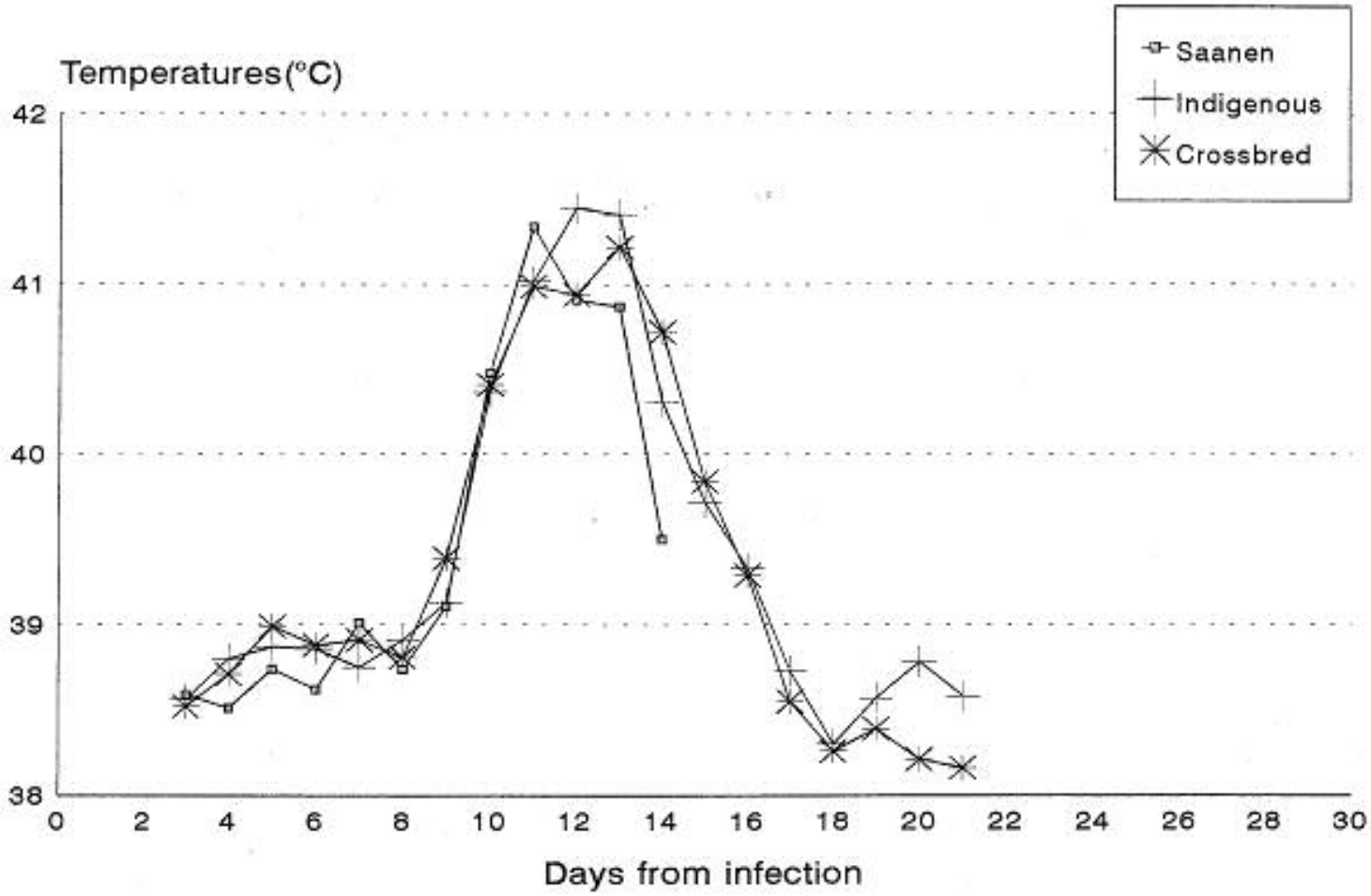


Figure H2: Heartwater in Goats
1992: Phase 1 : Indigenous and Crossbred Goats

