(SR-CRSP)

Small Ruminant - CRSP

Proceedings of the Tenth Scientific Workshop

Held at ILRAD, Nairobi Kenya
26th - 27th February, 1992

Sponsored by:
Kenya Agricultural Research Institute and
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OPENING SESSION

HIGHLIGHTS FOR OPENING REMARKS
USAID MISSION IN KENYA

Current Situation

- Kenya's population to increase by 50% to the year 2000 and therefore a great need for increased food production.

- High potential land already in production and therefore production must be intensified to increase overall output and promote high value export crops. Kenya must exploit every opportunity to increase food production.

- USAID and the GoK are particularly concerned about reaching the smallholder farmer - 1.7 million with less than five acres. An integrated approach is needed.

- Livestock and crops - are ideally suited for small size ar[illegible]source-poor farmers.

- The Small Ruminant Collaborative Research Support Programme (SR-CRSP) was started on a worldwide basis in 1978 as a Title XII initiative. It has become one of the most successful initiatives with its focus on smallstock and directed toward resource-poor subsistence farmers.

- The Kenya involvement in the SR-CRSP began in 1981 with a collaborative research programme that coupled Kenyan researchers with scientists from Winrock International, Texas A&M, Washington State University, University of California-Davis and the University of Missouri-Columbia. The Kenya Programme was to focus on goats and more specifically the development of a new dual-purpose animal and that this breeding programme should be complemented with research in nutrition and animal health problems.

Results After 10 Years of Work

- We believe the project is an excellent example of how an appropriate research programme should be conducted. This programme is well thought out, well managed and represents a multidisciplinary farming systems research approach. It directly involves those farmers for whom the benefits of the research are intended. As we now prepare for the phase II support to KARI, we believe that the work in western Kenya can serve as a model for other research efforts that KARI will undertake. For example, the idea of developing a programme which is then supported by adequate financial resources and for which the individual researcher and the organisation are held responsible, is an idea that we will strongly encourage as we work with KARI management over the next five years.

- Within another 2-4 years, we fully anticipate that a new dual-purpose breed will have been established, stabilised and ready for commercialisation. The economic importance to Kenya's small scale farmers, as well as those in other parts of Africa, will be significant. An interesting aspect of this breeding programme is that with slight genetic modifications, an animal can be produced that will either be a more prolific milk producer or greater producer of meat, depending on environmental conditions and farmer needs.

- Concurrent with the development of this dual-purpose breed, researchers have been working on a multivalent vaccine designed for sheep and goats. While this research effort began later than the breeding programme, good progress has been made and by 1995 when the first five year phase is complete, we look forward to important results with direct benefits to farmers.

Where Do We Put Our Efforts in Research and What Steps Need To Be Taken to Institutionalise This Commendable Research Effort Over the Next Few Years

- As mentioned there is need to provide several more years of support to the breeding programme and to integrate the western Kenya model into KARI's overall research approach.

- I would also like to mention that as a separate part of the planning process for Phase II of the NARP, USAID contracted with three individuals to prepare a report outlining the necessary steps it will take to integrate the SR-CRSP into KARI. Their report, along with the MIAC design team recommendations, offers suggestions as to the steps which need to be taken in order for KARI to maximise the potential contribution of the SR-CRSP to its programmes, both in livestock and other areas. These suggestions are as follows:

  (1) To recruit counterpart staff for all disciplines involved in the SR-CRSP and provide terms of service which are sufficiently attractive to retain them in the programme;

  (2) Counterpart staff assigned to the SR-CRSP need to be transferred to KARI from the MoLD;

  (3) The SR work sites need to be transferred to KARI from the MoLD;

  (4) The SR-CRSP Programme Administration Committee (PAC) needs to be reconstituted to better represent the range of interests represented in the SR-CRSP research programmes. In particular, a representative from the KARI administrative unit which has responsibility for farming systems research needs to be on the committee. A broader sense of ownership of the SR-CRSP within KARI if the programme is to achieve all of its potential.

If these relatively simple steps are taken, KARI will have positioned itself to make full use of the resource which the SR-CRSP represents. Moreover, the SR-CRSP will have provided KARI with much more than a dual-purpose goat technology package. It will also have left a significant imprint on a number of KARI scientists in terms of their approach to research. That may well be the most significant impact of all.

In closing, I would like to wish you well as you meet to discuss past progress, future needs and research direction and the institutionalisation of this very important programme within KARI. I look forward to hearing of the results of your deliberations.

Thank you.

OPENING SPEECH BY HON. M. M'MUKINDIA
MINISTER FOR RESEARCH, SCIENCE AND TECHNOLOGY

Mr. Chairman, Ladies and Gentlemen.

I feel greatly honoured to be among you today as you start this scientific workshop which concerns an important food resource, the small ruminant, in Kenya. I wish to welcome you all to this workshop. I would like to specially welcome our guests from other countries. I hope it will be possible for you to visit other parts of Kenya after the workshop, particularly those areas where the majority of the national flocks and herds of sheep and goats are found.

One of the primary goals of the Kenya government is to produce sufficient food for domestic consumption and surplus supplies for the export market. It is recognised that this is a challenging task in the light of a rapidly growing population. The demand for food of both crop and animal origin will continue to grow. For instance, the projected demand for meat by the year 2000 is estimated to be over 500,000 tonnes annually while current production has been recorded at about 170,000 tonnes. This indicates that production of meat in Kenya must increase at the rate of about 20% annually. We recognise that this a difficult undertaking. However, it is possible to make significant progress to alleviate the deficit if resources for research and development are deployed in areas that are likely to respond quickly. Sheep and goats whose population is currently estimated at 19 million have some inherent characteristics such as high reproductive efficiency that can enable them to respond fast to increased meat production if provided with proper management.

Deficiencies in milk production in the country are being recorded despite current campaigns to develop the dairy cattle industry. The estimated annual production of milk has been reported as two billion litres. It is projected that the Kenyan population will require about three billion litres of milk annually by the year 2000. This is another area where small ruminants could play a major role.

Currently, contribution of this class of livestock to the recorded milk production is estimated at a low figure of about 30,000 tonnes per year. However, the contribution of milk from small ruminants to the nutrition of rural population, particularly in the semi-arid and arid areas, cannot be overlooked. Most of the world has gone dual purpose and it is only fair that this is looked at in respect to the goat.

For nearly twelve years, the Small Ruminant Collaborative Research Support Programme (SR-CRSP) in Kenya has carried out commendable research on development of a goat that can produce both meat and milk. The findings of these research efforts are indeed encouraging. I am aware that you researchers have constantly exchanged ideas on the results of these studies during the past nine workshops.

A brief look at the two-day programme shows that you will be discussing results of breeding, health, production and utilisation of feed resources not only as they apply to the dual purpose goat, but also to other goats in Kenya and neighbouring countries. The diversity of agro-climatic zones and management practices found in the areas you work in should provide for a lively exchange of ideas. I am sure this will be a learning experience for all of us.

Studies carried out in Kenya on feed production and utilisation by the dual purpose goat in small scale farms of western Kenya have shown that the potential for production of both meat and milk is high.

It is my hope that future research in this area will, in addition, be addressing the drier parts of the country where the majority of sheep and goats are found. It is very encouraging to note that involvement of farmers in the forage production, nutrition and management studies in western Kenya has yielded positive results. The socio-economic studies carried out by the multi-disciplinary team in western Kenya will provide useful information on constraints to production other than nutrition and management. I hope that the proposed programme of multiplication and release of does and bucks goes on as planned.

The current application of biotechnology for improvement and rapid multiplication of the dual purpose goat will no doubt form the basis of extensive discussion in the breeding section. It is recognised that large numbers are required before meaningful evaluation of the dual purpose goat can be achieved. As noted earlier, it is, important to evaluate the performance of the dual purpose goat in several ecological zones where plane of nutrition and disease challenge will be different from that of western Kenya.

Diseases are a major limiting factor to production and more resources should be channelled in this direction. I have in mind particularly CCPP, worms and parasites.

In the area of health, the Ministry and the farmers will be eagerly awaiting the findings of the current studies on genetic resistance to gastrointestinal nematodes. The idea of reducing production costs by cutting down on the amount of antihelmintics used in sheep and goat systems is most welcome.

Mr. Chairman, I realise that development of a breed of sheep or goats resistant to helminthiasis will take considerable time. I would like to encourage the scientists involved in this area to try some of the products of this research even before the final resistant breed is produced, that is, following along the lines of the development of the dual purpose goat where performance of first and second crosses have been assessed even before the pure dual purpose goat is evaluated.

Mr. Chairman, I am happy to note that the SR-CRSP, in addition to carrying out research, has also implemented a rigorous training programme. To date, the programme has trained a total of 31 Kenyans, 6 PhD, 23 MSc while two and five other Kenyans are undergoing training at PhD and MSc levels, respectively. This effort has been made in recognition of the fact that one of the greatest achievements of the programme will be to build the capacity of Kenyan scientists to continue research in small ruminants when the project ends.

Finally, Mr. Chairman, I am sure the Kenyan team will join me in expressing my sincere thanks to the government of the United States of America and various collaborating institutions in the USA for their continued technical and financial support to the SR-CRSP. I would also like to thank the Director General of ILRAD and his staff for availing these excellent facilities to this workshop. To all the participants of this workshop, thank you for sparing the time to share these two days with us.

Mr. Chairman, ladies and gentlemen, it is now my sincere pleasure to declare the tenth scientific workshop of the Small Ruminant Collaborative Research Support Programme formally open.

Thank you.

SESSION I

BREEDING AND SYSTEMS ANALYSIS

CURRENT STATUS OF THE KENYA DUAL-PURPOSE GOAT (KDPG) BREEDING PROJECT AT NAIVASHA

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SUMMARY

The design and present output of the KDPG is reviewed with an objective of updating the Kenyan livestock researchers and producers as to the current development level of the synthetic goat. As the KDPG is developed, information has been generated on various goat breed-type comparisons in growth, milking practice, meat characteristics, dairy yields, teeth eruption patterns, heartgirth relationships with weight, fertility and productivity and some indications of 'tolerance' to *Haemonchus* parasites. Artificial insemination (AI) and embryo transfer technologies have been tested. Some of the proven practices from this information pool have been incorporated in the technology package that will be released soon. The limits of the project in generating other information are also highlighted. The indigenous parents of the flock are being phased out and the second generation composite kids are being produced. Four-way bucks are now being sold to farmers. The first composite dam has recorded 1.3 kg of milk/day while nursing a kid. In an analysis of 102 lactations, the linear effect of lactation length (mean of 112.7±71.6 days) was the main source of milk yield variation (P<.0001) with a regression coefficient of .685±.141 kg/day. Although season of kidding had no influence on milk yield, it affected weaning weight of the kids (P<.05) that suckled about 50% of the milk associated with respective lactations with the January to March season giving the heaviest weaners and the October to December season giving the lowest weights (difference of 6.6 kg). Apparently, the F_1 and KDPG does do not differ in milk yield. Dairy and other data are being accumulated for more analyses and development of parameter estimates that are necessary for future individual animal evaluation and improvement of the KDPG.

INTRODUCTION

The KDPG breeding project at Ol'magogo farm, Naivasha, has now been in place for about 10 years. This project has been detailed previously (Cartwright et al, 1990). The project's essential objective is to synthesise a dual-purpose goat from equal proportions of two indigenous female parents of Galla and East African and two exotic male parents of Toggenburg and Anglo Nubian. Both natural service (Toggenburg males) and AI (Toggenburg and AngloNubian males) have been used. It was projected that by 1988 a gene pool of the first composites would have been formed for further breed stabilisation and selection. This was not readily achieved. Due to the early projections and possibly some over-enthusiasm from farmers and institutions who heard of and developed interest in the goat parents being used in the project, some general public enquiry has been directed to the project. Questionnaire: (1) when the KDPG will be ready, (2) whether the project produces Toggenburg dairy goats and (3) whether the project also produces pure Galla goats. This paper answers some of these enquiries and reports on the current progress of the project in terms of numbers of the KDPG gene pool and comparative lactation yield of mainly the F_1s and the 4-ways. Kid weaning weights associated with the respective lactations are also reported.

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THE PUBLIC INQUIRY

The KDPG

The KDPGs are the 4-ways and the composites. Presently, there are a total of 500 such animals at Ol'magogo with a target of establishing 1000 breeding females of the KDPG. The first composite (cross of 4-way x 4-way) females are being milked and their lactation curve will be reported in a future workshop. There are presently three second generation composite kids. We hope that by the third generation of composite breeding, there will be enough stability in the KDPG production and conformation characters to warrant breed declaration even though further refining and improvement will continue. The envisaged KDPG breed society that will be formed in consultation with the research component at Naivasha will be charged with the future development of the breed at Naivasha and in the hands of the active breed society members.

By then, the continuous selection plan for the breed that will connect the nucleus flock at Ol'magogo with those in the herds of active breeders will also be in place. These breeders will be located in both high and low potential areas of Kenya including the coastal belt. Thus, the evaluation of the breed will be on different ecological potentials and management systems, taking into consideration genotype-environment interactions. The process of looking for potential KDPG breeders has started and we hope by 1995-96 the set-up will have been concluded. In the meantime, Ol'magogo is selling excess KDPG bucks to prospective breeders at KSh 1000 so that upgrading of flocks to the KDPG can continue while progressing with nutrition and management as advocated by the technology package (Techpak) that will be released this year.

Toggenburg Goats

According to the breeding plan, the exotic dairy goats, Toggenburg and AngloNubian, were used as sires through AI technology. However, we keep a handful of pure Toggenburg to produce males to back-up the artificial insemination. The project has no objective of producing pure dairy goats because it was shown that target farmers did not have enough resources to maintain pure dairy goats. Instead, the dual-purpose goat was established as the most appropriate intermediate goat technology for these small scale farmers and that development emphasis has remained the main thrust of the project. Occasionally, excess Toggenburg bucks are sold at a minimum price of KSh 2000.

The Indigenous Breeds

Of the two indigenous female parents used in the programme, the East African is used as the basis of comparison in all the breed comparison done so far. The project, therefore, allowed the pure-breeding of the East African by natural service alongside the crossing of East African with the exotics for sound comparisons. Similar breeding for the Galla does not exist and the project does not therefore, produce Galla bucks for sale. Excess East African bucks are sold as culls for meat. Due to the urgent need to get the numbers of the KDPG we need to establish a stud, we do not sell breeding females. Females are sold on the basis of reproductive unsoundness for meat and culling is done annually towards the end of the year when there is a demand increase for slaughter goats.

Other Factors

Some of the technical and environmental factors that have constrained achieving the goal of reaching the number of KDPGs in the projected time need to be reviewed.

(a) Initial goal setting. To arrive at the KDPG goal for the small scale farmers, systems analysis technology was utilised. This approach entailed incorporating resource and market surveys to acquire base data for validation of models necessary for testing alternative goals. Farm and other relevant data for such an undertaking is seriously lacking in Kenya and it took quite some time before accumulation of relevant data could be achieved for appropriate simulation that produced the goal of the KDPG as the appropriate technology for the Kenyan smallholder with inherent flexibility of adaptation to different farming systems.

(b) Breed technology testing. Other technologies that were tested are AI and embryo transfer. Both of these are attractive technologies for faster multiplication of superior animals and possibly for use in animal conservation in gene banks. While these technologies are elegant if completely transferred and embedded into our livestock breeding industry, experimental testing can be expensive. Apart from the direct costs, indirect costs in terms of low conception rates and delay in project objectives can be very high.

(c) Technology package. For the KDPG technology to thrive, a complete package of health, nutrition and management and socio-economic acceptability had to be developed simultaneously at Kabete and Maseno. To this end, the Breeding project had to support the development of a smaller breeding site at Maseno for development of the intermediate F_1s that were used for comparative studies on-station and on-farm. While the Techpak was being developed, the pace of developing the KDPG at Ol'Magogo was slowed down.

(d) Natural disasters. Main droughts tend to strike about every 9-11 years (1964-65, 1975-76, and 1984-85). If this trend continues, a main drought could soon occur. The result could be major nutritional problems and death losses as experience in 1984-85 when even commercial feed supplements were not easily available in the market. The problem is compounded by smaller droughts between the main ones and occasional bush fires. After a drought, malnutrition and the rainstorms that soon follow can be more devastating in terms of deaths due mainly to hypothermia and pneumonia. Nutritional diarrhoea and fast worm build-up follow soon after.

INFORMATION AND TRAINED PERSONNEL OUTPUT

Information

Valuable information has been generated on various production components of the KDPG and other breed types on the basis of East African that has application in the breeding management of goats in Kenya and other areas of the tropics.

On body weights, growth and gestation length, mature weights of East African and Galla were 31 and 35 kg. respectively (Ruvuna et al, 1988a). With Galla having superior maternal ability over East African (Ruvuna et al, 1991a), Galla does tended to lose more weight during lactation than East African does. Mean gestation length of the does was 149 days and the value of crossbreeding indigenous goats with exotics for faster growth was demonstrated. Toggenburg and Anglo Nubian sires showed similar growth rates. On milking and rearing methods (Ruvuna et al, 1988b) based on milk output and kid growth, daily partial milking incorporating residual milk was found suitable for smallholder farmers while giving reliable milk yield estimates for animal evaluation.

For easier and reliable estimates of weight and age on-farm, results are indicating an earlier eruption of first 3 incisor tooth pairs of 4-way crosses, F_1s and indigenous breeds, respectively, within the limitation of small sample size (Okeyo et al, 1991). Monthly heartgirth measurements, on the other hand, could estimate body weights, possibly within breed type with appropriate regressions to be developed after accumulating sufficient data on the KDPG (Ahuya et al, 1991).

One of the main production components for the KDPG is milk yield which is projected to satisfy the dairy demand of a farm family keeping three or more does. With a mean of about 1 litre of milk/doe/day in the morning only (Mwandotto et al, 1991), the 3-doe model seems a satisfactory replacement of a cow if kidding dates can be appropriately staggered across the year and given that accelerated kidding management can produce more than one kidding per year from a doe. The extremely low milk yield of the East African does at Ol'magogo which necessitates regular foster-mothering supports the original finding that East African goats are not suitable for dairy purposes.

Some meat characteristics observed on the breed types at Ol'magogo indicate that Toggenburg and Anglo Nubian sire breeding did not differ in meat traits while the Galla dam breeding gave higher slaughter weight and dressing percentage than the East African dam breed (Ruvuna et al, 1991b). Male castration increased total carcass internal and kidney fat, implying that castration can be used as a management tool to produce a desired meat quality in goats.

On the resistance to *Haemonchus contortus*, Rohrer et al (1991) showed that egg per gram (EPG) count and packed cell volume (PCV) characters are heritable (h^2=397 and .185, respectively) indicating that resistance to *Haemonchus* infestation can be selected for. This knowledge has management implications on lowering the maintenance costs of goat flocks by utilising less antihelmintics in producing a KDPG biologically resistant to *Haemonchus*. This approach may even be more useful given the findings reported elsewhere in this proceedings that there is increased resistance of this nematode to present antihelmintics in the market.

While individual production component evaluation is important, combined productivity estimates (Okeyo et al, 1992) gives a more valid comparison, especially where many breed types (including indigenous breeds) are involved. Some of the information noted above has been summarised in a technology package that will be released this year for field use by the extension service, research and training institutions. It is expected that the package will have ready application in other developing countries, particularly in Africa.