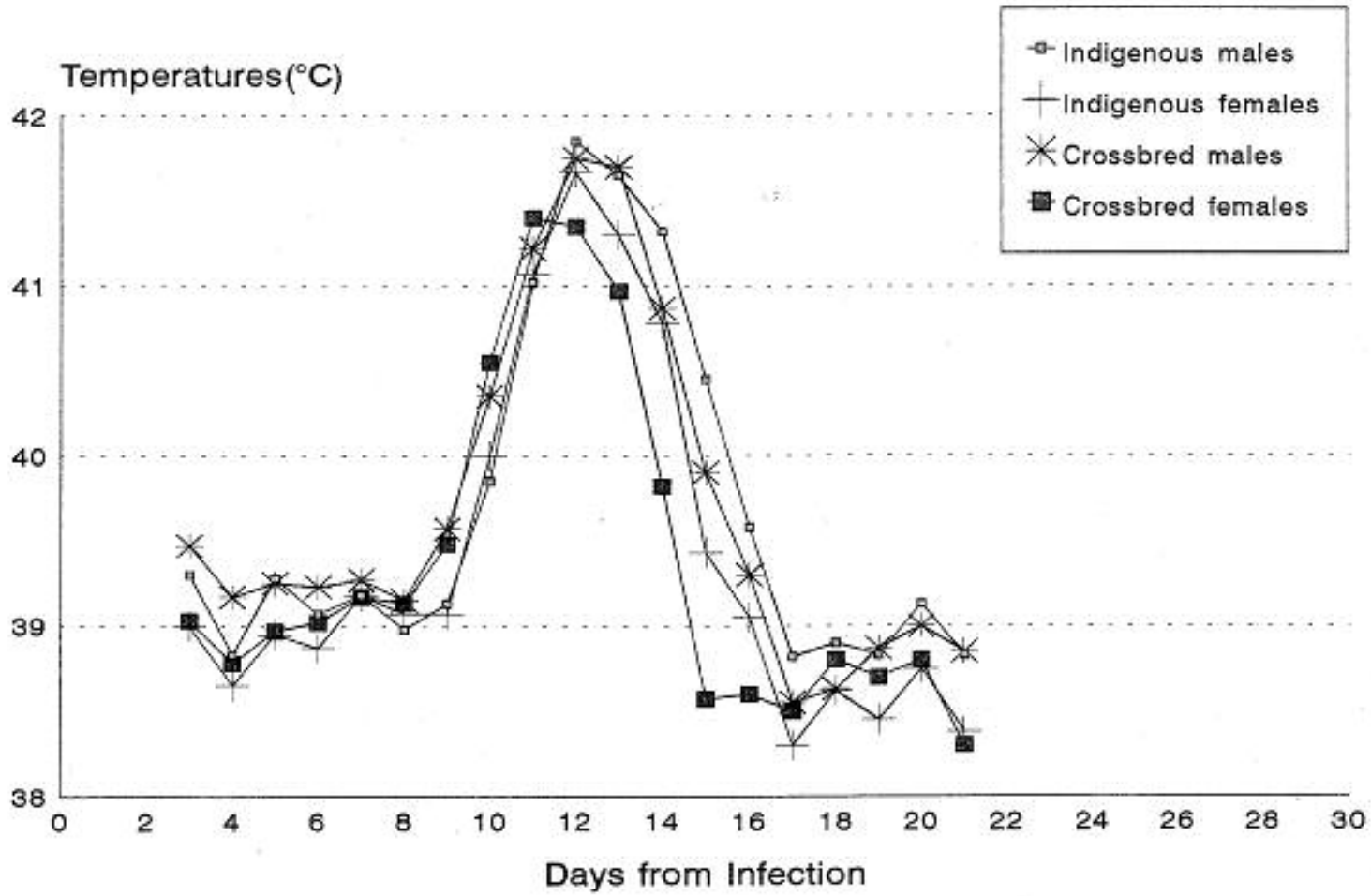


Figure H3: Heartwater in Goats
1992: Phase 2 : Saanen and Three-quarter Saanen Goats

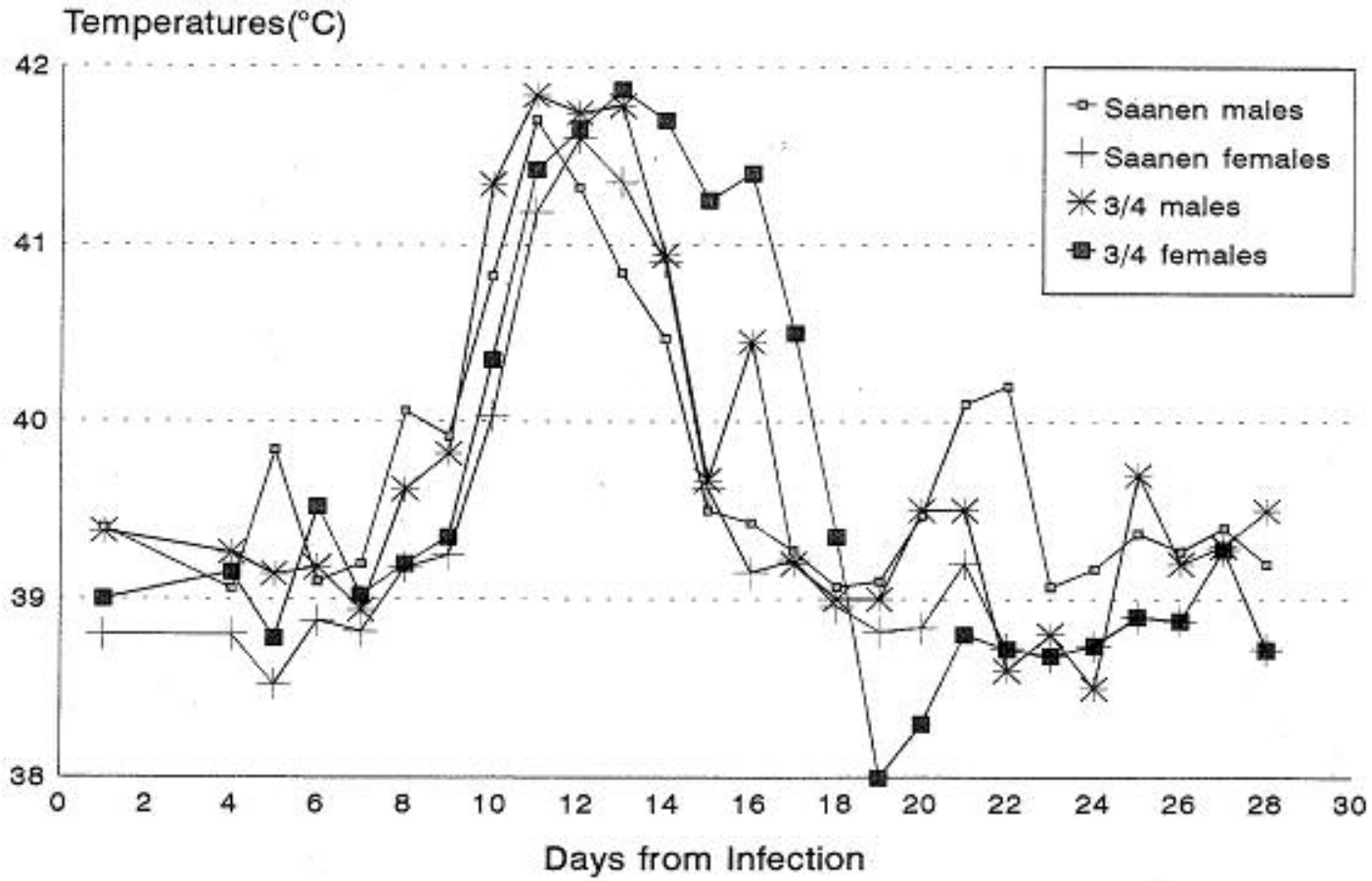