Trained Personnel

In the course of the development of the KDPG, many Kenyans have been trained up to the MSc. degree in animal breeding. These personnel are now enhancing small ruminant technology in the Kenya in research, training, extension and actual production fields. One officer is at the breeding site at Ol'magogo while one is placed at Ministry of Livestock Development (MoLD) headquarters. The MoLD is the main extension agent for livestock research information. One officer is the Principal of Embu Training Institute, two are senior lecturers at Egerton University and one is a lecturer at the University of Nairobi. One graduate student is doing private goat stud breeding. We currently have one graduate in training and we hope to train one more in reproductive physiology to perfect embryo transfer technology with our local experimental goats.

All personnel who have taken up engagements elsewhere have maintained strong links with the Ol'magogo KDPG project. Most farmers who come to buy our excess bucks are directed by them to us. The lecturer in Nairobi university is one of our strong collaborators in data analyses and presentations in our annual workshops and the private farmer buys our bucks. The latter promises to be one of our projected strong members of the KDPG breeders society when it is formed.

ANALYSES OF 102 LACTATIONS AND ASSOCIATED WEANING WEIGHTS

To further update our information base, 102 lactations completed last year were analysed together with the weaning weights that were associated with the lactations for main factors affecting their variations. Lactations that were less than 40 days (mainly for East African and Galla, Mwandotto et al, 1991) were not included in the analyses.

Data and Analysis

This elimination left 10 indigenous 76 F_1 and 16 4-way doe lactations in the analysis with a mean yield of 79.5 ± 96.3 ltrs in a mean of 112.7 ± 71.6 days; mean weaning weights were 10.13 ± 2.87 kg. The lactation yield is less than that of 81.6 kg from Boer x East African crosses reported by Banda et al, (1992) in Malawi. These lactations were from does that were managed according to Mwandotto et al 1991. Data were analysed with the LSMLMW mixed model program of Harvey (1987) which allows for data analysis with unequal subclass numbers. The fixed model fitted for lactation yield included doe breed, year of birth, lactation length (both linear and quadratic), season (January - March = 1; April - June = 2; July - September = 3 and October - December = 4), age of dam at parturition and doe body weight change during lactation. For the associated weaning weights, the model included year, season, breed of kid and dam body weight change during lactation. All these effects were tested against random error that was assumed $N(0,\sigma^2e)$.

RESULTS AND DISCUSSION

Lactation yields

Of all factors analysed, only the linear effect of lactation length had a significant influence ($P < .0001$) in milk yields with a regression coefficient of milk yield on mean lactation length of $.685 \pm .141$ kg/day. Lactation length showed great variations. In developing the KDPG selection for stable lactation, length will have to be done. The target lactation length for the breed is a minimum of 120 days. Short lactations appears to be the main cause of low milk yields in indigenous goats. It is common practice at Ol'magogo to foster-feed kids of these very low yielders. Foster dams in all cases are crossbred does which tend to milk beyond weaning age. Depending on weaning season, such dams occasionally wean their kids at increasing levels of milk yield. These dams become ideal foster mothers as long as fostering and extended lactation does not interfere with effective recycling and rebreeding. Since in this study the dams were able to complete their lactations without significant body weight changes, it can be expected that their fertility is not negatively affected by yields.

Lack of doe breed effect on lactation yields ($P > .05$) in this study is an interesting result. Most of the does milked were F_1s and 4-ways. It was reported earlier (Mwandotto et al, 1991) that the greatest improvement in milk yield from the indigenous base was at the F_1 level of crossing. It appears from the present study that further improvement in yields at the 4-way crossbred level is only slight. This could be due to some loss of hybrid vigour in subsequent generations. This will be a subject of further study as the KDPG composite is refined. The first composite dam to be milked has so far recorded a yield of 1.35 kg/day under Ol'magogo management. The similarity in potential milk yield of the F_1s and the 4-ways validates the on-farm testing and evaluation of the KDPG technology (Semenye et al, 1989) that has so far been done in western Kenya. The technology package mentioned above was based on the use of F_1s as biological proxies to the KDPG. The Ol'magogo study shows that the proxy model is valid enough in the generation of the Techpak for future utilisation in the management of the KDPG. Therefore, the Techpak may have long-term usage in the development of the small ruminant industry in Kenya. The results also indicate that crossbreeding has created a good and wide enough genetic base that will be used in the future in individual animal evaluation of the KDPG as emphasis gradually shifts from breed comparisons.

Weaning Weights

The environment effects of year and season had significant influence on weaning weights of kids ($P<.05$) but breed and the covariate body weight change of dam had no effect on weaning weight ($P>.05$). The least square means for the significant effects are shown in Table 1. With the limitation of few observations that are highly disproportional, the mean weights compare well with those reported by Ruvuna et al (1988a) for crossbred kids. Low weaning weights in 1991 could be associated with low rainfall in that year. The drought could have imparted a negative influence on the growth of kid by weaning age due to low availability of quality grazing forages around the barns where kids are raised.

Table 1. Weaning weight least squares means ± SE for years and seasons

Effect	No.	Least Squares Means (kg)
μ	72	10.37±1.72
Year		
1989	39	13.06±1.14
1990	38	10.66±0.99
1991	3	7.39±1.90
Season		
January - March	2	14.29±2.55
April - June	18	9.89±0.91
July - September	17	9.66±1.08
October - December	35	7.64±0.97

Season has been shown to affect goat productivity in arid areas (Carles et al, 1990). In the present study, a difference of 6.6 kg in weaning weight was recorded between season 1 (January to March) and season 4 (October to December). Based on weaning weights, an indication of seasonal breeding is advanced. As we consider overall productivity of the flock, however, seasonal breeding may not be appropriate in view of family requirements for the continuous supply of dairy products. There may also be possibilities of year x season interactions influencing productivity. Such effects could not be tested due to the small data set. The seasonal effects on different components of productivity and the existence of interactions may make productivity indices have low repeatability, hence lowering their usefulness in animal evaluation.

As data accumulate on the KDPG, more reliable estimates of these factors will be generated and possible interactions will be tested. This information will be useful in developing the necessary parameter estimates for future individual animal evaluation and improvement of the KDPG. In the next season, the first lactation and growth from birth to weaning of the KDPG composites will be presented.

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APPLICATION OF A NUCLEUS BREEDING PROGRAMME IN THE DEVELOPMENT AND IMPROVEMENT OF THE KDPG

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INTRODUCTION

A well-designed breeding programme combines management, nutrition and breeding considering inputs and outputs that meet the needs of producers possessing varying resources and abilities. For KDPG development, the breeding goals emphasised output of dairy milk and sale liveweight, considering environmental constraints of smallholder production systems. Therefore, the suitable strategy was one of optimisation of production, reproduction and adaptability rather than maximisation of output. Hence, the adopted breeding strategy was to develop a composite breed (Ruvuna et al, 1990) involving the incorporation of adaptive traits of indigenous and productivity traits of exotic breeds which would exploit and retain maximal heterosis and would create a wide base population amenable to selection for total merit.

The KDPG development project is based on the nucleus breeding concept. A nucleus breeding programme is designed so that genetic improvement is achieved within a small sub-population in which extensive record keeping is possible and advanced reproductive technologies such as embryo transfer (ET) and artificial insemination (AI) can be used to maximise genetic progress. From this nucleus, improved animals are distributed to producers to effect genetic progress. The nucleus breeding concept is advocated as potentially the optimal livestock improvement strategy in environments where field progeny testing and AI are not possible due to the lack of widespread recording infrastructure.

The KDPG strategy was unique in that a goat simulation model and data by the SR-CRSP on the production resources of smallholder farms were available to determine the optimum genotype characteristics of a new composite breed for western Kenya. Thus, it was possible to match inputs with breed characteristics to optimally fit the prevailing conditions. This paper describes the nucleus breeding strategy employed in the development of the KDPG, focussing on aspects of base population screening, selection, stabilisation, multiplication and distribution.

Base Population Establishment

A goat simulation model using experimental and field data provided the following "benchmark" breeding, forage and management technologies as the basis for developing an optimal KDPG for smallholder farmers in western Kenya:

(1) The optimal goat was identified to possess a genetic potential of 40 kg for mature doe size and 4.0 kg peak lactation daily milk yield (40/4.0). A goat possessing a 40/3.0 genetic potential was identified as satisfactory for forming the base flock.
(2) The base forage production of a western Kenya smallholder was insufficient to support viable KDPG flock production (without improved management intervention).

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(3) For an average family of five, a flock size of six does was required to sustain minimal milk supply throughout the year.

Based on the matching of genotype and production resources using systems analysis, crossbreeding on a continuing basis to utilise heterosis and to introduce higher milk yield was ruled out because it required adherence to a breeding plan that was not feasible for smallholders. Selection and breeding of higher-yielding goats from among the indigenous breeds was also ruled out because of the duration required to reach the desired level. A composite breed was synthesised from two native breeds, East African (E) and Galla (G) and two higher yielding imported breeds, Toggenburg (T) and Anglo Nubian (N), known as the KDPG (1/4T x 1/4N x 1/4E x 1/4G), was determined to be the most suitable and manageable approach with an end product likely to be better than any alternative. The detailed mating plan to produce the KDPG was presented by Ruvuna et al (1990).

A nucleus foundation flock of does of the two indigenous breeds was established under controlled conditions at Ol'magogo, a Kenya Government farm. The population was established by purchasing does with high potential for milking ability from all districts in Kenya known to have goats. Screening of these does was on the basis of udder development and size, since there were no production records kept. For an animal to qualify for purchase, it had to have had at least one kidding and be less than four years of age (determined by dentition). The intense screening in conjunction with the premium price offered to farmers as an inducement to sell the best animals, provided the opportunity to secure the best of the indigenous animals under prevailing conditions. Toggenburg and Anglo Nubian bucks or semen were imported from Britain or the US to use on indigenous breed does to form a population of F_1 animals. The F_1's were mated to produce the base population of KDPG from which selection and stabilisation was to originate.

KDPG Stabilisation and Genetic Improvement Strategy

Stabilisation and improvement is an important phase of the breeding programme since it will provide farmer confidence and promote widespread utilisation for the KDPG genetic resource. Milk and meat production and adaptability (especially resistance to internal parasites) are the major selection criteria. Table 1 summarises current levels of growth and milk production of KDPG.

Table 1. Weights and growth rates of the indigenous breeds, F_1 and four-way (KDPG) goat breed groups at Ol'magogo

	Breed or Cross[1]			
Character	E	G	F1	KDPG
Preweaning				
No. of records	208	64	837	96
Birth weight, kg	2.0^a	2.6^b	2.4^b	2.4^b
Weaning weight, kg	8.6^a	9.0^a	10.4^c	10.9^c
Postweaning				
No. of records	62	9	334	81
Yearling Weight, kg	15.7^a	20.4^b	18.9^b	19.6^b
Milk Yield, kg/d	.089	.542	.709	1.08

[1]E = East African; G = Galla; F_1 = First crosses between E and G does mated to Toggenburg (T) and Anglo Nubian (N) sires;
KDPG = 4 breed composite (1/4E, 1/4G, 1/4N, 1/4T) foundation population
[a,b,c,d] Breedtype means within a row not sharing a common superscript differ ($P < .05$).

Body weights and growth rates are within the range of values for the most promising meat goat raised under similar production systems. Milk yield is lower than targeted. Screening for resistance to

Haemonchus contortus has resulted in the identification of 38 resistant goats, using eggs per gram (EPG) as a measure of worm burden. Molecular genetic studies using randomly amplified polymorphic DNA (RAPD) markers suggest the existence of a quantitative trait locus (QTL) associated with packed cell volume (PCV). Individuals with the AP9:500 allele, which was significantly (P<.01) associated with PCV, had PCV 1.73% higher than goats without this allele (Table 2).

Table 2. Reverse genetics to identify genetic markers for resistance to Haemonchus contortus

Genetic effect	Nematode EPG (egg/g)	Coccidia COC (oosysts/g)	PCV(%)
Heritability	.37	.00	.26
AP9:500 Genotype:			
AP9:500 allele			
i. Present (+/+ or +/-)	.04	.0	.0
ii. Absent (-/-)	.0	350.1	-1.73*

*Individuals with the allele were significantly (P<.01) associated with PCV and had 1.73% PCV higher than goats without.

RAPD polymorphism was detected using 10 base oligonucleotide primers and amplified using the polymerase chain reaction. To date, 79 randomly synthesised primers have been screened yielding a total of 24 polymorphic markers. Eighteen of these have been used score a total of 82 goats defining 8 sire families. Genotype scoring was based on the presence or absence of an amplification product. Available field data include PCV, strongyle eggs per gram of feces and coccidia oocytes all sampled at 2 week intervals. An animal model with fixed effects of month of measurement, family and marker genotype was fitted to determine the level of association between marker loci and *Haemonchus* susceptibility. Month of measurement was a significant source of variation for all variables, whereas no marker effect was detected for any of the 18 scored loci for any trait (Table 3).

Table 3. Marker frequency in families segregating for resistance

RAPD Marker	Frequency +/+ and +/-	No. of Animals Scored
A5	.244	82
.7	.585	82
A10	.667	82
A11(a)	.085	82
A11(b)	.415	82
A12(a)	.329	82
A12(b)	.573	82
A16(a)	.250	82
A16(b)	.167	82
A16(c)	.333	82
B01	.829	82
B03	.134	82
B04	.073	82
B08	.049	82
B09	.720	82
B20	.098	82
C01	.475	82
C07	.463	82
C11	.329	82
C14	.512	82
C17	.083	82
D02	.333	82
D04	.917	82
D10	.146	82

Several attempts have been made at modifying PCR reaction conditions to allow differentiation of individuals that are homozygous from those heterozygous for a particular marker. To date, this has not proven possible. Further, research has examined the effects of variation in DNA concentration on the repeatability of PCR amplification products. It seems that alternate DNA fragments may be preferentially amplified with varying DNA concentrations, hence repeatability of RAPDs is a problem where DNA concentrations cannot be standardised. We are pursuing research to identify those markers that are readily reproducing and also to identify alternate markers using PCR-based approaches.

Progeny Testing

Selection based on individual performance is being phased into progeny testing as more records accumulate for different economic traits. Growth, a highly heritable character, is now near the optimal 40 kg doe weight at maturity. Milk was estimated from simulations to currently average about 3.5 kg/d at peak lactation under ideal feed and management for a mature doe and selection is targeted to increase this to 4.0 kg optimal value. Resistance to *Haemonchus contortus* has been incorporated into the breeding programme to the extent that screened resistant bucks and does are used as much as possible in the matings to produce future KDPG progeny. Marker-assisted selection for this trait will be established when and if a genetic marker is identified.

A computer program (DFREML) suitable for use in Kenya has been adapted to a personal computer to allow the estimation of genetic parameters for multiple traits. These parameters are necessary for the application of statistical models for the prediction of breeding values of individual goats using Best Linear Unbiased Prediction (BLUP), which allows a more efficient selection programme. The program can handle data with any kind of pedigree structure and employs an individual animal model. The statistical basis for DFREML as provided by Meyer (1985, 1986, 1987) and Smith and Graser (1986).

MULTIPLICATION AND DISCUSSION

To establish the KDPG as a viable breed available to all Kenyan farmers requires establishing nucleus breeding flocks in collaboration with private and institutional breeders. The plan is to identify 3 - 5 private farmers or institutions to work closely with KARI and the SR-CRSP breeding project. Figure 1 shows proposed functions and linkages between KARI, the SR-CRSP and the private sector for KDPG multiplication and distribution. It is expected that the major supply of KDPGs to other farmers will be through these core breeders, although there may be some releases directly from the Ol'magogo foundation flock. The principal role of the Ol'magogo foundation flock during the multiplication and distribution phase is the genetic improvement of the KDPG so that it is truly a superior dual-purpose breed, adapted to Kenya, with the potential to produce milk and meat at an optimal level for farm families. The flock will be maintained in a long-term programme as an elite flock, where detailed production records will be collected and an intense genetic improvement plan followed.

A basic data collection regimen will be necessary in the core private breeders' flocks, supervised by the SR-CRSP breeding project resident scientist for progeny testing sires. This data collection will be a condition of participation in the nucleus programme for the private breeders. The proposed plan will be a joint venture between the SR-CRSP and KARI and the core private breeders, each providing incentives, as well as checks and balances, to the other - all to the betterment of the KDPG and farm families who will utilise this new breed. This strategy will provide the opportunity to evaluate KDPG performance on-farm as well as on-station and will also allow the development of the infrastructure for the orderly transition of the project to the Kenyans after the SR-CRSP terminates its research programme.

Attempts are being made to speed up multiplication of the KDPG using multiple ovulation and embryo transfer (MOET). In smallholder environments that lack a developed recording system, a nucleus breeding system coupled with MOET may offer the best approach for maintaining and improving production. Initial results with MOET conducted in 1991 are that out of 140 transfers, only 29 kids were born. Increased competence of AI and MOET with goats must be emphasised in order to more effectively disseminate superior genetic stock across Kenya and to meet future export opportunities.

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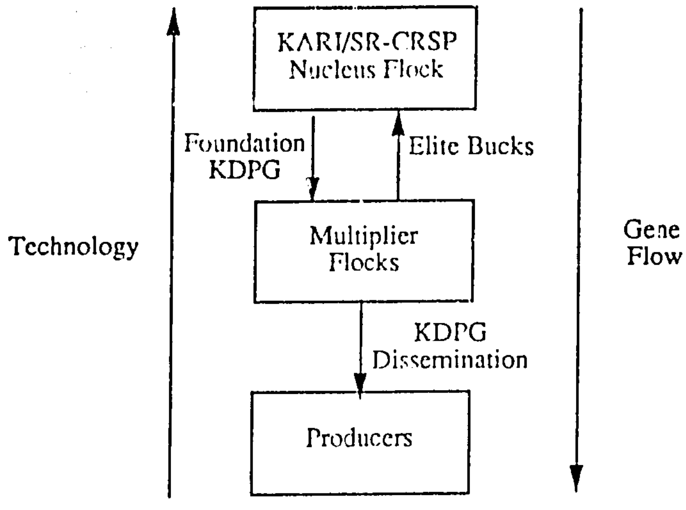

Figure 1. Functions and linkages between the government and private sector in the multiplication and dissemination of the KDPG.

REGRESSION MODELS FOR ESTIMATING GENETIC PARAMETERS FROM CROSS- BREEDING DATA

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INTRODUCTION

Crossbreeding research programs are directed towards performance evaluation of hybrid animals in comparison to their purebred contemporaries to detect additive genetic and specific heterotic effects expressed in breed combinations. If different breeds combination heterotic effects are confounded with breed effects, then the breed comparisons will be biased and will not reflect the direct genetic differences among the breeds. These problems arise from the confoundings leading to dependencies in the coefficients of the least squares equations.

Regression models are increasingly being used to disentangle the confounding problems in crossbreeding data, because regression coefficients do not usually create dependencies in least squares equations and are simple to use. These regression models are based on a reparameterization of breed effects into additive and non additive genetic effects expressed as regression coefficients (Touchberry 1970; Koger, 1975, Robinson et al., 1981; Elzo and Famula, 1985). With this parameterization, there are as many regression coefficients as there are number of breed groups represented in the data set, and therefore, no more regression can be estimated than there are degrees of freedom associated with the total number of breed groups.