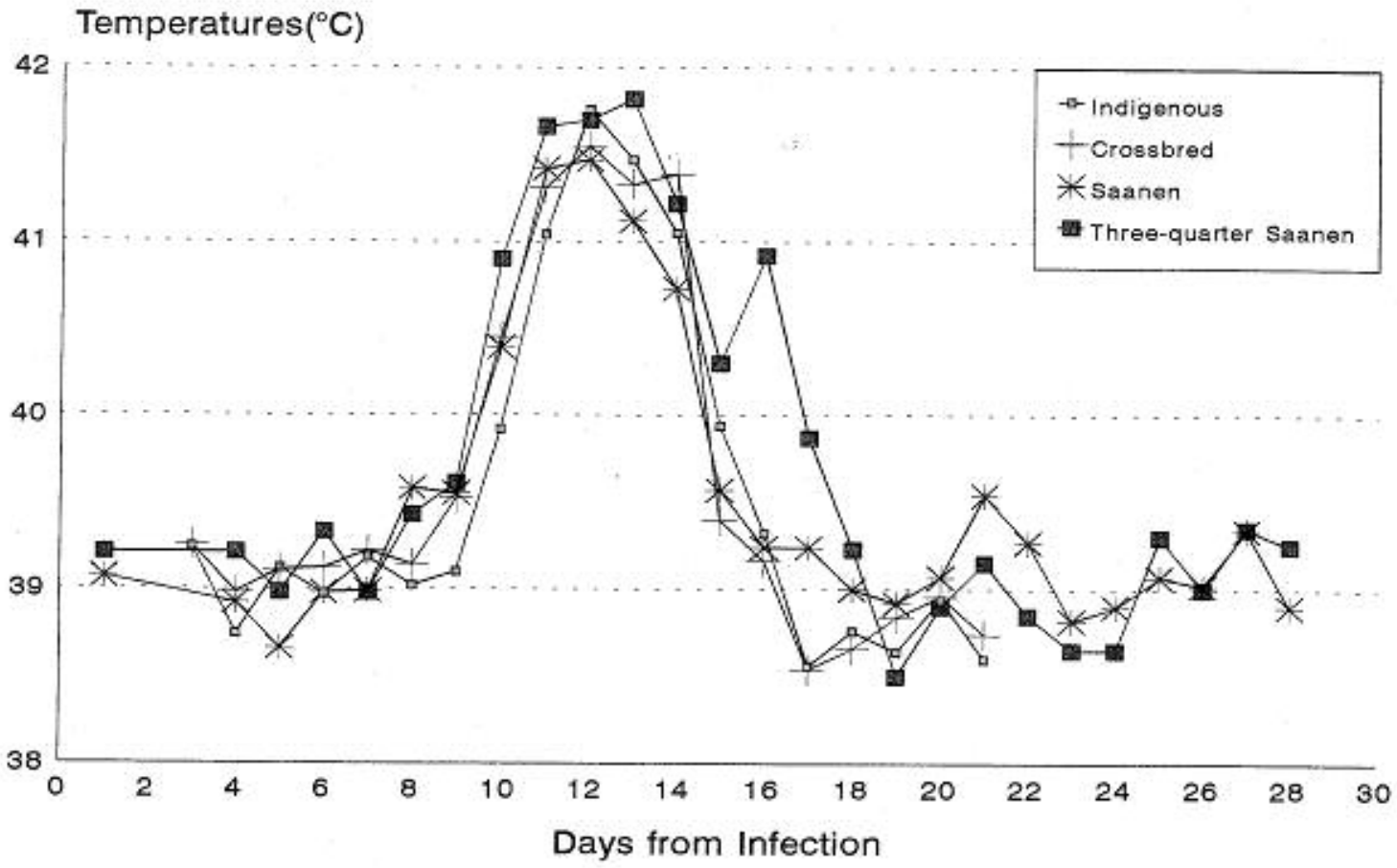


Figure H4: Heartwater in Goats
1992: All Goats



4.3 TABLES OF HEARTWATER EXPERIMENT

Note: Tables H1 to H29 are in Appendix D

Table H30: Incidence of clinical signs: goats with heartwater: breed comparisons
[Number of goats for which a clinical sign was recorded]

	Saanen		Indigenous		Crossbred		75% Saanen	
Number of goats	10		20		20		9	
GENERAL:	No.	%	No.	%	No.	% 4	No.	%
Anorexia	6	60	0	0	20		0	0
Listlessness	9	90	7	35	13	65	9	100
Recumbency	0	0	0	0	4	20	3	33
Diarrhoea (mild)	4	40	15	75	17	85	8	89
Diarrhoea (severe)	0	0	1	5	4	20	2	22
FLUID ACCUMULATION:	No.	%	No.	%	No.	%	No.	%
Oedema: facial	0	0	0	0	7	35	0	0
Oedema: abdominal	0	0	0	0	0	0	1	11
Nasal discharge	0	0	7	35	10	50	3	33
Cough	1	10	2	10	8	40	4	44
Respiratory distress	1	10	10	50	10	50	5	56
NERVOUS SIGNS:	No.	%	No.	%	No.	%	No.	%
Licking of lips	0	0	3	15	8	40	3	33
Chewing movements	2	20	0	0	0	0	0	0
Grinding teeth	0	0	9	45	5	25	4	44
Tremors	1	10	3	15	5	25	6	67
Ataxia/ unsteady gait	4	40	1	5	2	10	0	0
Stance: wide-based	1	10	1	5	0	0	0	0
Head-pushing	1	10	0	0	1	5	0	0
Hyperaesthesia	6	60	1	5	4	20	1	11
COLLAPSE:	No.	%	No.	%	No.	%	No.	%
Recumbency (lateral)	6	60	1	5	1	5	1	11
Convulsions (if seen)	4	40	1	5	1	5	0	0
Extensor rigidity	1	10	0	0	0	0	0	0
DEATH:	10	100	1	5	9	45	7	78

Table H31: Incidence of clinical signs: goats with heartwater: Gender comparison.
[Number of goats for which a clinical sign was recorded].

	Males		Females		All goats	
Number of goats	25		34		59	
GENERAL:	No.	%	No.	%	No.	%
Anorexia	2	8	8	24	10	17
Listlessness	18	72	20	59	38	64
Recumbency	4	16	3	9	7	12
Diarrhoea (mild)	23	92	21	62	44	75
Diarrhoea (severe)	6	24	1	3	7	12
FLUID ACCUMULATION:	No.	%	No.	%	No.	%
Oedema: facial	5	20	2	6	7	12
Oedema: abdominal	1	4	0	0	1	2
Nasal discharge	14	56	6	18	20	34
Cough	9	36	6	18	15	25
Respiratory distress	15	60	11	32	26	44
NERVOUS SIGNS:	No.	%	No.	%	No.	%
Licking of lips	8	32	6	18	14	24
Chewing movements	0	0	2	6	2	3
Grinding teeth	8	32	10	29	18	31
Tremors	7	28	8	24	15	25
Ataxia/ unsteady gait	1	4	6	18	7	12
Stance: wide-based	0	0	2	6	2	3
Head-pushing	0	0	2	6	2	3
Hyperaesthesia	4	16	8	24	12	20
COLLAPSE:	No.	%	No.	%	No.	%
Recumbency (lateral)	2	8	7	21	9	15
Convulsions (if seen)	1	4	5	15	6	10
Extensor rigidity	0	0	1	3	1	2
DEATH:	9	36	18	53	27	46

Note: Excluding Saanen goats that were treated with tetracycline.