Often, crossbreeding involves one or more imported breeds via semen that is used on indigenous breeds, resulting in crossbreds with no reciprocal crosses or contemporary purebred progeny of the imported breeds. Data arising from such designs tend to have relatively few levels of breed groups represented, resulting in problems of estimability. There is need for identification and evaluation of breeds to recommend for importation based on the importing country and given the unbalanced types of mating designs employed. The purpose of this paper is to present alternative regression models and evaluate their limitations for estimating additive and heterozygosity effects from different crossbreeding data structures. Regression models considered are the Robinson Genetic model; Sire-Dam Genetic model, Sire Genetic model and Dam Genetic model. The KDPG data structure is used to illustrate parameter estimates and confounding problems.

REGRESSION MODELS

Relative to a complete diallel mating plan involving n parental breeds, four basic data structures defined by the presence or absence of specific progeny breed groups are possible that result in a degree of balance of breed representation. The figure below shows a hypothetical example representing the four progeny data structures arising from matings of 4 purebred parental breeds.

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Figure 1. Example of crossbreeding data structures showing different degrees of balance of progeny breed groups

	Data1				Data2				Data3				Data4			
	♂				♂				♂				♂			
♀	A	B	C	D	A	B	C	D	A	B	C	D	A	B	C	D
A	X	X	X	X	X	X	X	X		X	X	X		X	X	X
B	X	X	X	X		X	X	X	X		X				X	X
C	X	X	X	X			X	X	X	X		X				X
D	X	X	X	X				X	X	X	X					

The X represent cells with data on progeny breed groups

The possible progeny breed groups represented are:

1. All possible straightbreds, F1 crosses and their reciprocal crosses (complete diallel) totaling n^2 progeny breed groups (Data1).

2. All possible straightbreds and one set of F1 crosses (no F1 reciprocals) totaling n(n+1)/2 progeny breed groups (Data2).

3 All F1 crosses and their reciprocal crosses totaling n(n-1) progeny breed groups (Data3).

4. Only F1 crosses from matings of males from breed i to females of breed j; for i>j=1,...,n-1 totaling n(n-1)/2 progeny breed groups (Data4).

Other data structures are possible that involve combinations of two or more of the different breed groups but these result in a further loss of orthogonality of design. Depending on the data structure, one or more of the following regression models may be appropriate for the estimation of additive and non-additive genetic effects assuming a fixed effects model

1. Robinson Regression Model (RO)
2. Sire- Dam Genetic Regression model (SD)
3. Sire Genetic Regression model (SI)
4. Dam Genetic Regression Model (DA)

In this paper, presentation and comparison of these 4 regression models will be restricted to the estimation of additive and heterozygosity effects. However, these models may be readily extended for the estimation of breed maternal, breed paternal, average heterosis and specific heterosis effects as discussed by Robinson et al. (1981).

Assume fixed effects models of random matingbreeds with arbitrary gene frequencies at all loci. For each model, the regression parameters are defined as functions of the gene frequencies and additive and dominance effects summed over all loci. If the interest is to obtain estimates of additive and heterozygosity effects using regression, the general underlying genetic model (Robinson et al, 1981) is as follows:

$$C_{ij} = \mu + \Sigma r_i a_i + \Sigma r_j a_j + \Sigma r_{ij} h_{ij} + e_{ij} \qquad (1)$$

where:

C_{ij} = phenotypic expression of ijth cross progeny; μ is the overall genetic mean; r_i is the expected proportion of genes in individuals from sire breed i; r_j is the expected proportion of genes in individuals from dam breed j; (a_i and a_j) are the additive effects of i^{th} and j^{th} breeds. r_{ij} is the expected proportion of loci in individuals with one allele from the i^{th} breed and the other from the j^{th} breed; h_{ij} is a heterozygosity (dominance) effect due to the interaction between the two alleles at the same locus; Σ is summation across all loci; and e is a random error term. Following the notation of Gardener and Eberhart (1966), $\mu + a_i$ is the breed additive effect which represents the contributions of homozygous and heterozygous loci of the i^{th} breed. In the absence of inbreeding, these cannot be partitioned and are collectively refereed to as "additive effects". The h_{ij} are heterozygosity parameters that are due to differences in gene frequencies between breeds i an j to dominance. They are expressed when breeds i and j are crossed. Again, these concepts might be expanded to include paternal and maternal effects as well as maternal and paternal heterosis (Robinson et al., 1981).

We will illustrate the application of the four regression models using a hypothetical data set of birth weights. Suppose we have a sample of progeny from four breeds of sire and four breeds of dam derived from a random mating population, and there are 5 progeny per breed group and subclass means are as in Table 1:

Table 1. Hypothetical birth weight (kg) data of progeny from crossing four parental breeds

Sire Breed	A	B	C	D
A	51.54	69.05	56.61	64.18
B	54.92	71.47	54.25	59.83
C	59.86	69.61	48.30	65.45
D	57.07	62.52	44.96	59.74

We assume that the true genetic model for this data set comprises sire additive, dam additive, heterozygosity and reciprocal effects. The model assumes that heterosis is due to dominance and that the reciprocal effects are due to sex linkage or mitochondrial genome effects.
Based on (1), the statistical models are as follows:

RO: $Y_{ijk}=\mu + a_A r_A + a_B r_B + a_C r_C + a_D r_D + h_{AB} + h_{AC} + h_{AD} + h_{BC} + h_{BD} + h_{CD} + h'_{AB} + h'_{AC} + h'_{AD} + h'_{BC} + h'_{BD} + h'_{CD} + e_{ijk}$

SD: $Y_{ijk}=\mu + s_A r_A + s_B r_B + s_C r_C + s_D r_D + d_A r_A + d_B r_B + d_C r_C + d_D r_D + h_{AB} + h_{AC} + h_{AD} + h_{BC} + h_{BD} + h_{CD} + h'_{AB} + h'_{AC} + h'_{AD} + h'_{BC} + h'_{BD} + h'_{CD} + e_{ijk}$

SI: $Y_{ijk}=\mu + s_A r_A + s_B r_B + s_C r_C + s_D r_D + h_{AB} + h_{AC} + h_{AD} + h_{BC} + h_{BD} + h_{CD} + h'_{AB} + h'_{AC} + h'_{AD} + h'_{BC} + h'_{BD} + h'_{CD} + e_{ijk}$

DA: $Y_{ijk}=\mu + d_A r_A + d_B r_B + d_C r_C + d_D r_D + h_{AB} + h_{AC} + h_{AD} + h_{BC} + h_{BD} + h_{CD} + h'_{AB} + h'_{AC} + h'_{AD} + h'_{BC} + h'_{BD} + h'_{CD} + e_{ijk}$

Where: Y_{ijk} is an observation of birth weight on an individual progeny; μ is population constant; a,s,d,h,h' represent the regression coefficients for partitioning the progeny breed group effect into additive, sire genetic, dam (additive and maternal) genetic heterozygosity and reciprocal effects, respectively; r are coefficients for each breed group combinations as defined in (1); and e is a non-observable random error with null mean and variance σ^2_e. The 4 regression models differ in the derived covariates and the assumed underlying genetic model. The SD is the optimal model in that it is parameterised to reflect all possible underlying genetic effects. However, it is overparameterized because it has 21 parameters for a design with 16 cell means. Nevertheless, informative contrasts among model parameters are estimable. The other 3 models which are reduced parameterizations over SD either confound effect from the "true" genetic model or ignore them (pooled in the error). Ignoring certain model terms will influence the estimation of model parameters from unbalanced data.

Table 2 shows the coefficients for each model for the data in Table 1. Estimates of parameters from the hypothetical data for additive and heterozygosity effects from the 4 models were obtained using GLM (SAS, 1985). The imposed constraints followed strategies commonly reported in literature (Robinson et al)., 1981 Elzo and Famula 1985) for these regression models for estimating crossbreeding effects. Due to the linear dependencies of breed additive ($\Sigma a_i = 1$), sire genetic ($\Sigma s_i = 1$), and dam genetic ($\Sigma d_j = 1$) effects, regression coefficients were obtained as deviations from breed A additive, sire A genetic and dam A genetic effects, respectively. For data structures that allow reciprocal effects these estimates are provided.

Table 2: Coefficients for effects in breed groups used in different regression models[a]

Breed group[b]	Sire Additive[1] A	B	C	D	Additive[2,3] A	B	C	D	Dam Additive[2,4] A	B	C	D	Heterozygosity[1,2,3,4] AB	AC	AD	BC	BD	CD
A	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0	0
B	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0	0
C	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0	0
D	0	0	0	1	0	0	0	1	0	0	0	1	0	0	0	0	0	0
AB	.5	.5	0	0	1	0	0	0	0	1	0	0	1	0	0	0	0	0
AC	.5	0	.5	0	1	0	0	0	0	0	1	0	0	1	0	0	0	0
AD	.5	0	0	.5	1	0	0	0	0	0	0	1	0	0	1	0	0	0
BC	0	.5	.5	0	0	1	0	0	0	0	1	0	0	0	0	1	0	0
BD	0	.5	0	.5	0	1	0	0	0	0	0	1	0	0	0	0	1	0
CD	0	0	.5	.5	0	0	1	0	0	0	0	1	0	1	0	0	0	0
BA	.5	.5	0	0	0	1	0	0	1	0	0	0	1	0	0	0	0	0
CA	.5	0	.5	0	0	0	1	0	1	0	0	0	0	1	0	0	0	0
DA	.5	0	0	.5	0	0	0	1	1	0	0	1	0	0	1	0	0	0
CB	0	.5	.5	0	0	0	1	0	0	1	0	0	0	0	0	1	0	0
DB	0	.5	0	.5	0	0	0	1	0	1	0	0	0	1	0	0	0	0
DC	0	0	.5	.5	0	0	0	1	0	0	1	0	0	1	0	0	0	0

[a]The heterozygosity and reciprocal coefficients are combined in this table
[b]Breed of sire is identified by first symbol of the cross
[1]Coefficients for Robinson regression model (RO)
[2]Coefficients for Sire-Dam regression model (SD)
[3]Coefficients for Sire regression model (SI)
[4]Coefficients for Dam regression model (DA)

RESULTS COMPARING REGRESSION MODELS

The numerical solutions to the hypothetical data for additive and heterozygosity effects from the 4 models applied to data structure subsets of Table 1 are presented in Table 3.

Table 3. Additive and heterozygosity estimates from different regression models

	Data1				Data2			
Estimate	RO	SD	SI	DA	RO	SD	SI	DA
a_B-a_A	19.93				19.93			
a_C-a_A	-3.24				-3.24			
a_D-a_A	8.20				8.20			
s_B-s_A		3.69	19.93			Nest	19.93	
s_C-s_A		1.02	-3.24			Nest	-3.24	
s_D-s_A		-1.26	8.20			Nest	8.20	
d_B-d_A		16.24		19.93		Nest	19.93	
d_C-d_A		-4.26		-3.24		Nest	-3.24	
d_D-d_A		9.46		8.20		Nest	8.20	
h_{AB}	7.55	.48	17.51	-2.41	7.55	Nest	17.51	-2.41
h_{AC}	6.69	8.31	5.07	8.31	6.69	Nest	5.07	8.31
h_{AD}	8.53	4.98	12.64	4.43	8.53	Nest	12.64	4.43
h_{BC}	-5.63	2.05	-17.22	5.95	-5.63	Nest	-17.22	5.95
h_{BD}	-5.77	-4.43	-11.64	0.08	-5.78	Nest	-11.64	0.08
h_{CD}	11.41	1.17	17.13	5.69	11.41	Nest	17.13	5.69
h'_{AB}	-6.59		-16.55	3.38				
h'_{AC}	9.94		11.56	8.32				
h'_{AD}	1.43		-2.67	5.53				
h'_{BC}	9.73		21.31	-1.85				
h'_{BD}	-3.08		2.78	-8.95				
h'_{CD}	-9.06		-14.78	-3.34				

RO = Robinson genetic model; SD = Sire-dam genetic model;
SI = Sire Genetic model, DA = Dam genetic model
Nest = No estimate

DATA 1: Assuming equal sire and dam additive effects (i.e., negligible maternal effects) and equal heterozygosity of each cross and its reciprocal, all 4 models provided equivalent estimates of additive and heterozygosity effects. It is important to note the following equalities of estimates obtained from the 4 models:

1. The additive estimates (Σa_i) from RO were equivalent to sire genetic effects (Σs_i) from SI, equivalent to dam genetic (Σd_i) effects from DA, and equivalent to the aggregate of sire and sam genetic effects ($\Sigma s_i + \Sigma d_i$) from SD.

2. Estimate of Σh_{ij} from SD were equivalent to 1/2 ($\Sigma h_{ij} + \Sigma h'_{ij}$) from each of RO, SI and DA.

3. Estimates of Σh_{ij} and of Σh_{ij} from RO were, respectively, equivalent to the average of Σh_{ij} from SI and DA, and to the average of Σh_{ij}, from SI and DA.

4. The rankings of specific breed heterosis combinations based on Σh_{ij} and $\Sigma h'_{ij}$ were different.

For completely balanced diallel data, either of the regression models was suitable for analysis. The SD has the advantages of providing maternal additive effects as the difference between direct additive sire and dam genetic effects. It is theoretically the best model. Comparison of specific breed combination heterosis based on data on crosses without information on the reciprocals may provide incorrect ranking.

DATA 2: Assuming equal direct sire genetic and dam genetic effects, and equal heterozygosity of each cross and its reciprocal, SD parameters were not estimable, because the number of parameters to be estimated were greater than the number of progeny breed groups in the data set. Direct additive, direct sire genetic and direct dam genetic effects from RO, SI and DA were equal. For each cross, the RO heterozygosity estimates were equal to the average of SI and DA heterozygosity estimates. It is important to note the difference in heterozygosity estimates from Data1 and Data2 if reciprocal differences are important.

DATA 3: Considering a subclass model for this data structure, the number of estimable sire, dam by dam interaction effects are 3, 3 and 5, respectively. None of the 4 regression analyses provided the model parameter estimates under the constraints imposed, because the minimum number of heterozygosity regression coefficients for each model was 6, which was greater than the independent estimable interaction effects in a subclass model. However, it is important to note that some linear combinations among model parameters were estimable.

DATA 4: All the 4 approaches resulted in non-estimable model parameters under the constraints imposed because the number of breed groups were less than the number of regression parameters to be estimated. Again, some linear functions of the model parameters were estimable.

Overall, this example has shown that depending on data structure and the validity of the genetic assumptions underlying the models, different estimates may be obtained. Care should be taken in the interpretations of these results from regression models. There is need to understand what linear functions are being estimated for meaningful biological interpretations.

APPLICATION OF REGRESSION MODELS TO KDPG DATA

The four regression models were applied to growth data arising from KDPG goat development. The same statistical models and constraints were employed except that reciprocal effects were excluded and fixed effects of year of birth, month of birth, type of birth and age of dam at kidding were added to each model. A detailed description of the data and breeding plan were provided by Ruvuna et a. (1990). The progeny breed groups represented included two straightbred indigenous breeds, East African (E) and Galla (G), F1 crosses of the indigenous breeds with imported Toggenburg (T) and Anglo Nubian (N): TxE, TxG, NxE, NxG and four way crosses, TxExNxG. The problems of the statistical analysis of these data is that the models are overparameterized because in the mating plan no T or N purebred progeny or reciprocal crosses were produced. Under the assumed constraints, some of the model parameters were not estimable. Table 4 shows an example of the assumed underlying genetic model for each progeny breed group for RO model. The table illustrates the confounding of genetic parameters associated with the various breed groups comparisons. From the model coefficients, there are 4 additive genetic terms, 4 direct maternal terms and 6 heterozygosity terms for a total of 14 parameters. If we assume maternal heterosis effects to be negligible, then the 10 least squares equations require 3 constraints to provide estimable functions. Studies are underway to derive the appropriate constraints in the overparameterized models that will yield solutions to allow meaningful constraints of genetic parameters. One strategy being explored is to use the Echelon Function in SAS/ISL (1985) to reduce the model coefficient matrix to lower echelon form as a means of determining contrasts that will provide meaningful biological estimable functions. Table 5 provides an example of breed contrasts and solutions obtained from analysis of KDPG birth weights using RO. The statistical model for the example, considered the breed group regression effects and no other fixed effects were added to the model. These results are intended for illustration of estimable functions. From the table, the following interesting linear functions are estimable:

Table 4. Expected genetic effects of each progeny breed group

Breed Group	Expected genetic effects
E	$a_E + m_E$
G	$a_G + m_G$
ExG	$\frac{1}{2}(a_E + a_G) + m_G + h_{EG}$
GxE	$\frac{1}{2}(a_G + a_E) + m_E + h_{EG}$
TxE	$\frac{1}{2}(a_T + a_E) + m_E + h_{TE}$
TxG	$\frac{1}{2}(a_T + a_G) + m_G + h_{TG}$
NxE	$\frac{1}{2}(a_N + a_E) + m_E + h_{NE}$
NxG	$\frac{1}{2}(a_N + a_G) + m_G + h_{NG}$
(TxE) x (NxG)	$\frac{1}{4}(a_T + a_E + a_N + a_G) + \frac{1}{2}(m_N + m_G) + \frac{1}{4}(h_{TN} + h_{TG} + h_{NE} + h_{EG})$
(TxG) x (NxE)	$\frac{1}{4}(a_T + a_E + a_N + a_G) + \frac{1}{2}(m_N + m_E) + \frac{1}{4}(h_{TN} + h_{TE} + h_{NG} + h_{EG})$
(NxE) x (TxG)	$\frac{1}{4}(a_T + a_E + a_N + a_G) + \frac{1}{2}(m_T + m_G) + \frac{1}{4}(h_{TN} + h_{TE} + h_{NG} + h_{EG})$
(NxG) x (TxE)	$\frac{1}{4}(a_T + a_E + a_N + a_G) + \frac{1}{2}(m_T + m_E) + \frac{1}{4}(h_{TN} + h_{TG} + h_{NE} = h_{EG})$

a = direct effects; m = maternal effects; h = heterosis effects in offspring
E = East African; G = Galla; T = Toggenburg; N = Anglo Nubian.

Table 5. Breed parameter estimates and expected contrasts from RO

Effect	Expectation of breed contrast	Estimate
Intercept	Intercept + GA	2.8797
EA	EA - GA	-.7032
GA		.0000
TA		.0000
NA		.0000
HET21 (ExG)	HET21	-.0594
HET31 (TxE)	HET31 - 1/2GA + 1/2TA	.1045
HET32 (TxG)	HET32 - 1/2GA + 1/2TA	.3396
HET41 (NxE)	HET41 - 1/2GA + 1/2NA	.0815
HET42 (NxG)	HET42 - 1/2GA + 1/2NA	.4480
HET34 (TxN)	HET34 - GA + 1/2TA + 1/2NA	-.9375

EA, GA, TA, NA = Direct effects for East African (E), Galla (G), Toggenburg (T) and Nubian (n), respectively

Direct effects of GA - EA = .7032 kg
HET32 - HEAT31 = .2352 KG
HET42 - HET41 = .4480 - .0825 = .3665 KG
HET21 = -.0594 KG
HET31 + HET41 + HET34 = .1045 + .0815 + .9375 = 1.1235kg
HET32 + HET42 - HET34 = .3396 + .4480 + .9375 = 1.7251 kg

CONCLUSIONS

Although regression models are easy to use and are useful in analysis of crossbreeding data, they still have problems in providing unbiased estimates of genetic parameters in unbalanced crossbreeding designs. Breed solutions may be biased and may not reflect genetic differences among the breeds due to confounding. Reducing the design matrix to lower echelon form may provide the means of designing constraints that will result in meaningful biological comparisons.

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TEAT SIZE AND UDDER CONFORMATION AND THEIR RELATIONSHIP TO MILK POTENTIAL OF EAST AFRICAN AND GALLA GOATS

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ABSTRACT

Two thousand three hundred records on measurements of udder size collapsibility, teat diameter, teat length and milk yield from East African and Galla goats were analysed using GLM procedures in SAS package. Teat diameter and teat length had no significant effect ($p < .01$) on milk yield in the East African breed although they were highly significant in the Galla breed ($p < 0.001$). Phenotypic correlations were positive in both breeds but higher in the E.A. than the Galla breed.

INTRODUCTION

Goats form an important part in livestock production particularly in the arid and semi-arid areas of Kenya. In these areas, the production systems being followed can be described as extensive and hence individual animal records may not be kept by the farmers. However, this condition must be improved in order to increase their productivity. Lack of individual animal records can be a major hinderance to livestock improvement even in other species of livestock. Recording in itself is expensive both in terms of money and time, hence its unpopularity among farmers. Any simple way to assess the productivity of the animals in terms of milk production would improve objectivity in selection at the farm level.

The objectives of this study was:

(a) Comparing teat and udder size of the two indigenous breeds E.A. and Galla.

(b) To estimate correlations between teat length, udder size, collapsibility, teat diameter and milk yield.

MATERIALS AND METHODS

The data used in this study were collected from SR-CRSP Breeding project at Olmagogo field station of the National Animal Husbandry Research Centre (N.A.H.R.C.). The establishment and management of the flock has been described by Ruvuna et al 1984, 1985; Ahuya et al, 1987, 1988. Measurements for udder size, collapsibility, teat diameters and teat lengths were taken from East African and Galla breeds. Udder size was obtained by taking the distance between posterior and anterior ends of the udder. Collapsibility was the difference between the teats before and after each milking. Teat diameter was the approximate diameter of the teat at its mid-point, while the teat length was the distance from the teat's base once in the morning and once in the evening. Animals recorded were in their 1st and 5th lactations. The statistical analysis of the data were performed using the General Linear Models (G' M) procedure of the Statistical Analysis System (SAS 1987).

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Model:

Y_{ijklm}	=	$U + Uds_i + coll_j + Titd_k + Titlen_l + e_{ijklm}$
Y_{ijklm}	=	Milk yield of the m[th] doe, of l[th] teat length, k[th] teat diameter, j[th] collapsibility, i[th] udder size.
U	=	Constant to all observations
Uds_i	=	effect due to i[th] udder size
$Coll_j$	=	effect due to j[th] collapsibility
$Titd_k$	=	effect due to k_{th} teat diameter
$Titlen_l$	=	effect due to l[th] teat length
e_{ijklm}	=	randon residual error associated with Y_{ijlkm} NID $(0,0^2)$

RESULTS AND DISCUSSIONS

Table 1 shows the Analysis of Variance for milk yield in breeds E.African and Galla. Teat diameter and Teat length had no significant effect on milk yield of the E.African breed ($p<.01$) although they were highly significant in Galla breed. Udder size and collapsibility had significant effects on milk yield in both breeds. The mean values along with S.E. and C.V.% are shown in Table 2. No work on Teat and Udder measurements has been reported on indigenous goats. Great variation in the shape of Udder as a breed characteristic has been reported for various breeds of cattle by several authors, Sharma, 1967. Least squares means for Udder size, Collapsibility and Teat diameter are shown in Table 3.

Table 1. Analysis of Variance for Milk Yield

Source	Breeds		Pooled
1	2		
Udder size	*	*	*
Collapsibility	*	*	*
Teat diameter	NS	*	*
Teat Length	NS	*	*

Table 2. Least square Means, S.E. and coefficient of Variation of Udder size, Collapsibility, Teat Diameter and Teat Length

Trait	Udder size	Collapsibility	Teat diameter	Teat length
Mean	18.37(cm)	10(cm)	1.3 (cm)	3.1 (cm)
S.E.	5.6	6.8 .6	1.2	2.1

Table 3. Least Squares Means of Udder size, Collapsibility, Teat Length within Parity

Trait Udder size	East African Mean	Parity	Galla Mean
	18.72±6.2	1	18.16±6.6
	18.72±6.1	2	18.43±5.6
	18.56±3.5	3	18.13±3.3
	16.16±7.3	4	20.70±5.5
	15.12±6.5	5	17.42±3.
Collapsibility	9.64±5.6	1	11.21±5.7
	11.20±6.4	2	10.96±5.6
	10.76±6.1	3	11.29±6.0
	10.18±6.7	4	11.11±5.6
	8.14±4.6	5	9.00±5.8
Teat Length	0.9±.59	1	1.47±1.1
	1.4±1.1	2	1.35±1.1
	1.2±.7	3	1.13±.9
	1.5±.9	4	1.21±.9
	1.2±.6	5	1.11±.8

Table 4. Phenotypic Correlations Between Udder size, Collapsibility, Teat Diameter, Teat length and Milk Yield

	Uddersize	Collapsa.	Teatdiam.	Teatlen	M/Yield
Udder size	1	0.39	0.46	0.61	0.51
Collapsibility		1	0.22	0.35	0.33
Teat Diameter			1	0.48	0.34
Teat length				1	0.39
Milk Yield					1

SESSION II

SOCIO ECONOMICS

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SMALLHOLDER LIVESTOCK MARKETING PATTERNS IN WESTERN KENYA

F. Nyaribo and E. Ospina[1]

INTRODUCTION

Goats and sheep make significant contributions to Kenyan national income and food security. In 1989 about 1 million head of goats and sheep worth over K£22 million were slaughtered (Statistical Abstracts, 1990). This was a 6% increment over the previous year. These animals produce 60,000 tons of meat, 886,000 kgs of wool, and 35 million litres of milk (Kenya Agricultural Research Institute, 1991). A majority of slaughter animals come from smallholders who rear 55% of the national small ruminant flock (Winrock International, 1983). In addition to income and food security considerations, the Kenya Agricultural Research Institute (KARI) has given high priority to goat and sheep research due to their high income generation and distribution potential as well as the potential to offer better employment opportunities to the burgeoning rural population.

The Ministry of Livestock Development (MLD) and more recently KARI have been working in conjunction with the Small Ruminant Collaborative Research Support Program to develop a dual (milk and meat) purpose goat (DPG) suitable for the densely populated medium to high potential agroecological zones of Kenya. For more than a decade significant research has been carried out to develop and determine the biological and socio-economic feasibility of the DPG for smallholder resource poor farmers in the country. The DPG is a new breed based on two indigenous genotypes (Galla and East African) and two exotic genotypes (Toggenberg and Anglo Nubian).

On-farm testing of the F_1's of the DPG has been done in Siaya, Kakamega and Kisumu districts in western Kenya. So far, much of the economic research has focused on smallholder farm production aspects of the DPG and farmer supply response to this new technology. As a consequence, little research has been done to link up production with demand and markets for goats and other small ruminants. Having determined the farm level technical (can it work?) and economic (does if pay?) questions, more attention is being given to marketing and market characteristics as well as demand and demand characteristics of goat and goat product markets - all of which are important determinants of the farmer's profit margin.

Previous work in this area has identified existing markets and their distribution and quantified seasonal demand and supply of goats and sheep in selected regional and local markets (Ogada et al, 1985; Oyugi et al, 1986). Oyugi et al also presented data on live weight prices of goats, sheep,and cattle. These studies provided insight into the structure of livestock trade, regional livestock movement patterns and conduct of trade at stock yards located in open air market centres. This study builds upon this previous work and focuses on livestock trading at the producer level and analyses factors influencing sale decisions at the farm level. Some preliminary results are presented in this paper. Specific objectives are:

1. To identify local marketing channels for livestock.
2. To determine factors that influence sale decisions.
3. To quantify marketing and other transaction costs incurred by livestock producers.
4. To quantify revenues received by project participant farmers from sale of livestock.
5. To draw conclusions and implications for the marketing and diffusion of the DPG.

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Sale patterns of local goats, sheep and cattle (later referred to as 'other livestock' in the remainder of the paper) were observed in order to compare and contrast market behaviour of buyers and sellers with regard to the DPG. Marketing characteristics will also reveal to what extent the DPG technology can be widely diffused through farmer to farmer or farmer to market sales.

MATERIALS AND METHODS

Data were collected from the six study villages of Masumbi, Kaimosi, Hamisi, Lela, Rabuor and Muhanda in the months of July, August and December 1991. A total of 146 project participant farmers were interviewed once in July and August and again in December. The second interview was conducted at the end of the year in order to obtain data that reflected annual livestock inventories for the year. Standard project data collection procedures were followed in conducting the surveys. These include enumerator training on various aspects of the survey such as purpose and content of the survey and a demonstration of interview techniques. The questionnaire was also pretested to fine tune the survey instrument. To minimise respondent fatigue, any data that could be obtained from records at the research station were entered in the survey instrument before being sent to the field. For each farm household, a livestock inventory was done for goats, sheep and cattle. Data on sales included age, sex, price, reason for sale and who did the marketing. Marketing and transaction cost data included location and distance to the nearest market, time taken to reach the market, the mode and cost of transport and amount of cess (tax) paid to enter the stock yard.

RESULTS AND DISCUSSION

As in other parts of Africa, farmers in western Kenya keep their livestock mainly for sale. Rarely are animals slaughtered for home consumption. The only exceptions are on very special occasions such as family or village festivities or for cultural reasons. For example, the results of this survey from five study villages show that during the first half of 1991, only 34 animals were slaughtered while a total of 102 animals were sold. Table 1 shows a comparison of factors which influence sale decisions for DPGs and other livestock.

Table 1. Factors Influencing Sale Decisions

Item	DPG	Other Livestock
Financial need	54	43
School fees	18	32
Medical expenses	12	9
Sick animal	9	3
Poor condition	3	-
Unproductive	3	2
Land purchase	-	4
Cultural or festival needs	-	6

Source: Survey data

Of the animals sold in the last three years, 54% of DPGs and 43% of other livestock were sold in order to meet family financial needs. Some 18% of the DPGs and 32% of other livestock were sold to enable families to pay school fees. Farmers also sold some of their animals to meet emergency medical expenses in 12% (DPGs) and 9% (other livestock) of the cases. A few DPGs (3%) were sold because the farmers felt they were in poor condition or animals were sick. In this case, farmers sold their animals as a means of transferring mortality risks with an attempt to recoup some monetary gains. Two percent of the sheep, local goats and cattle were sold because they were unproductive. This figure is not significantly different from that of DPGs. About 4% of animals were sold to augment family cash balances to purchase land. And, as expected some animals were sold to raise funds to enable cultural and (or) family festivities to take place.

Figure 1 shows the various buyers of small ruminants at the producer level. Out of 149 documented sales of local goats, sheep and cattle 85% were to livestock traders, 14% were to relatives or other farmer neighbours and only 1% was sold directly to butcheries for slaughter. It is noteworthy that no farmers marketed their animals at the stock yards.

Figure 1.

BUYERS OF L. GOATS, SHEEP & CATTLE

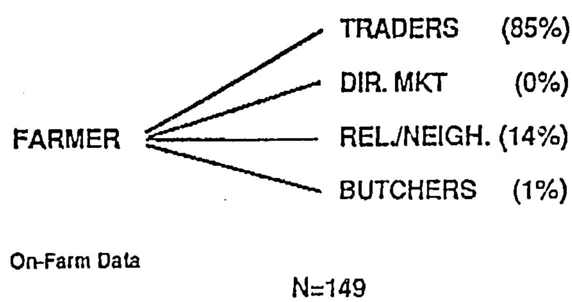
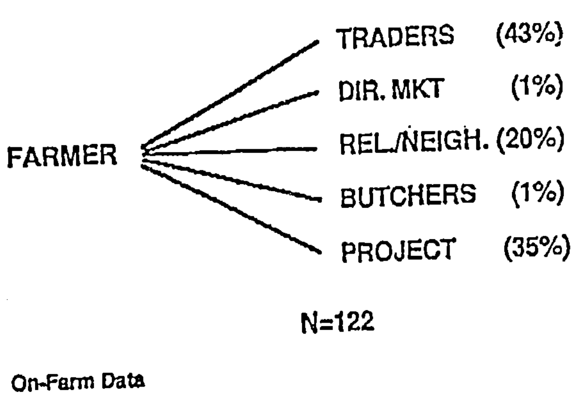


Figure 2 displays the same information but for DPGs only. The data show that 43% of the DPGs were sold to livestock traders, 1% were sold at stock yards, 20% to relatives and neighbours, 1% to butcheries for slaughter and 35% to the project. The sales to the project were based on an agreement with farmers where female offspring could be bought back by the project for research purposes. A comparison of the two data sets indicates no significant difference between sale patterns of DPGs and other livestock. In each case, livestock traders are the principal buyers of both small and large ruminants.

Figure 2:

BUYERS OF DPGs



A majority of the farmers sell their animals to livestock traders who tour the villages in search of potential sellers. In some cases, a farmer who has an animal for sale will send for a livestock trader to come to the homestead. The main reason for livestock farm gate sales is that when this kind of sale takes place, transactions costs for the farmer are almost nil. While this may be the case, farmers have stated that it gives the trader more leverage to dictate the selling price.

Project participant farmers live anywhere from three to ten kilometers to the nearest livestock market. As a consequence, a whole day is needed to sell one or more animals. This includes the time taken to walk the animal to the market, to conduct the sale and to return to the farm. Once a farmer gets to the stock yard, he has to pay a market cess (tax) to enter the stock yard. At the time of the survey for this study, the cess ranged between Ksh. 9.00 to Ksh. 15.00 per animal for entry and a similar amount for exit for every animal that is sold. The lower range is for small ruminants while the cess for cattle is on the higher range. Thus, the total tax collected per animal sold ranges from Ksh. 18.00 to Ksh. 30.00. If an animal is sold, the tax is split evenly between the buyer and the seller. In addition to these costs, if the nearest stock yard is closed due to quarantine measures or other reasons, the farmer would need to walk an additional distance to the next market. This may involve more than one day, and would include animal storage costs as well as feed costs.

Other risks that have been reported include animals dying before they are sold, a decline in selling price relative to the reservation price and repeat visits to the market before selling the animal which would further increase feed, storage, animal health costs and other miscellaneous costs such as sustenance for the seller. For these reasons, many farmers prefer to sell their animal to specialised livestock traders who can bear the costs and risks of marketing and can charge a premium for the animals.

Figure 3.

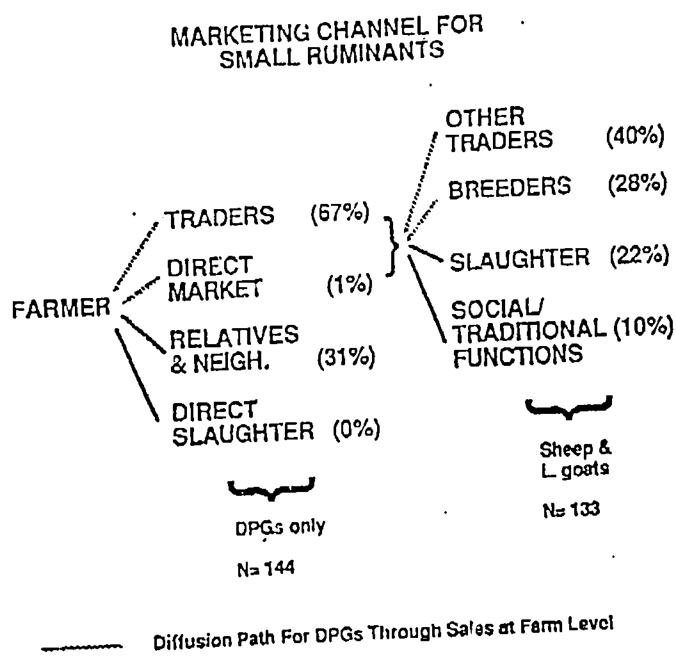


Figure 3 shows the marketing channel for small ruminants at the local level. The figure illustrates the channel at the producer level as well as sales beyond the stock yard. Data for sales of sheep and local goats beyond the stock yard were obtained from an economics marketing survey conducted in 1985. In addition to mapping out the small ruminant marketing channel, the purpose of superimposing the 1985 data on the 1991 data is to attempt to chart out a diffusion path for the DPG technology *at* and *beyond* the farm level. As was previously shown, specialised livestock traders are the principle buyers (67%) of DPGs at the farm level. These are followed by sales to relatives and neighbours (31%). Sales to relatives and neighbours were reported to be for breeding purposes. Of the 67% of the sales to traders, it can be anticipated that about 40% will be sold to other traders who are likely to market the animals outside the immediate local area. Some 22% are likely to be sold directly to local slaughter houses, while some 28% are likely to be sold for breeding purposes. Another 10% may be sold for social and traditional functions. It appears that from this market channel model, farmer to farmer sales and farmer to trader sales are significant paths through which the DPG technology can be diffused.

Table 2 indicates the value of livestock sales for 1989, 1990 and the first half of 1991. DPGs contributed about 20% of the cumulative total of livestock revenue. Sheep and local goats contributed 4% and cattle contributed 76% to total revenue.

Table 2. Value (Ksh) of Livestock Sold in Five Villages

Year	DPG	Sheep and Goats	Cattle	Total
1989	18265	3400	54825	76490
1990	14885	2270	77805	94960
1991	24825	5865	92185	122875
Total	57975 (20%)	11535 (4%)	224815 (76%)	[illegible]4325 (100%)

Source: Economics survey data, 1991
Economics survey data, 1985

CONCLUSIONS

The data indicate that DPGs have made a significant contribution to family cash income over the last few years. Farmer to farmer breeder sales are and will continue to be an important diffusion path for the new goat breed. This may be particularly important to those smallholders who cannot afford to purchase mature breeding stock from the foundation flock. As the project moves to the extension phase, there will be a need to maintain technical assistance at the divisional level where farmers can have quick and easy access to animal health and management advice.

Farmers treat their animals as bank accounts with different species taking on relative magnitudes of liquidity. The small stock are easily saleable and act as a hedge against market price risk when a farmer must sell an animal to meet emergency cash needs. The majority of animals are sold in order to meet general household financial needs, other pressing needs such payment of school fees force farmers to sell their animals for reasons other than profit maximisation. The sales pattern of DPGs at the farm level is similar to that of sheep, local goats and cattle. This suggests that the DPG is readily acceptable to farmers in the area.

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ECONOMICS OF EAST COAST FEVER VACCINE PRODUCTION

A.W. Mukhebi[1] and B.D. Perry

INTRODUCTION

East Coast Fever (ECF), caused by the parasite *Theileria parva* and transmitted by the tick *Rhipicephalus appendiculatus*, is a major disease of cattle in eastern, central and southern Africa. It is controlled conventionally by the control of ticks with acaricides. However, this method of control has become less reliable because of the high cost of acaricides in foreign currency, poor management and maintenance of dips, the development of acaricide resistance, shortages of water and uncontrolled cattle movements. Alternative strategies are being considered based upon immunisation and controlled exposure to ticks through strategic acaricide use.

At present, the only practical method of immunisation against ECF is the infection and treatment method (Radley, 1981). This involves inoculation of cattle with a previously characterised dose of sporozoites of *T. parva* and simultaneous treatment with an antibiotic.

Several studies have demonstrated that the infection and treatment immunisation is technically efficacious (e.g. Robson et al, 1977; Morzaria et al, 1985; Dolan, 1989) and potentially financially viable (Mukhebi et al, 1992), particularly in more productive but also more ECF susceptible dairy cattle. A number of countries in the affected region, including Kenya, are exploring modalities for more widespread application of this immunisation.