Table H32: Incidence of clinical signs: goats with heartwater: Comparison of Saanen goats treated or untreated with tetracycline.

[Number of goats for which a clinical sign was recorded].

	Untreated		Treated	
Number of goats	10		9	
GENERAL:	No.	%	No.	%
Anorexia	6	60	0	0
Listlessness	9	90	9	100
Recumbency	0	0	0	0
Diarrhoea (mild)	4	40	3	33
Diarrhoea (severe)	0	0	0	0
FLUID ACCUMULATION:	No.	%	No.	%
Oedema: facial	0	0	0	0
Oedema: abdominal	0	0	0	0
Nasal discharge	0	0	1	11
Cough	1	10	0	0
Respiratory distress	1	10	4	44
NERVOUS SIGNS:	No.	%	No.	%
Licking of lips	0	0	0	0
Chewing movements	2	20	0	0
Grinding teeth	0	0	1	11
Tremors	1	10	0	0
Ataxia/ unsteady gait	4	40	0	0
Stance: wide-based	1	10	0	0
Head-pushing	1	10	0	0
Hyperaesthesia	6	60	0	0
COLLAPSE:	No.	%	No.	%
Recumbency (lateral)	6	60	0	0
Convulsions (if seen)	4	40	1	11
Extensor rigidity	1	10	0	0
DEATH:	10	100	1	11

Table H33: Incidence of clinical signs: goats with heartwater: Comparison of goats that survived or died.
[Number of goats for which a clinical sign was recorded].

	Died		Survived	
Number of goats	27		32	
GENERAL:	No.	%	No.	%
Anorexia	7	26	3	9
Listlessness	22	81	16	50
Recumbency	4	15	3	9
Diarrhoea (mild)	18	67	26	81
Diarrhoea (severe)	3	11	4	12
FLUID ACCUMULATION:	No.	%	No.	%
Oedema: facial	3	11	4	12
Oedema: abdominal	1	4	10	31
Nasal discharge	7	26	13	41
Cough	10	37	5	16
Respiratory distress	12	44	14	44
NERVOUS SIGNS:	No.	%	No.	%
Licking of lips	8	30	6	19
Chewing movements	2	7	0	0
Grinding teeth	5	19	13	41
Tremors	9	33	6	19
Ataxia/ unsteady gait	6	22	1	3
Stance: wide-based	2	7	0	0
Head-pushing	1	4	1	3
Hyperaesthesia	10	37	2	6
COLLAPSE:	No.	%	No.	%
Recumbency (lateral)	7	26	0	0
Convulsions (if seen)	6	22	0	0
Extensor rigidity	1	4	0	0
DEATH:	27	100	0	0

Table H34: Effect of conglutinin level before heartwater on death or survival of goats.

Conglutinin (dilution)	Goats died	Goats survived	Totals
< 20	2	1	3
20	5	9	14
40	4	6	10
80	2	1	3
160	1	1	2
Totals	14	18	32

Note: None of the tests showed significance. However, the Chi-squared tests were not valid because too many of the cells had expected counts of less than 5. Therefore, the data were consolidated into smaller groups:

Table H35:
Consolidated Table: Effect of conglutinin level before heartwater on death or survival of goats.

Conglutinin (dilution)	Goats died	Goats survived	Totals
20 or less	7	10	17
40 or more	7	8	15
Totals	14	18	32

Comment: No significant effect was evident of the level of conglutinin before heartwater on survival of the goats.

Table H36: Conglutinin levels in goats before and after heartwater.

Conglutinin (before)	Conglutinin (after)						
	< 20	20	40	80	160	320	Totals
< 20	0	0	0	1	0	0	1
20	1	2	3	1	1	1	9
40	0	2	1	1	2	0	6
80	0	0	0	0	1	0	1
160	0	0	0	1	0	0	1
Totals	1	4	4	4	4	1	18

Comment: There are too few expected counts in each cell for the Chi-squared test to be valid.
Therefore, the Table was consolidated into smaller categories.