This paper describes a computer spreadsheet model for assessing the economics of a laboratory for producing the vaccine used in the infection and treatment immunisation. The methodological framework presented could be applied by a government, a donor or development agency or a private firm in assessing the financial viability of commercial production of the infection and treatment or any other type of vaccine for livestock disease control.

MATERIALS AND METHODS

The Laboratory

A hypothetical national laboratory costed by Mukhebi et al (1990) was used in this analysis. It was assumed that the laboratory was constructed from scratch with the intention to produce 100,000 doses of vaccine per annum priced at Kenya Shillings (KS) 50 per dose over a planning period of thirty years. The capital and operating cost components identified by Mukhebi et al (1990) were updated to 1991 price levels for Kenya and held constant over the 30-year period.

Spreadsheet Model

The structure of the model is illustrated in Figure 1. The model was developed using the Smart Spreadsheet (version 3, Innovative Software Inc.. 1986). The laboratory was assumed to earn revenue from the sale of the vaccine produced. The stream of discounted capital and operating costs was subtracted from the discounted stream of revenue. Using built-in formulae, the model calculates measures of financial viability for the laboratory such as net present value (NPV), benefit-cost ratio (BCR) and internal rate of return (IRR). The break-even vaccine price and the volume of vaccine doses produced, at which NPV equals zero or BCR equals one, can be derived by appropriately varying the level of vaccine price or doses produced in a sensitivity analysis.

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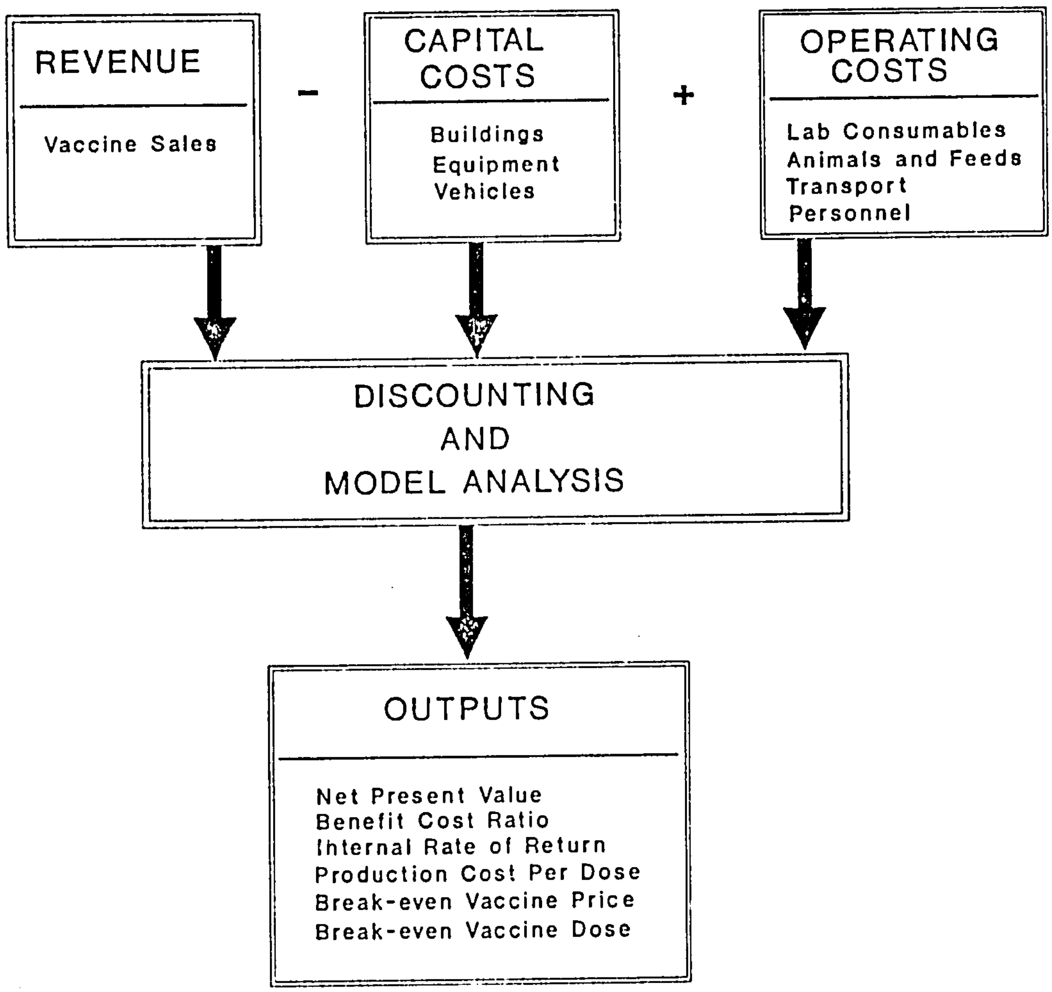

Figure 1. Structure of the analytical spreadsheet model.

Four scenarios were analysed. In the base scenario (Scenario A), it was assumed that the entire laboratory would be constructed from scratch, with all the cost components included, as well as staff houses. In Scenario B, it was assumed that the laboratory and staff houses already existed. Scenario C was like Scenario A, but with the assumption that a professional expert costing US$ 80,000 per y. foreign exchange for an initial three-year period was not required. The final Scenario D, was a combination of Scenarios B and C.

RESULTS AND DISCUSSION

Results of the base scenario (A) are presented in Table 1, in which total capital and operating cost components, revenue and discounted values are reported for the whole 30-year period in column 2. Due to the large size of the table, the results are also reported by year for the first six years only in order to illustrate the potential annual cash out-flow and cash in-flow for individual cost and revenue components, respectively, during the plan period. The surplus/deficit row shows the total annual cash-flow position and also indicates the years in which cash surpluses or shortages are likely to be experienced.

Table 1: Economics of East Coast fever vaccine production based upon hypothetical Kenya data, 1991

	Total Years 1-30 KS '000	Year 1	2	3	4	5	5
Capital Costs:							
Staff houses	2951	2951	0	0	0	0	0
Immunization laboratory	1992	1992	0	0	0	0	0
Cattle facility	598	598	0	0	0	0	0
Tick pick-up pens	371	371	0	0	0	0	0
Furniture, 5% buildings	1478	296	0	0	0	0	296
Utility works, roads, fencing 10% buildings	739	591	0	0	0	0	0
Laboratory equipment	6598	2491	0	6	0	6	66
Vehicles	4250	810	0	0	0	0	688
Miscellaneous, 15% above	2847	1515	0	1	0	1	157
Sub-total	21824	11615	0	7	0	7	1207
Operating Costs:							
Personnel:							
salaries, wages, housing and other benefits	25010	2496	2496	2496	649	649	649
Laboratory consumables	2320	80	0	80	80	80	80
Animal purchase and feeds	7308	252	0	252	252	252	252
Transport	957	8	25	33	33	33	33
Supplies and materials	712	57	50	57	20	20	20
General repairs and maintenance	10453	348	348	348	348	348	348
Sub-total	46760	3241	2920	3267	1383	1383	1383
Total capital and operating costs	68584	14856	2920	3274	1383	1390	2590
Contingencies, 10%	6858	1486	292	327	138	139	259
Total cost, Kshs.	75442	16342	3212	3601	1521	1529	2849
Revenue from vaccine sales:							
Vaccine doses produced, '000	2900	25	75	100	100	100	100
Vaccine price per dose, KS	50	50	50	50	50	50	50
Vaccine revenue, KS '000	145000	1250	3750	5000	5000	5000	5000
Other revenue, KS'000	0	0	0	0	0	0	0
Total revenue KS '000	145000	1250	3750	5000	5000	5000	5000
Remaining capital value, end yr 30	2910	0	0	0	0	0	0
Surplus+ or deficit-, KS'000	72460	-15092	538	1399	3479	3471	2151
Cummul. surplus/deficit	72460	-15092	-14553	-13154	-9675	-6204	-4053

Table 1 continued

Discounted values:							
Discount factor, i = 16%	0.8620	0.7430	0.6410	0.5520	0.4760	0.4100	
Present value of costs, KS'000	26307	14086	2386	2308	840	728	1168
Present value of revenue, KS'000	26749	1078	2786	3205	2760	2380	2050
Net present value, KS'000	441	-13009	400	897	1920	1652	882
Measures of Financial Viability:							
Net present value, KS'000	441						
Benefit: Cost ratio	1.02						
Internal rate of return	14.87						
Discounted cost of vaccine production per dose, KS	9						
" " US$	0.31						
Break-even constant price/dose, KS	49						
Break-even doses, no. '000	2887						

Source: Mukhebi et al, 1990, Cost components, Table 1, updated using derived 1991 prices for Kenya

The total discounted cost of operating the laboratory over the thirty year period was KS 26.3 million, of which 68% were operating and 32% were capital costs. The present value of revenue from vaccine sales was KS 26.7 million, yielding a NPV of KS 0.4 million, . BCR of 1.02 and an IRR of 14.87%. The discounted vaccine production cost was KS 9.00 (US$ 0.31) per dose. A sensitivity analysis on vaccine price yielded a break-even price per dose of KS 49.00, while a sensitivity analysis on the quantity of doses produced yielded a break-even amount of 96,233 doses per annum.

Results on the alternative scenarios are reported in Table 2. On the basis of NPV and BCR, the base scenario barely breaks even and scenarios D and B would be the most preferred, in that order.

Table 2: Economics of alternative vaccine production scenarios

Financial Indicator	Scenario* A	B	C	D
NPV, KS'000	441	8196	5096	12851
BCR	1.02	1.44	1.24	1.92
IRR, %	14.87	29.28	40.03	26.55
Disc vacc. cost/dose, KS	9	6	7	5
Break-even const. price/dose, KS	49	35	41	26
Break-even No. doses '000	2887	2660	2762	2465

*Scenario:
A: Building new laboratory and staff houses
B: No new laboratory and staff houses
C: No expatriate personnel
D: Combination of B and C.

CONCLUSION

This paper has presented a methodological framework for assessing the economics of the infection and treatment vaccine production. Given a stream of capital and operating costs involved, the break-even volume of vaccine to be produced, or the break-even price to charge for the vaccine can be determined. Both the components and levels of costs involved will vary depending on the circumstance being analysed.

Laboratory costs for vaccine production for a particular site and country, or for a different type of vaccine, could be established based on the same or similar approach. Cost components could be selected and incorporated according to local conditions and requirements, and adjusting prices accordingly. This approach could be used for the analysis of other types of vaccines.

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SESSION III

ANIMAL HEALTH

PREVALENCE OF GASTROINTESTINAL NEMATODES, COCCIDIA AND LUNGWORMS IN GOATS IN KENYA

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ABSTRACT

A prevalence survey of gastrointestinal parasites of goats was conducted at Ol'magogo field station from January 1989 through December 1991. Faecal eggs, oocyst, and larval counts revealed that 75% of the goats were infected with at least one type of parasite. Fifty nine percent of the adults and 67% of the kids had strongyle parasites. Twenty percent of the kids were infected with *Trichuris ovis*. Seventy seven percent of the adults and 64% of the kids had coccidia. Fifty five percent of the adult goats were infected with lungworms. Six percent of the adults and 12% of the kids had tapeworms, whereas 3% of the adults and 2% of the kids were infected with *Strongyloides papillosus*. Strongyle infections were primarily due to *Haemonchus contortus, Trichostronglus axei* and *Oesophagostomum venulosum* and the coccidian species identified were *Eimeria arloingi, E. ninakohlyakimovae, E. hirci, E. alijevi, E. christenseni, E. jolchijevi* and *E. caprovina*. The only lungworm found was *Muellerius capillaris*.

INTRODUCTION

Helminths and coccidia parasites are the most common gastrointestinal parasites of domestic animals. Subclinical manifestation is the most important ecomonic form of infection since in the majority of cases, it leads to retarded growth, delayed and reduced productivity and increased susceptibility to other infections (Allonby and Urquhart 1975; Ndarathi et al, 1989). Gastrointestinal nematodes, especially *Haemonchus contortus*, have been recognised as an important constraint in sheep and goat production in the tropics (Allonby et al, 1975). According to Preston and Allonby (1979), there is an annual loss of US$ 26 million in Kenya's agricultural sector due to *Haemonchosis* in sheep.

The goat population in Kenya stands at 7.7 million compared to 5.0 million sheep and one million cattle (Stotz, 1983). If improved for dual-purpose (meat and milk) production, goats would be an important source of the much needed animal protein in the rural populations (Fitzhugh, 1982). Currently, little is known about the importance of gastrointestinal parasites as health hazards to goats in Kenya. With the increasing interest in domestic goats as meat and milk producing animals, attention should be directed to the role of parasitism in the economics of production (Lloyd and Soulsby, 1978; Ashraf and Nepote, 1990). Parasitic infections in goats are associated with enteritis, anaemia, diarrhoea, colic, pulmonary diseases, emaciation, malnutrition, retardation of growth and even death, especially among young kids (Soulsby, 1968; Levine, 1973, 1980; Lincicome, 1982; Georgi, 1985). In spite of the increasing popularity of goats in Kenya, there is very little information about the prevalence of parasitic infections in the goat. Thus, this study was initiated to monitor the incidence and intensity of gastrointestinal nematode, coccidia, and lungworm infections in goats at Ol'magogo farm, Rift Valley Province, as a basis of other studies on the effect of parasitism on goat production in Kenya.

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MATERIALS AND METHODS

Area of Study

Ol'magogo farm is situated about 50 km to the north-east of Naivasha town, Rift Valley Province. The farm lies on latitude 0.37° East, with an altitude of 2000 masl. The farm receives an annual rainfall of about 750 mm per annum (range: 300 - 1000 mm). The long rains begin in late March and decrease in frequency towards the end of May and early June. Short rains, however, occur from mid-October through December and are generally not as reliable as the long rains. This area has a minimum and maximum temperatures of 10° and 26°C, respectively.

Experimental Design

The investigation was carried out on a breeding stock of about 1300 goats which were housed during the night and left in open pastures during the day. The survey commenced in January 1989 and ended in December 1991. The goats used in this study were either pure breeds or crosses of East African, Galla, Anglo Nubian and Toggenburg. Faecal samples were collected once a month from one or two randomly selected herds, and each herd was divided into: young animals (kids) and adults comprising does and bucks. The animals from which the samples were taken were not necessarily showing disease signs.

Faecal samples were collected from individual goats directly from the rectum and stored at 4°C until examination, which was performed within two days of collection. Counts of coccidian oocysts and helminth eggs were performed on all samples using a modified McMaster technique (Davis 1973; Georgi, 1985). The minimal detectable egg count used was 100 egg/g of faeces (EPG). Eggs of the following genera were counted: *Strongyloides, Trichuris* and *Moniezia*. Other strongyle Ova were not distinguished and were recorded as strongyle eggs. Faecal samples were assayed for lungworm larvae by a modified Baermann technique (Georgi, 1985). Faecal samples with high strongyle egg counts were pooled and single, bulk faecal cultures prepared. Nematode parasites were identified based on the total length of the larvae and tail structure or cuticular extension (Boev, 1957; Levine, 1980). Species prevalence was based on a differential count of a minimum of 100 larvae obtained from faecal cultures.

Faecal samples with high oocysts per gram (OPG) were cultured in 2.5% (w/v) aqueous potassium dichromate solution and incubated at room temperature for one week. Coccidian parasites identification was based on the morphological features of sporulated oocysts (Christensen, 1938; Levine et al, 1962; Davies et al , 1963; Shah, 1963; Levine and Ivens, 1970; Levine, 1973; Lima, 1979, 1980; O'Callaghan, 1989). For analysis of data, the term prevalence was defined according to Margolis et al, (1982) as the percentage of hosts infected.

RESULTS

Strongyles Faecal examination indicated that at least 63% of the goats examined were infected with strongyles. The infection levels (percentages of infected goats) in adults were 59% and in kids, 67%. In comparing EPG, adult goats generally had lower egg counts than kids. The bi-monthly percent infection level and average EPG for the adults and kids are indicated in Table 1. In adult goats, the infection level peaked during March to April and May to August. In kids, infection level peaked during January to February and May to August. The genera of strongyles identified on coproculture were: *Haemonchus contortus* (49%), *Trichostronglus axei* (30%), *Oesophagostomum venulosum* (10%), *Ostertagia circumcincta* (7%) and *Cooperia curticei* (4%). Three percent of the adult goats and 2% of the kids examined were infected with *Strongyloides papillosus*.

Lungworms

Fifty five percent of adult goats were infected with lungworms. Cultured larvae isolated from faecal samples appeared to be *Muellerius capillaris*. The percentage infection and average larval counts are shown in Table 2.

Table 1. Prevalance of Strongyle infections and number of eggs in faeces of goats at Ol'magogo Farm

	Adult goats			Kids		
Months	Number examined	% infected	Average EPG[1] (range)	Number examined	% infected	Average EPG[1] (range)
Jan-Feb	104	59	769 (100-6067)	46	94	1326 (100-7800)
Mar.-Apr.	108	67	1254 (100-4392)	40	73	564 (100-1250)
May-Jun.	103	63	999 (100-4768)	42	55	2392 (100-4759)
Jul.-Aug.	96	65	985 (100-4561)	30	57	1322 (100-2792)
Sep.-Oct.	102	57	803 (100-3024)	41	51	729 (100-1700)
Nov.-Dec.	73	44	627 (100-3550)	49	71	685 (100-1550)

[1]Eggs per g of faeces.

Tapeworms

Nine percent of the goats had tapeworm infections; 6% in adult goats and 12% in kids. The bi-monthly percent infection level and average EPG for adults and kids are indicated in Table 3.

Table 2. Prevalence of lungworm (Muellerius capillaris) infection and number of larvae in faeces of adult goats at Ol'magogo farm

Months	Goats examined	Average larval counts[1] (range)	% infected[2] with *M. capillaris*
Jan.-Feb.	47	279 (1-1500)	58
Mar.-Apr.	39	129 (1-960)	48
May-Jun.	41	111 (1-624)	69
Jul.-Aug.	23	96 (1-450)	36
Sep.-Oct.	57	75 (1-386)	51
Nov.-Dec.	42	60 (1-550)	66

[1] Larvae developing from 10 g of faeces.
[2] Based on specific larvae and the number of positive goats over the total goats examined.

Whipworms

Based on egg size and shape (Siddiqi and Ashraf, 1980), at least 30% of the kids were infected with *Trichuris ovis*. The percent infected and average EPG distribution are presented in Table 4. The infection level and EPG distribution of whipworms followed the same pattern as that of tapeworms in kids.

Table 3: Prevalence of tapeworm infection and number of eggs in faeces of goats at Ol'magogo farm

	Adult goats			Kids		
Months	Number examined	% infected	Average EPG[1] (range)	Number examined	% infected	Average EPG[1] (range)
Jan.-Feb.	104	10	198 (100-300)	46	11 (100-200)	105
Mar.-Apr.	108	13	176 (100-300)	40	13 (100-300)	125
May-Jun.	103	5	202 (100-400)	42	7 (0-200)	150
Jul.-Aug.	96	2	134 (0-200)	30	20 (0-200)	104
Sep.-Oct.	102	4	195 (100-300)	41	10 (0-200)	100
Nov.-Dec.	73	4	175 (100-300)	49	12 (0-200)	100

[1]Eggs per g of faeces.

Coccidiosis

Coccidiosis was the most prevalent parasitic infection in goats examined. An average of 71% of all goats examined were infected with coccidia and the infection levels for both adults and kids were 77% and 64%, respectively. The bi-monthly infection level and average OPG for adult goats and kids are shown in Table 5. In adult goats, the infection level peaked during the months of July to October. In kids, infection level peaked during May to June and November to December. Kids generally had a relatively higher average OPG compared to adult goats. Seven coccidian species were identified: *Eimeria arloingi* (25%), *E. ninakohlyakimovae* (23%), *E. hirci*, *E. alijevi* (13%), *E. christenseni* (10%), *E. jolchijevi* (4%) and *E. caprovina* (4%).

Table 4. Prevalence of Trichuris ovis infection and number of egg in faeces of kids at Ol'magogo farm

Months	Kids examined	Average EPG[1] (range)	% Infected[2] with *T. ovina*
Jan.-Feb.	46	15[illegible] (100-[illegible])	20
Mar.-Apr.	40	[illegible] ([illegible]-500)	20
May-Jun.	42	254 (100-570)	27
Jul-Aug.	30	223 (100-400)	
Sept.-Oct.	41	315 (100-600)	20
Nov.-Dec.	49	214 (100-400)	16

[1]Eggs per g of faeces
[2]Based on specific eggs and the number of positive goats over total goats examined.

This survey indicated that 71% of all goats were infected with at least one type of parasite, and substantial OPG (counts greater than 1000) were found in 50% of all goats. In comparing adult goats and kids, 16% of the adults and 40% of the kids had substantial OPG. Although faecal strongyle counts or lungworm larval counts are not truly representative of the number of adult worms present, 34% of all goats examined had substantial strongyles EPG (EPG greater than 1000) and were considered highly infected. Lungworm larval counts of more than 100 were found in 17% of adult goats examined and were considered highly infected.

Table 5. Prevalence of coccidian infections and number of oocysts in faeces of goats at Ol'magogo farm

	Adult Goats			Kids		
Months	Number examined	% infected	Average OPG[1] (range)	Number examined	% infected	Average OPG[1] (range)
Jan.-Feb.	104	82	3833 (100-118,722)	46	78	4887 (100-534,400)
Mar.-Apr.	108	76	4177 (100-158,317)	40	80	8630 (100-167,000)
May-Jun.	103	65	3194 (100-74,261)	42	67	49,154 (100-300,000)
Jul.-Aug.	96	70	9466 (100-56,907)	30	67	19.600 (100-159,800)
Sep.-Oct.	102	94	9626 (100-124,963)	41	61	11,700 (100-144,000)
Nov.-Dec.	73	77	3200 (100-41,462)	49	31	31,690 (100-216,000)

[1]Oocysts per g of faeces

DISCUSSION

The results of this prevalence survey revealed that parasite infections are common in goats at Ol'magogo farm. Infection patterns (infection levels and intensity) are affected by four primary factors (Ashraf et al, 1990) which include: parasite contamination, environmental conditions, host resistance and management practices. Results from this study may also be affected by the fact that the goats examined were drug treated with anthlmintics and coccidiostats when EPG and/or OPG counts were exceedingly high.

Gastrointestinal nematodes were prevalent in goats examined and the established mean strongyle egg counts were moderate to high (Soulsby, 1965). High average EPG in kids may reflect a lack of resistance, since kids which have no previous exposure to strongyle infections have not developed resistance to infections, a controlling factor in adult goats (Baker, 1975). Low resistance resulted in increased worm burdens and high EPG. These findings would suggest that the health and productivity of goats might be affected by infections with strongyle parasites. Thus, to maximise productivity of the animals, treatment of goats suffering from such infections should be carried out. Treatment should reduce the egg load and the chances of infecting the more susceptible young animals. The most predominant genus of nematodes infecting goats in the study area was *H. contortus*, followed by *Trichostongylus axei*, *Oesophagostomum venulosum*, *Ostertagia circumcincta* and *Cooperia curticei*. The dominance of strongylosis in this study conforms with other surveys carried out previously (Njanja et al, 1984; Omara-Opyne, 1985, Ndarathi et al, 1989).

Muellerius capillaris was a common parasite of goats in the farm surveyed. Generally, *M. capillaris* is considered to be non-pathogenic in sheep, although heavy infections are said to predispose the animals to secondary bacterial infections (Soulsby, 1968). However, Euzeby (1961) reported that faecal larval counts of over 150/g were indicative of a pathogenic infection in sheep. It is possible that *M. capillaris* may be pathogenic in heavily infected goats (Lloyd et al, 1978). Seventeen percent of adult goats examined in this study had larval counts of more than 100 and were considered highly infected even though they were not necessarily showing any clinical signs. The presence of *Strongyloides*, *Trichuris* and *Moniezia* eggs was sporadic and burdens were light. These parasites are probably not important factors affecting the health of herds of goats in the survey area.

This study also provided evidence that coccidiosis of goats is prevalent in Ol'magogo farm. Most of the goats examined were shedding oocysts in their faeces, with the kids having higher OPG counts compared to adult goats. Such findings have been reported by Lloyd et al (1978)where coccidial oocysts were found in 100% of the faecal samples and the greatest oocyst counts were found in goats under six months of age. The high infection level of coccidia in kids may be due to lack of development of resistance. In kids, ingestion of even a few sporulated oocysts can produce millions of oocysts in the first 2-3 weeks (Craig, 1982). Due to acquired resistance of the older goats, few coccidia can complete their lifecycle, and fewer oocysts are passed in faeces of adult goats (Craig, 1982).

Seven species of *Eimeria* were encountered in the survey and *E. arloingi* was the predominant species. *E. arloingi* seems to be the most prevalent species in goats. It has been found in 98% of faecal samples in the USA (Lima, 1980), 94% in S.E. England (Norton, 1986) and 58% of goats in Nigeria (Opoku-Pare et al, 1979). Of 32 goats that died of coccidiosis at Kabete, Kenya, post-mortem examination indicated that *E. arlongi* was the cause of death (Mugera, 1968).

It is likely that the incidence of clinical signs in coccidial infections depends upon the balance between the rate of development of resistance and the rate of infection (Vercruysse, 1982). This balance can be affected by weather conditions, type of management, hygiene, methods of feeding, weaning and the presence of either infections. Outbreaks of coccidiosis are likely to occur with more intensive systems of management. Confinement and over-crowding was found to be a cause of an outbreak of acute intestinal coccidiosis in young goats in Nigeria (Opuku-Pare et al, 1979). Treatment schemes should include drug treatment for coccidia, eventhough the majority of goats do not show signs of disease. Treating of kids and improving sanitation will reduce the coccidial and helminth infection levels.

As in many countries of the world, the present findings indicate that gastrointestinal parasites and lungworms are widespread in goats and cause serious unthriftness and retarded growth. The danger from these parasites is undoubtedly greatest where large herds are kept and especially where overstocking occurs (Fabiyi, 1970). Thus, with the expanding goat industry, an extensive study of goat parasites is called for in order to be able to make sound recommendations for the control of these parasites. The effects of treating kids with anthelmintics and coccidiostats should also be assessed to establish the actual role of gastrointestinal parasite infections in productivity of goats in Kenya.

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GUT SURFACE ANTIGENS AS TARGETS TO IMMUNISE AGAINST *HAEMONCHUS CONTORTUS*

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INTRODUCTION

Haemonchus contortus is one of the most important gastrointestinal nematodes of small ruminants in tropical and subtropical regions of the world. Within the ruminant host the parasite resides in the abomasum where, as a fourth stage larva and adult, it penetrates the mucosa and sucks blood. It is this blood sucking behaviour of the parasite that accounts for the majority of clinical signs associated with *H. contortus* infections. Severe anemia, hypoproteinemia and tissue edema are dominant clinical signs occurring during acute haemonchosis. Acute disease most often occurs in the young susceptible host and can lead to death, but at a minimum, these animals will experience reduced productivity. More chronic conditions also develop from *H. contortus* infections in both younger and older ruminants, leading to long-term impact on productivity of these animals. *Haemonchus contortus* is one of the most prevalent gastrointestinal nematodes of small ruminants in Kenya (Shavulimo, 1985) and it represents a major impediment to production.

Current methods to control *H. contortus* and other gastrointestinal nematode parasites include the combined use of management practices and anthelmintics. Management practices such as pasture rotation and segregation of host age groups can benefit control programmes, but require relatively larger tracts of land, which may be a limitation for many producers. Management practices alone are insufficient to control *H. contortus* and must be used in the context of anthelmintics. The most significant problem presented by *H. contortus* in this context is its capacity to develop resistance to most contemporary anthelmintics (Prichard et al, 1990; Egerton et al, 1988). Strains of *H. contortus* resistant to several anthelmintics have been identified in Kenya (Njanja et al, 1987) and this problem is likely to increase with time. Consequently, efforts for new approaches to control of this parasite are greatly needed.

Two approaches that we are interested in to control *H. contortus* include vaccine development and genetic selection of small ruminants that are naturally more resistant to infection by the parasite. These two divergent approaches are potentially complementary since there seems to be an immunological basis for natural resistance to *H. contortus* (Presson et al, 1988). In this paper, our discussion will be limited to progress achieved in vaccine development.

An effective vaccine against *H. contortus* will likely be required to induce protection in host animals 2-4 months of age. Young animals are most severely affected by Haemonchosis and contribute most significantly to pasture contamination and subsequent transmission. While this age group of animals is more refractory to immunisation (Smith and Angus, 1980), a few studies have demonstrated induction of protective immunity in lambs and kid goats that were immunised at less than 6 months of age (Munn etal, 1987; Neilson and Van de Walle, 1987; Jasmer and McGuire, 1991). Identification of antigens that induce this protection are currently being investigated. Two of these studies have focused attention on gut antigens of the parasite (Munn et al, 1987; Jasmer and McGuire, 1991), while a third study investigated "somatic antigens" of *H. contortus* (Neilson and Van de Walle, 1987).

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It is not yet clear whether the somatic antigen preparation would have contained gut antigens of the parasite, but that possibility cannot be excluded.

The rationale for targeting the gut in a protective immune response stems from the blood sucking behaviour of the worm. It was thought that this mode of feeding could serve as a mechanism to deliver the host immune response to the parasite's gut. Immune components such as antibodies or immune cells could then either damage the gut or otherwise interfere with its function. This approach has been successful toward development of vaccines against ticks (Opdebeeck et al, 1988; Willadsen et al, 1989), and it was seen that antibodies are made to gut antigens of *Nippostrongylus braziliensis* in experimental infections (Seesee et al, 1976).

Initial evidence that gut antigens may induce protective immunity to *H. contortus* were obtained by Munn et al (1987). Experiments designed to isolate a gut-associated protein, contortin, lead to fractions of the parasite that induced significant reductions in total worm weight of immunised versus control animals. However, while feacal egg counts were consistently less in immunised versus control groups, the difference was not statistically significant. Importantly, lambs that were protected were less than 6 months of age. Progress toward identifying specific gut antigens that can induce protective immunity to *H. contortus* can be found in patent applications, but as of yet no published data are available. Ongoing research in our laboratories is also designed to identify and isolate specific gut antigens that induce protection against *H. contortus* and is described here.

RESULTS AND DISCUSSION

To obtain preliminary observations regarding the ability of gut antigens to induce protective immunity to *H. contortus*, we chose to focus on whole gut dissected from adult female worms. The reason for choosing female worms was due to their relatively large size. Immunised goats received about 4 mg (wet weight, ca. 300 μg protein) of gut antigen per immunisation dose. The initial dose was delivered in Freund's complete adjuvant and the 6 booster immunisations in Freund's incomplete adjuvant. Three weeks after the final booster, kid goats were challenged with 10,000 *H. contortus* third stage larvae. Feacal egg counts were obtained from goats until about 35 days post-infection, when goats were killed and worm counts obtained from their abomasa. In the first experiment using Saanen kid goats that were immunised at less than 5 months of age, a 95% reduction in feacal egg counts and 65% reduction in worm counts was achieved compared to age matched control kids. With yearling pygmy goats, a 95% reduction in feacal egg counts and 89% reduction in adult worm counts was achieved compared to matched control goats. A third experiment in which Saanen goats received only three booster immunisations resulted in an 87% reduction in feacal egg counts, but worm counts were not assessed in these goats. The results provided direct evidence that gut antigens of *H. contortus* could induce protective immunity to challenge infections. Significantly, protective immunity was achieved in kids less than 6 months of age.

Antigens recognised by the immune response of protected goats were analysed using antibody from the infected goats. The sole use of antibody in these experiments does not imply any assumptions regarding involvement of other arms of the immune system in the observed immunity. Use of antibody merely reflects a practical starting point in our analysis. Using fluorescently-labelled antibody from immune goats, it was shown that dominant antigens recognised were localised to the gut of the worm in cryosections, which is not unexpected. However, it was also shown that the brightest fluorescence was associated with the microvillous layer, which lines the gut lumen. In addition, reactivity of this antibody was detected in tissues lining the body wall, suggesting that epitopes associated with the gut also occur in other tissues. The results suggested that microvillar gut antigens were immunodominant with the respect to the antibody response for the goats tested. This may be important because if immunity acts at the site of the gut, then surface antigens of the microvillous layer are likely targets.

The recognition of membrane surface antigens by antibody from immune goats was assessed in further experiments. Integral membrane proteins can be extracted in the detergent triton X-114, which was used to extract isolated *H. contortus* guts. Several gut antigens recognised by immune antibody were extracted in this detergent, indicating that they are integral membrane proteins. To determine whether antibody was generated against gut surface antigens, pieces of freshly isolated *H. contortus* gut were reacted with the fluorescently labelled antibody from protected goats. This antibody clearly reacted with microvilli of the gut, while antibody from control goats showed no reactivity. Thus, immunisation with crude gut induced antibody production against gut surface antigens in protected goats. Proof of the ability to induce this antibody reactivity to gut surface antigens provided a simple strategy for developing monoclonal antibodies to gut surface antigens, as described below.

Conservation of gut epitopes was also investigated for third stage larvae of *H. contortus* and other species of gastrointestinal nematodes. Using antibody to gut antigens from protected goats, antigens of 33, 45, 50, 98 and 173 were identified in both adult gut and whole third stage larvae. However, additional antigens specific to third stage larvae were also identified. Four antigens of 50, 98, 105 and >200 kDa were identified in gut preparations of *Ostertagia ostertagia*, of which the first two comigrated with *H. contortus* gut antigens. Direct fluorescence assays on cryosections of *H. contortus* third stage larvae and adults of *O. ostertagia* and small strongyles of horses (species not determined) were next conducted. Antibody to *H. contortus* gut antigens reacted specifically with all of these samples. While it was not possible to determine organ specificity in third stage larvae, antigens recognised in adult worms were predominantly located in the gut microvilli. These data then indicate that gut epitopes of *H. contortus* adult worms are conserved among different life cycle stages, and importantly among different species of gastrointestinal nematodes. The results raise the possibility that vaccines developed for one of these species may have direct or indirect application to development of vaccines against other species.

Based on results using crude gut extracts, it was established that gut antigens induce protective immune responses in a relevant age group of small ruminants. If the protection is achieved through reactivity with parasite antigens in the gut, then surface membrane antigens are likely to be involved because of their accessibility. This rationale has led us to the hypothesis that gut surface antigens will induce protective immunity to *H. contortus*. To test this hypothesis we have chosen to identify and isolate gut surface antigens with monoclonal antibodies (mAbs).

It was shown in previous results that immunisation with crude gut induced antibody production to gut surface antigens in goats. This antigen preparation was therefore used to immunise mice for development of mAabs to gut surface antigens. Hybridomas were generated from mice immunised with crude gut antigens. Hybridoma supernatants containing secreted antibodies were initially screened by indirect immunofluorescence against crysections of adult *H. contortus*. This procedure identified 49 supernatants containing antibodies to microvilli of *H. contortus* gut. These supernatants were further screened to determine surface reactivity of these antibodies, life cycle stage and species cross-reactivity, and apparent molecular weight of recognised antigens.

Twenty-five supernatants reacted with surface determinants on microvilli of freshly isolated *H. contortus* gut. Eight of these also reacted the surface of *O. ostertagia* gut sections, while 13 reacted with third stage larvae of *H. contortus*. Therefore from these preliminarystudies, mAbs have been generated against gut surface antigens which are conserved among life-cycle stages and at least one other related species. Of the mAbs characterised, seven identified antigens on western blots of whole adult *H. contortus*. From other experiments, it was determined that epitopes recognised by the remaining surface reactive mAbs are sensitive to denaturing conditions, suggesting they are conformational epitopes. The remainder of the discussion will be directed toward those mAbs which identified antigens under denaturing conditions.

mAbs recognising denatured gut surface epitopes can be separated into two groups. Group I mAbs (six different mAbs) have similar reactivity and are represented here by one designated 42/10.6.1. This mAb reacts with several different tissues within the worm, including the body wall and weakly to cuticular regions. The reactivity suggests that the gut surface epitope and possibly whole protein occurs on various tissues. On western blots, this mAb reacts to numerous different protein bands ranging in size from about 175 to 18 kDa. The explanation for the multiplicity of bands is not yet clear, but could represent a common epitope on degradation products of a single protein and/or multiple proteins which share a common epitope. The epitope is sensitive to periodate oxidation, indicating that it is composed of carbohydrate.

An interesting aspect of the epitope recognised by mAb 42/10.6.1 is that it is widely conserved among different gastrointestinal nematode species. The mAb reacts to the gut of *O. ostertagia, Trichostrongylus colubriformis* and small horse strongyles. It also reacts with third stage larvae of *H. contortus* and *O. ostertagia* (the only species tested). Thus, as indicated using polyclonal sera to crude gut antigens, gut surface antigens of *H. contortus* are conserved both among life-cycle stages and different species of gastrointestinal nematodes.

Group II is represented by one mAb designated 42/53.3.6. In contrast to Group I, this mAb reacts with the surface of adult *H. contortus* gut, but not with other tissues, life-cycle stages or gastrointestinal nematodes species tested. On western blot, a single protein is recognised at 46 kDa. However, similar to the epitope recognised by Group I mAbs, this epitope appears to be carbohydrate- based on its sensitivity to periodate oxidation.

We are currently using the mAbs described to isolate gut antigens identified by immunoaffinity chromatography. Antigen isolated by Group I and II mAbs is being tested in immunisation trials.

Results obtained in this research indicate that gut antigens of *H. contortus* can induce protective immunity which can greatly reduce worm burdens and feacal egg counts in kid goats. The reduction in worm burdens was achieved previously using putative gut antigens (Munn et al, 1987) and is of a magnitude that it is likely to reduce clinical disease from *H. contortus* infections. The young susceptible host is the most important factor in amplifying infective larvae on pasture. The dramatic reduction of feacal egg counts in immunised kids demonstrated here is important because it indicates potential for significantly reducing field transmission of this parasite.

Analysis of gut surface epitopes recognised by mAbs has identified both a stage- and species-specific epitope and an epitope which occurs in various tissues, life cycle-stages and a variety of species. This broad conservation of gut surface epitopes could have important practical applications if *H. contortus* antigens isolated by the mAb (group I) induce protective immunity to challenge infections. In any case, the results raise the possibility of protective gut surface antigens that are conserved among various gastrointestinal nematode species.