Table H37: Consolidated Table: Conglutinin levels in goats before and after heartwater.

Conglutinins (before)	Conglutinins (after)		
	40 or less	80 or more	Totals
20 or less	6	4	10
40 or more	3	5	8
Totals	9	9	18

Comment: Although conglutinins were at lower levels before than after heartwater, there was no significant relationship between the levels before and after.

Table H38: Deaths from Heartwater: Breeds 1 to 4; Treated and Untreated: Consolidated for both years.

Group	Died No.	%	Survived No.	%	Totals
Saanen:					
Untreated	10	100	0	0	10
Treated	1	11	8	89	9
Indigenous:					
Untreated	1	5	19	95	20
Crossbred:					
Untreated	9	45	11	55	20
Three-quarter Saanens:					
Untreated	7	78	2	22	9

Table H39: Deaths from Heartwater: Breeds 1 to 4; Treated and Untreated:
Years 1991 and 1992.

Group	Died No.	%	Survived No.	%	Totals
Saanen:					
Untreated: 1991	8	100	0	0	8
1992	2	100	0	0	2
Treated: 1992	1	11	8	89	9
Indigenous:					
Untreated: 1991	1	12	7	88	8
1992	0	0	12	100	12
Crossbred:					
Untreated: 1991	2	25	6	75	8
1992	7	58	5	42	12
Three-quarter Saanens:					
Untreated: 1992	7	78	2	22	9

Table H40: Deaths from Heartwater: Breeds 1 to 4; Untreated goats only: Consolidated for both years.

Group	Died No.	%	Survived No.	%	Totals
Saanen	10	100	0	0	10
Indigenous	1	5	19	95	20
Crossbred	9	45	11	55	20
Three-quarter Saanens	7	78	2	22	9

Table H41.1: Heartwater experiments: Statistical analysis of breed differences between those goats that survived or died: Chi-squared test: pairwise comparisons: Fisher exact test.

Breed	Died	Survived
1: Saanen	10	0
2: Indigenous	1	19
3: Crossbred [50:50]	9	11
4: Three-quarter Saanen [75:25]	7	2

Table H41.2: Pairwise comparisons: Fisher exact test (Chi-squared test: $p < 0.05$)

Comparison	P value	Significance
1 vs 2	0.0000	***
1 vs 3	0.0041	***
1 vs 4	0.2105	NS
2 vs 3	0.0084	***
2 vs 4	0.0002	***
3 vs 4	0.1296	NS

Table H41.3: Summary of tests of significance

Breed	Indigenous	Crossbred	Three-quarter Saanen
Saanen	p = 0.0000 ***	p = 0.0041 ***	p = 0.2105 NS
Indigenous	-	p = 0.0084 ***	p = 0.0002 ***
Crossbred	-	-	p = 0.1296 NS

Table H42: A comparison of the effect of gender on the resistance of goats to heartwater. [Fisher exact test]

	Male	Female
Died	9 (36%)	18 (53%)
Survived	16 (64%)	16 (47%)

p= 0.29 ; no significant difference.

Table H43: Ages and weights of goats in heartwater experiment.

Groups	Age	Weight (pre-infection)		Weight (post-infection)	
	months	No.	kg ± SE	No.	kg ± SE
1991: Saanen	7 to 8	8	24.5 ± 3.5	0	-
Crossbred	7 to 8	8	22.1 ± 4.0	6	23.7 ± 4.2
Indigenous	7 to 8	8	14.0 ± 1.7	7	14.4 ± 2.0
1992: Indigenous	11 to 12	12	29.1 ± 4.5	5	27.0 ± 3.4
Crossbred	11 to 12	12	39.2 ± 7.3	12	34.8 ± 8.2
1992: Saanen (treated)	12	9	40.9 ± 4.4	8	-
Three-quarter Saanen	12	9	39.5 ± 7.5	2	-