The occurrence of gut surface antigen epitopes on other tissues may also relate to mechanisms of immune damage to the parasite. It is possible that immunisation with gut antigens could induce immune response to other tissues of the worm, including the outside surface. Thus, immune damage to the worm may not be restricted to the gut. Likewise in natural infections, antigens occurring on other tissues could induce an immune response that recognises gut antigens. Therefore, protective immune responses induced by gut antigens could be similar to those acquired from natural infections. The approach and availability of reagents described here should facilitate more detailed investigations on mechanisms of this protective immunity.

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SESSION IV

PRODUCTION SYSTEMS AND

FEED RESOURCES

51a

ADOPTION OF FEED RESOURCES IMPROVED TECHNOLOGIES FOR DUAL PURPOSE GOATS BY FARMERS IN WESTERN KENYA

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ABSTRACT

The Feed Resources Project has, in the last decade of SR-CRSP research in Kenya, developed several improved technologies to improve the feed quantity and quality for dual purpose goats in western Kenya. These technologies are: (1) Improved pastures and fallow lands, (2) Improving soil conservation and fertility, (3) Feed production from maize and cassava based systems, (4) sweet potato as food and feed crop, (5) feeds from grasses and legumes and (6) feed conservation and storage. Farmers have tried all of these technologies; however, only the maize-based feed production system, fodder grasses and legumes and sweet potato production technologies have been most successful. An attempt to combine six of these technologies into a "model farm" has been tested for the last three years and farmer interest is growing. The reasons for slow and non adoption of the technologies and the success of the others are discussed in the paper.

INTRODUCTION

The main mandate of the Feed Resources Project (FRP) since its inception in 1980 was to develop several improved technologies to enhance the quantity and quality of feeds for dual purpose goats (DPGs) for smallholder farmers in western Kenya. The first FRP resident scientist (1980) relied on feed-base characterisation by the Nutrition and Management project (NMP) scientist who surveyed Hamisi and Kaimosi clusters in Kakamega district and Masumbi and Bar Ding clusters in Siaya district (Sands, 1983). The idea then was to develop feeds strictly for the DPG, e.g. napier grass (*Pennisetum purpureum*, *Leucaena leucocephala*) and others. However, the NMP feed-base characterisation survey indicated that farmers in the four clusters integrated their livestock, namely cattle, sheep and goats, very well into their cropping activities (Sands, 1983). Therefore, the first FRP approach was not well received by farmers (1980-1982). A consultant was hired to study the farming systems in western Kenya to recommend to Production Systems (PS) how best DPG feed resources could be developed from the resource-poor farms of western Kenya. The consultant's main recommendation was that most of the DPG feeds should be derived from food crops, fortified with planted forages, like feed banks, and a little from fruit and cash crops (Onim, 1982).

In 1983, major research shift was made by the FRP to encourage farmers to feed their DPGs from food crops that also had potential to generate livestock feeds. These included maize (*Zea mays*), cassava, (*Manilot esculenta*), sorghum (*Sorghum bicolor*) sweet potatoes (*Ipomoea batata*), bananas (*Musa acumunata*) and pigeon pea (*Cajanus cajan*). This was the beginning of research by the FRP into feed-food crops, commonly referred to as dual-purpose crops.

The DPG respondent farmers in the clusters actively participated in the development of the improved feed technologies, which the FRP tested on-station, by trying the technologies in their fields during the various stages of development and modifying them to suit their individual needs. This paper

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reports the evolution of improved DPG feed technologies by the FRP between 1980 and 1991 and their adoption by DPG and non-DPG farmers in western Kenya and beyond.

MATERIALS AND METHODS

By working closely with DPG respondent farmers and field assistants who were based in the clusters, FRP scientists observed or were told by the farmers their feed-related problems. Frequencies of such problems were recorded through farmer questionnaire surveys in the clusters. The problems were ranked and research protocols were developed every year for the most pressing researchable problems. The research protocols were then presented annually to a multidisciplinary Kenyan SR-CRSP team for discussion and modifications. Several other disciplines often joined in the study if the data to be generated would impact on their own projects. Such participating disciplines often contributed to the budget for executing that experiment. During the execution of the experiments, field assistants and scientists from participating projects worked together, either on-station, on-farm or in both places, depending on the nature of the experiment. The protocols from various projects were pooled and presented to a Kenyan SR-CRSP annual planning meeting which was attended by Kenyan SR-CRSP resident scientists, collaborating scientists from the hosting research institution (KARI), the principal investigators (PIs) from the US leading institutions and the host country representative. Farmers, research and extension workers from the clusters visited the research station during field days every year to review the progress made on various feed technologies and provide input to the feed technology development. The feed technologies under development were also displayed in various agricultural shows within the Ministry of Livestock Development or KARI stands in the district or provincial shows in western Kenya. Only feed technologies that received the greatest support from farmers in general and our DPG respondent farmers in particular were tried widely on-farm.

The level of technology adoption by farmers was monitored not only by the FRP, but also by NMP and the economics and sociology projects of the SR-CRSP based at Maseno Research Station. Each of these projects conducted independent adoption surveys which augmented those done by the FRP. By the end of 1991, only nine feed resource technologies had survived farmer screening and that of the multi disciplinary team of Kenyan SR-CRSP scientists and PIs. These technologies were written up into technological packages. These nine packages comprised the improvement of:

(1) Pasture and fallow lands
(2) Soil conservation and soil fertility
(3) Feed production from maize based cropping systems
(4) Feed production from cassava based cropping systems
(5) Sweet potato as food and feed crop
(6) Legume fodder crops and tree nurseries
(7) Grass fodder crops
(8) Feed conservation as hay and silage
(9) Feed storage

RESULTS AND DISCUSSION

Improvement of Pastures and Fallowlands

There are hardly any pastures or fallowlands in Hamisi, Muhanda and Kaimosi clusters in Kakamega district because of acute land pressure (Jaetzold and Schmidt, 1982). This has led to very small land holdings of approximately 1.0-1.5 ha per household comprising about 6-12 people (Onim, et al, 1985). Small patches of grass within the homesteads are severely overgrazed. Roadside grass are communally grazed, hence no one is keen to improve them. In Lela and Masumbi clusters near the shores of Lake Victoria, land holdings per household are larger, approximately 2.9 ha (Mbabu et al, 1989). Consequently, there are more livestock in Lela and Masumbi than in Rabuor, Hamisi and Kaimosi clusters. However, the DPG farmers in Lela and Masumbi clusters exploited larger communal pastures without any interest to improve them.

The improvement of pastures and fallowlands includes removal of weeds like *Sporobolus puramidalis, Lantana camara* bushes and establishment of browse species like ***Sesbania sesban*** var. ***nubica*** and *Leucaena leucocephala*. The experimental pastures established in Lela clusters under the supervision of FRP scientists were very successful. However, farmers in all clusters showed no interest for this feed technology. Thus adoption rate was zero.

Soil Conservation and Soil Fertility

Soil conservation and soil fertility are generally improved in Kenya by reducing soil erosion by digging soil erosion terraces and ploughing across the field rather than down the slope. However, the FRP has recommended planting of forages like napier grass in alleys across the fields and on soil erosion bunds. These recommendations have also been made by the Ministry of Agriculture and extension workers teach farmers about them. The FRP, however, emphasised establishment of feeds not only for soil conservation, but also for generating feeds for the DPGs. The pattern of establishment of forages for soil conserva.'on and feed generation is presented in Table 1.

Table 1. Patterns of feed establishment for soil conservation and feed production (1991)

Cluster	Feed Established	% of farmers in cluster Terrace bunds	 Alleys across field
Kaimosi	napier grass	30	45
	Leucaena/Sesbania	10	30
Hamisi	napier grass	45	40
	Leucaena/Sesbania	-	-
Muhanda	pigeon pea	35	45
Lela	napier grass	13	26
	Leucaena/Sesbania	10	15
Rabuor	napier grass	23	33
	Leucaena/Sesbania	-	-
	pigeon pea	18	28
Masumbi	napier grass	37	35
	Leucaena/Sesbania	22	35
	pigeon pea	-	-
	Means	24.3	33.2

On the average, adoption rate for soil conservation was 24.3% for planting feeds on soil erosion bunds and 33.2% for planting feeds in alleys across the field. There was higher adoption rates for soil conservation in Hamisi, Kaimosi and Muhanda clusters than in Rabuor, Lela and Masumbi clusters.

Adoption of optional soil conservation measures by farmers is usually slow because of the long term-nature of benefits accruing from such practices. However, the benefits from feeds generated from soil conservation/feed production technology are short term. Hence, the relatively high adoption rate by farmers for this technology.

Improvement of Soil Fertility

The FRP recommended four major methods for improving soil fertility: application of livestock manure directly into the field from goat houses or heaped for about six or 12 months before applying it to crop fields; green manure and leaf litter from legumes; compost heaps; and use of inorganic fertilisers. Table 2 shows how the various recommendations were adopted by farmers in various clusters.

Table 2. Various methods used by farmers for improving their soil fertility (% of DPG respondent farmers)

Cluster	Goat[1] manure	[2]	Green[3] manure	Compost[1] heaps	Inorganic[2] fertilisers on maize
Kaimosi	---	50	0	---	17
Hamisi	100	50	0	100	50
Masumbi	100	60	0	45	0
Muhanda	100	80	0	95	10
Rabuor	100	89	0	86	0
Lela	100	100	0	40	0
Means	100	71.5	0.0	61.0	12.8

-- Not surveyed
1. Mbabu et al, 1991 (on all source crops)
2. Onim et al, 1991 (on maize crop)
3. Onim et al, 1990

Taken together, DPG farmers relied on goat manure as the major means of improving soil fertility (100% for all crops, Mbabu et al, 1991). Green manures were not adopted because there were no free fields throughout the year for growing green manure crops. Onim et al. (1990) reported that goat manure increased maize and beans yields at Maseno Research Station by 54% over the recommended rate of diammonium phosphate fertiliser, and 233% over control on farmers' land.

Compost manure from the remains of goat feeds was also a valuable source of manure for improving soil fertility. Adoption rate was 61%. However, the use of inorganic fertilisers was only 12.8% (Onim et al, 1991). This was mainly because of very high prices which the farmers could hardly afford.

Feed Production from Maize-Based Cropping Systems

Feeds can be generated from maize-based cropping system from pure maize fields, or maize intercropped with other food crops like beans, pigeon pea, sorghum, finger millet or maize alley cropped with feed crops like napier grass, *Leucaena, Sesbania, Calliandra* and others. Onim et al (1984) reported that while maize alone generated 10.2 t/ha of feeds as thinnings, leaf strippings, toppings and stover, and

4.2 t/ha of grain, maize intercropped with pigeon pea had a combined grain yield of 12.5 t/ha of higher quality grains for human consumption. Semenye et al (1991) have also reported that maize leaf stripped from 1.0 ha yielded 1.4 t/ha DM over a four month growing season of high quality feeds. This can feed a 40 kg lactating doe (0.7 of milk/day) for 1105 days, or six does for six months.

A high yielding maize cultivar has been developed jointly by the DPG farmers from four villages in western Kenya and FRP scientists from Maseno. The maize has been selected for high double cobbing frequency (50% on average, but farmers have recorded up to 75% double cobbing, Onim et al 1986; 1991). At that rate of double cobbing, this new maize variety outyields most of the commercial varieties recommended for 1500 m altitude range. This variety gives 50-75% more grain yields per ha as compared to its commercial competing varieties. It is ideal for alley cropping. The seed of this maize has been multiplied for the DPG and non-DPG farmers in the six clusters in western Kenya and beyond. It was grown by 100 farmers in 1989 and 1000 farmers in 1990 using 3.5 tonnes of seed. For 1992, 9.5 tonnes of seed have already being sold to farmers. The seed is selling at the same price as the recommended commercial maize varieties.

The seed has gone beyond the six DPG clusters in western Kenya. It has reached South Nyanza, Busia, Nandi, Nakuru and Kiambu districts in Kenya. It has crossed the borders into Mpwapwa, Morogoro and Mwanza regions of Tanzania and doing very well. Maseno Double Cobber was entered into both Kenya national yield maize variety trials and the East and the Southern African regional maize trial by CIMMYT at Egerton University Njoro, Kenya in 1991. Its adoption rate is phenomenal.

Adoption of methods of generating feeds from maize-based cropping systems is very high in Kaimosi, Hamisi, Muhanda and Rabuor, but low in Lela and Masumbi. In the high adoption clusters, the feeds generated from maize systems are fed to livestock in confinement, like under zero grazing and tethering. In the two low adoption clusters, the maize stover is grazed *in situ* in fields as soon as maize has been harvested.

Feed Production from Cassava-Based Cropping Systems

A cassava based cropping system is common in the two lowland clusters of Lela and Masumbi. Mathuva et al. (1985) reported that cassava can be planted in pure stand or be intercropped with maize to generate both food and high quality feeds for livestock. When cassava leaves were pruned at varying proportions, up to 4.3 t/ha of DM was realised. However, any leaf stripping over 25% of the leaves per plant reduced tuber yields. The intercropped maize also yielded 1.0 t/ha of grain and 3.8 t/ha DM of feeds.

This technology, however, was never adopted by farmers. They disliked that stripping cassava leaves caused tuber yield losses. They also feared that the cassava leaves would poison their goats due to high levels of hydrogen cyanide (HCN) poison. There is a very high incidence of goat, and other livestock deaths, resulting from consumption of cassava peels in the lowlands.

Sweet Potato as a Food and Feed Crop

Over 40 sweet potato cultivars from farmer fields around Maseno Research Station were screened for their tuber and vine yields (Onim et al, 1985). The sweet potato cultivars were grouped into three general categories: tuber types; dual-purpose types; and vine types. General characteristics of the groups are presented in Table 3.

Table 3. Major feed quality parameters and the fresh tuber yields of three sweet potato types in western Kenya

Cultivar Types	Fresh tuber Yield t/ha/yr	DM yield t/ha/yr	% DM in vitro digestibility	Mcal. DE/kgDM	%CP	%Moisture content
Tuber	18.5	7.6	66.0	2.91	15.8	75.0
Dual Purpose	6.7	9.7	70.0	3.09	16.1	78.0
Vine	3.8	14.1	74.0	3.26	16.0	80.0

Source: Onim et al, 1985.

From experimental plots in Maseno Research Station, up to 21 tonnes of fresh tuber yield/ha/yr, 21% CP in vines, 14 of vines of 77% have been realised in the best cultivars in these parameters.

In Hamisi, Muhanda, Lela, Masumbi and Rabuor clusters, respectively, 94%, 96%, 77%, 60% and 89% of DPG respondent farmers grew a small plot (about 0.1-0.25 ha) of sweet potato (Mbabu, 1991). Of these, 85% grew the recommended dual purpose type cultivar SP 14 from Maseno Research Station.

Semenye et al (1986) reported that goat kids can be weaned after three weeks on sweet potato vines as a milk replacer, rather than after 90 days on mother's milk. While weaning goat kids on sweet potato vines is an excellent idea, the FRP did not determine its adoption by farmers. It appears that few DPG farmers milked their goats at all. Mbabu et al (1990) reported that only 10.0%, 11.7%, 5.7%, 8.0% and 13.3% of the DPG farmers in Lela, Rabuor, Muhanda, Hamisi and Masumbi, respectively, milked their does. Adoption of sweet potato vines as a milk replacer by taking a mean for all clusters was not more than 9.7%. This would be a very low adoption rate.

Legume Fodder Crops and Tree Nurseries

Legume fodder crops are normally raised in a tree nursery before they are transplanted into the field at the onset of rains. Four legume forage crops: *Leucaena leucocephala, Sesbania sesban* var. *nubica, Gliricidia sepium* and lately *Calliandra calothysus* were introduced to the DPG farmers. Only *Leucaena* and *Sesbania* have been adopted by the farmers. Goats do not like to eat Gliricidia (Semenye et al, 1986) and *Calliandra* is difficult to establish in large numbers because of lack of seed. These legume forages were variously grown in intensive feed banks, hedge rows, alley cropping and occasionally intercropped with food crops, and on soil erosion bunds. Fodder grasses and forage legumes have been combined into a model farm where they are grown with maize and soil fertility maintained only with goat manure. This model farm produces more food and feeds than any single system along (Onim et al, 1990).

Farmers were advised to plant seeds in seed beds, and, soon after germination, to transplant the seedlings into polythene tubes (price KSh 9.00 for 100 tubes). However, all farmers did not adopt the tube transfer method because of the cost element. Farmers left their seedlings in the nursery until rains started when they transplanted them directly into the field. Watering seedlings in the nursery is a difficulty for many farmers since water is often brought from afar by women. Adoption rate of the forage legume recommendations are presented in Table 4.

Table 4. Proportion of farmers who planted and cared for forage legumes in 1990 and 1991

Cluster	Forage Type (%)[1] Planted		Field care for forages (%)[2] Weeded		Fenced	
	Leucaena	*Sesbania*	*Leucaena*	*Sesbania*	*Leucaena*	*Sesbania*
Lela	90.0	40.0	13.2	15.6	1.3	0.0
Muhanda	100.0	100.0	98.4	96.8	99.9	100.0
Rabuor	90.4	25.0	52.7	57.4	0.0	0.0
Masumbi	33.3	28.0	28.3	23.7	0.0	0.0
Hamisi	79.5	67.3	72.7	68.0	84.0	78.6
Means	78.6	54.2	53.1	52.3	37.1	35.7

Source: [1] Mbabu et al, 1990
[2] Mbabu et al, 1991

Results presented in Table 4 indicate that 79% of the DPG farmers in all clusters planted *Leucaena,* while 54% planted *Sesbania.* However, all farmers in Muhanda planted both forages. About 50% of the farmers in all clusters weeded and fenced their legume forages respectively. Two highland clusters of Hamisi and Muhanda had much higher adoption rates than the two lowland clusters of Lela and Masumbi. The highland clusters rely more on zero grazing and tethering the DPGs hence requiring more cut and carry feeds. The lowland clusters practice more open grazing than zero grazing or tethering.

Research to determine the potential of the legume forage, *Sesbania,* as a *Sesbania* research legume forage, good source of protein for African livestock, was initiated at Maseno Research Station in western Kenya (Onim and Dzowela, 1987). Some authors have reported low intake of *Sesbania* by goats when fed as a sole diet (Sidahmed et al, 1984; Semenye et al, 1986, 1987). Others have reported that Sesbania outperformed other browse protein sources and animals on *Sesbania* supplementation had the fastest growth rate (ILCA, 1985/86; ILCA, 1990; Brown and Barnes 1987; Shqueir et al, 1989; Semenye 1990;). The *Sesbania* work has developed into a *Sesbania* Network for Eastern and Southern African countries with membership of over 10 countries. Kenya, as the founder member country for *Sesbania* research as a forage in Africa, has hosted several regional and international workshops and conferences.

Therefore, it is clear that the fodder legume technologies developed by the FRP have been very successful.

Grass Fodder Crops

The fodder grasses that were tried and approved by the FRP included napier grass derivatives like Pakistan hybrid, Clone 13 and Bana; Sudan grass, *Panicums* and Guatemala grass. However, only napier grass derivatives were adopted by farmers. Adoption rate is presented in Table 5.

Table 5. Proportion of farmers who planted and cared for fodder grasses in 1991

Cluster	% farmers who planted napier grass	% farmers who cared for their napier	
		Weeded	Fenced
Hamisi	98.0	69.9	69.1
Masumbi	39.0	7.5	0.0
Muhanda	99.6	99.2	99.4
Rabuor	97.0	46.9	0.0
Lela	76.0	8.8	0.0
Means	81.9	46.5	33.7

Source: Mbabu et al, 1991.

Results indicated that 92% of DPG farmers in western Kenya planted napier grass. However, only 47% and 34% weeded their napier and fenced them, respectively. These trends are similar to what was observed for legume forages. A high rate of adoption of napier grass as opposed to other fodder grasses is due mainly to farmers' awareness from field extension workers from the Ministries of Agriculture and Livestock. Napier grass also outyields all the other fodder grasses in western Kenya. It has well-established village markets where it fetches approximately KSh 3000-4000 /t of DM.

Feed Conservation as Hay and Silage

The FRP has developed simple and effective methods for hay making and baling for low income farmers (Onim et al, 1985). The only equipment required is a wooden baling box, a grass cutting sickle and sisal twine to make 20 kg, standard bales. The box can also be used to bale crop residues like bean haulms, cereal straws and stovers. However, this technology has not been adopted by farmers. There is lack of adequate feeds to conserve and insufficient labour.

Similarly, a simplified silage-making technology has been developed by the FRP (Otieno et al, 1986). This method requires empty used nylon gunny bags, a chaff cutter or a machete and molasses. The method is particularly amenable to small scale farmers. Again this technology has not been adopted by farmers.

Feed Storage

The FRP has developed four types of feed storage: pit silos for silage, hay stacking, raised beds for storing hay bales outdoors, and a multipurpose hay/grain store. Farmers have not adopted any of these feed storage methods.

CONCLUSION

Although these forage technologies were developed for the DPG, they are suitable for improving the production and quality of feeds for a wide range of other livestock species. Farmers usually have other types of livestock which they also fed with forages developed for the DPG. It is therefore clear that these adoption rates for the DPG have underestimated the potential adoption rates if other forms of livestock are considered. Moreover, goats are generally selective feeders and hence they left large proportions of feeds offered - sometimes above 50% (Onim et al, 1985). Outside the goat barns at Maseno Research Station, large quantities of feeds that have been rejected by goats are usually shared by barn staff to take to their cattle at home. Similarly, farmers give to their cattle feed remains after goats have taken their share. Thus, the feed technologies presented in this paper could better benefit farmers who have mixed classes of livestock rather than those who own only goats.

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CAN FODDER DIETS INCREASE GOAT PRODUCTION BY A QUANTUM LEAP?

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INTRODUCTION

Productivity of high biomass fodder has been advanced as the solution to low livestock productivity in the tropics. On feeding fodder, livestock have increased their performance by levels dependent on their nutritional and body status pre-feeding. Livestock below feeding maintenance level have responded better than those at or above maintenance level. The poor response of livestock on fodder that are at maintenance level is worrying since that is the nutritional level that most livestock are on smallholder farms. Farmers expectations are high on their investment return from fodder production. The question posed is the following. What limits matching response of livestock and, in particular, dual-purpose goats (DPG) fed on fodder? Specifically, is it feed intake as a result of low digestibility, palatability or imbalance of major metabolites?

MATERIALS AND METHODS

The trials were carried out on-station at Maseno which lies at an altitude of 1500 m and along the Equator. Five trials were conducted, each comprising napier grass (*Pennisetum purpureum*), mixed grasses (*Brachiaria brizantha, Digitaria scalarum* and *Cynodon dactylon*), pigeon pea (*Cajanus cajan*), sesbania (*Sesbania sesban*) and tylossema (*Tylossema fassoglensis*). Dual-purpose goats (Toggenburg x East African) were used. Mean body weight of kids was 15 kg; for does it was 37 kg. Minimum adaptative and experimental periods were 14 and 21 days, respectively. Individual metabolic cages were used.

Rations offered were weighed twice daily while goats were weighed twice weekly. Milk yields from does were taken daily and faecal output from all experimental goats was determined. Laboratory analyses involved dry matter, crude protein (Kjeldahl N*6.25), neutral detergent fibre (NDF), acid detergent fibre (ADF) and acid detergent lignin (ADL) (Goering and Van Soest, 1970). Energy calculations were based on the National Research Council (NRC, 1981), whereby:

1 kg total digestible nutrients (TDN)=4.409 mega calories (Mcal) digestible energy (DE); 1 Mcal=4.184 mega joules (MJ); and 76 DE=62 metabolisable energy (ME).

RESULTS AND DISCUSSION

Composition of the forage diets is shown in Table 1. Except for pigeon pea hay, other diets had comparable dry matter content. As expected, the leguminous species had higher crude protein content than graminoid species. For NDF, napier grass had the highest within-species variability with 26% coefficient of variation. This may indicate a fast maturing process for napier grass under a conducive environment such as that provided in western Kenya. ADF had a trend similar to that of NDF. Graminoids had lower ADL content than the leguminous species.

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[1]Small Ruminant CRSP, P.O. Box 2[illegible] Maseno, Kenya

Table 1. Chemical composition of forage diets

Forage Species	*Pennisetum purpureum*	Mixed Grasses	*Cajanus cajan*	*Sesbania sesban*	*Tylossema Spp.*
N	6	6	8	10	6
Form of forage	Fresh early growth	Fresh early leaves	Hay leaves	Fresh	Fresh leaves & vines
DM%	37 (1.7)	37 (10.1)	87 (1.9)	30 (7.4)	42 (5.2)
CP%	9 (0.3)	13 (3.0)	24 (2.7)	25 (2.2)	18
NDF%	55 (14.2)	69 (6.7)	57 (7.3)	45 (9.3)	---
ADF%	35 (10.1)	41 (6.1)	---	31 (3.9)	---
ADL%	8 (2.4)	7 (2.4)	---	11 (3.0)	---

Feed intake of forage diets is shown in Table 2. Except for hay, farmers should be advised to feed fresh feedstuff at the rate of 2 kg per day. At this level, goats' dry matter intake, as percentage body weight, falls between 3 and 5%. With a balanced diet - feed intake at 3% or more of their body weights -DPGs and livestock should meet their maintenance requirements, hopefully with a surplus for production. The dry matter intake (DMI) per kg metabolic body weight range of 48 to 110 g per day is an indication of the complexity of feed intake. The level of voluntary intake of a given forage and a given animal is determined by numerous and dynamic interactions involving attributes to the animal, the forage and gastrointestinal micro-organisms (Ellis et al, 1988).

Table 2. Dry matter intake of forage diets

Forage Species	*Pennisetum purpureum*	Mixed Grasses	*Cajanus cajan*	*Sesbania sesban*	*Tylossema* Spp.
As-fed kg	2.2 (0.8)	2.0 (0.5)	0.5 (0.1)	2.0 (0.4)	1.9 (0.5)
As-fed% BWt	7	12	3	15	11
DMI kg/day	0.8 (0.3)	0.8 (0.3)	0.4 (0.1)	0.6 (0.5)	0.8 (0.2)
DMI% BWt	3	5	2	5	4
DMI $g/kg^{0.75}$	63	97	48	93	110

As show in Table 3, pigeon pea had the lowest dry matter digestibility (DMD%) as was the case with DMI. This observation should not be reason to suggest pigeon pea was of the lowest nutritive value because other DPG diets performed equally poorly despite net energy surpluses. The grass mixture diet had the most net energy surplus of 3.95 MJ/kg, which was not converted to growth.

Table 3. In vivo dry matter digestibilities and estimated metabolisable energy

Forage Species	*Pennisetum purpureum*	Mixed Grasses	*Cajanus cajan*	*Sesbania sesban*	*Tylossema* Spp.
DMD%	70 (15)	70 (16)	55 (12)	67 (15)	61 (14)
ME MJ/kg (i)	7.87	7.95	3.39	5.94	6.78
ME for maintenance (ii)	6.78	4	4	4	4
Difference (i)-(ii)=MJ/kg	1.09	3.95	0.61	1.94	2.78
Production g/day	68	nil	nil	nil	14

It is likely that the surplus energy was not converted to production as expected because of inadequacies of NRC (1981) estimation of energy availability in forage diets and metabolic and environmental constraints. The coefficients and recommended minimum requirements for goats as published by NRC (1981) were used. As acknowledged by the authors, the recommendations should be taken with caution as they were derived from a limited number of unrelated experiments. Furthermore, recommendations were mainly based on concentrates and temperated forage diets that are more predictive in utilisation and, hence, productivity. Consequently, the less predictable forage diets may explain the unexpected, poor production response of the trial goats.

Net energy, which is derived from metabolisable energy, is a representation of different metabolites or nutrients with differing efficiency and productivity. Therefore, availability of metabolites and their interactions are crucial in the determination of their efficiency. As in the feeding trials, there was surplus ME for production. Failure of the goats to capitalise on it and to produce as expected could be attributed to imbalances of metabolites, namely, amino acids, volatile fatty acids (VFA) and long chain fatty acids (LCFA).

Stress of any kind may increase energy requirements (NRC, 1981). The surplus energy, instead of going into a productive purpose, may have been consumed by stressful factors. Stress could have emanated from metabolic cage effect (Mautz, 1971). Goats hate confinement because they are energetic and inquisitive in feed selection. Being kept in metabolic cages with no feed selection caused some stress. This had the potential of increasing energy demand. Although energy lost due to stress is difficult to quantify, amount lost could be minimised by a longer adaptation period for the experimental goats. The commonly used adaptive period of two or four weeks appears inadequate for goats. Longer adaptive periods of six to ten weeks has been suggested (Barry, 1985).

To discount breed and the Maseno environment as contributory factors of low performance, other goat trials of divergent breeds and situations were compared (Table 4). It is evident that in trials not incorporating concentrates, performance was poor with a liveweight gain of -1 g to 19 g per day. Where concentrates were the sole diet, the highest weight gain of 89 g per day was realised.

Table 4. Utilisation of feedstuffs by goats

Feedstuff	n	DMI kg/day	DMI $g/kg^{0.75}$	Production g/day	Source
Pennisetum purpureum	5	1.21	97	10	Brown et al, 1988
Cajanus cajan	5	0.40	31	19	Brown et al, 1988
Pennisetum purpureum	4	0.304	58	-1	Van Eys, 1986
Pennisetum purpureum	4	0.282	48	7	Van Eys, 1986
Panicum maximum	4	0.498	44	0	Ash, 1990
Panicum maximum + *Sesbania grandiflora*	4	0.530	47	0	Ash, 1990
Concentrates + Wheat straw	4	0.604	62	55	Lall and Pathak, 1991
Leucaena leucocephala	4	0.438	50	0	Lall and Pathak, 1991
Concentrates + Clover hay (H)	6	0.360	56	55	El-Gallad et al, 1988
Concentrates + Clover hay (L)	6	0.281	45	47	El-Gallad et al, 1988
Concentrates	3	0.723	68	89	Semenye et al, 1990
Overall	49	0.512	55	26	

The implications of these results is that feedstuffs made up of one to three species of forage are not sufficient to provide the required balance of nutrients for productive purposes. Concentrates as a supplement or sole diet appeared to provide the balance in the form of amino acids, glucose and LCFAs. As goats used in such trials are usually less than a year old, it is possible that concentrates, unlike forage feedstuffs, were utilised more efficiently because the goats' rumen were not yet fully developed. Whatever the reason, concentrates produced remarkable positive response. For quantum jumps in productivity, concentrates are essential.

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SESSION V

CONTRIBUTING PAPERS

GROWTH AND REPRODUCTIVE PERFORMANCE OF MEAT GOATS IN NORTHERN TANZANIA

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P.D. Saideiya and T. Mbeyela

INTRODUCTION

The semi-arid region of northern Tanzania lies in the rain-shadow of Mt. Kilimanjaro. The region is mainly dominated by nomadic Masai who are entirely pastoralist. The goats owned by these pastoralists are the indigenous small East African (Devendra and Burns, 1970) and have a small body size. In order to improve indigenous goats for meat purposes, Galla, Kamorai and Boer were imported to cross with the East African. In this way, the present Blended goat was developed. It is a three-way cross between the Kamorai, Boer and indigenous goat with an average genetic composition of 55% Kamorai, 30% Boer and 15% East African (Das, 1989). The Blended goat is larger in size and is a popular meat breed in Tanzania.

The present study investigates factors affecting growth and reproductive performance of Blended and Galla goats at the Livestock Research Centre, West Kilimanjaro and discusses the results in relation to reports on meat goats elsewhere in the tropics.

MATERIALS AND METHODS

Study Site

The study was undertaken at the LRC, West Kilimanjaro, which lies in the semi-arid zone of northern Tanzania. It is located 37°E and 3°S at an altitude of between 1300 and 1500 masl. Rainfall at the centre is bimodal with short rains occurring from October to December and long rains from March to May. Long dry spells of up to seven months are common. Relative humidity is generally low and ranges from 40% to 70%. Mean annual temperature is about 22.5°C with mean maximum and mean minimum temperatures of 27.5°C and 16.7°C, respectively. Dominant grass species are *Pennisatum schimperii, Pennisetum mezianum, Cyndon* species, *Themeda* species and *Bothrichloa* species with some legumes in isolated areas. In a few paddocks, some improved pasture species such as *Chloris guyana, Cenchrus ciliaris* and *Medicago sativa* are sown.

Animal Management

Does were mated twice a year with mating periods of 49 days each in the dry (October-November) and wet (April-May) seasons. Kid-does reaching 72 weeks of age were included in the mating season for the first time. The buck:doe ratio was set at 1:30. Kids were eartagged at birth and weighed within 24 hours. From birth to 16 weeks of age, kids were reared on dam's milk. At 16 weeks of age, kids were weaned and subjected to grazing from 8.00 am to 4.00 pm.

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[1]Livestock Research Centre, West Kilimanjaro, Box 147, Sanya Juu, Tanzania

No supplementary feeding was provided. Water was provided *ad libitum*. Routine disease control practices such as vaccination, dipping and deworming were regularly done. Clinical treatment of major diseases at the Centre was done.

Data Analysis

A total of 790 records on liveweights at different ages were considered. Kids were weighed at birth, weaning (16 weeks), 24 weeks, 48 weeks and 72 weeks of age. Parameters analysed included weights for age and reproductive performance.

A linear model (Snedecor and Cochran, 1980) was used for data analysis. This model included fixed effects of season, birth type, sex, dam age and breed. Reproductive indices were calculated as follows:

$$\text{Apparent fertility rate (\%)} = \frac{\text{Females Kidded}}{\text{Females mated}} \times 100$$

$$\text{Fecundity rate (\%)} = \frac{\text{Kids born alive}}{\text{Females mated}} \times 100$$

$$\text{Prolificacy rate (\%)} = \frac{\text{Kids born alive}}{\text{Females kidded}} \times 100$$

RESULTS

Liveweight and Growth Rate

Overall mean birth weight, weaning weight and weights at 24, 48 and 72 weeks of age were 2.4 kg, 11.03 kg, 13.3 kg, 19.38 kg and 25.41 kg, respectively (Table 1). Single born kids were significantly ($P<0.05$) heavier than twin born kids from birth to 48 weeks of age, but not at 72 weeks of age. Male kids were significantly ($P<0.05$) heavier that female kids and kids born during the wet season were significantly heavier than those born in the dry season from birth to 24 weeks of age. This superiority was not significant at later ages. Breed and age of dam significantly ($P<0.05$) influenced birth weight. Galla kids were heavier than Blended kids while older dams gave heavier kids compared to younger dams. This implies that older dams had higher mothering ability and more milk to rear their kids.

Table 1. Mean Liveweight (kg) of Meat Goats at LRC West Kilimanjaro

	Age in Weeks									
	Birth		16		24		48		72	
Variable	n	mean	n	mean	n	mean	n	mean	n	mean
Overall	790	2.45	545	11.03	469	13.34	367	19.38	314	25.41
Birth type										
Single	329	2.55a[1]	232	11.44a	206	14.22a	161	19.91a	144	25.74
Twin	461	2.37b	313	10.72b	263	12.66b	206	18.96b	170	25.12
Average SE		0.02		0.14		0.15		0.23		0.30
Sex										
Male	400	2.50a	277	11.62a	242	14.10a	177	20.70a	141	27.76a
Female	390	2.39b	268	10.41b	227	12.54b	195	18.21b	173	23.50b
Average SE	0.03		0.19		0.21		0.31		0.40	
Season										
Wet	280	2.69a	197	11.44a	172	13.79a	143	18.76	66	25.60
Dry	510	2.31b	348	10.79b	297	13.09b	254	19.65	248	25.36
Average SE	0.03		0.20		0.22		0.34		0.50	
Breed										
Blended'	434	2.39a	302	10.97	267	13.11	221	19.34	182	25.45
Galla	556	2.52b	243	11.09	202	13.66	146	19.43	132	25.36
Average SE	0.03		0.19		0.21		0.32		0.44	
Dam age (Years)										
2-3	302	2.35a	189	10.87	165	13.17	129	18.88	118	25.54
4-5	173	2.48b	128	10.83	113	13.29	84	20.00	72	24.91
>5	171	2.57c	125	11.34	110	12.72	87	19.41	61	25.19
Average SE	0.03		0.26		0.30		0.44		0.61	

[1]means within a column of a class with different superscript letter differ significantly ($P<0.05$)

Growth rate of kids was computed as average daily gain (ADG) from birth to advanced stages of life (Table 2). Overall mean daily gains from birth to weaning and from birth to maturity were 76.8 kg and 45.6 kg, respectively. Growth rate tended to reduce in magnitude as the animals grew from birth to maturity. Single born kids grew faster than twin born kids. Male kids exhibited higher growth rate compared to female kids. Seasonal effects on growth rate were observed up to 24 weeks of age, with kids born in the wet season growing faster than those born in the dry season.

Table 2. Mean Daily Gain (g) of Meat Goats at LRC West Kilimanjaro

	Age in weeks							
	16		24		48		72	
Variable	n	mean	n	mean	n	mean	n	mean
Overall	545	76.81	469	60.82	367	50.39	314	45.56
Birth type								
Single	232	79.38	206	69.46	161	51.67	144	46.01
Twin	323	74.55	263	61.25	206	49.38	170	45.14
Sex								
Male	277	81.43	242	69.05	172	54.17	141	50.12
Female	268	71.81	227	60.42	195	47.08	173	41.67
Season								
Wet	197	78.13	172	66.07	143	47.83	66	45.46
Dry	348	75.71	297	64.17	254	51.07	248	45.73
Breed								
Blended	302	76.61	267	63.81	221	50.45	182	45.75
Galla	243	76.52	202	66.31	146	50.33	132	45.32
Dam age (Years)								
2-3	189	76.07	165	64.40	129	49.20	118	46.01
4-5	128	74.55	113	64.35	84	52.14	78	44.50
>5	125	78.80	110	66.37	87	50.12	61	44.89

Reproductive Performance

Overall apparent fertility rate, fecundity and prolificacy rates were 60.9%, 86.5% and 143.4%, respectively, for Blended goats and 64.4%, 88.4% and 137.7%, respectively, for Galla goats (Table 3).

Table 3. Reproductive Parameters of Meat Goats at LRC West Kilimojaro

	Years								
Breed	1982	1983	1984	1985	1986	1987	1988	1989	Overall
<u>Blended</u>									
Apparent Fertility rate (%) 63.3	60.0	65.2	48.4	74.0	39.4	61.3	75.4	60.9	
Fecundity rate (%)	85.7	86.2	94.2	67.2	90.4	56.1	104.0	108.0	86.5
Prolificacy rate (%)	135.5	143.6	144.4	138.1	122.2	142.8	169.6	159.5	143.4
<u>Galla</u>									
Apparent fertility rate (%)	40.0	68.0	79.8	59.3	57.6	70.9	63.1	77.6	64.4
Fecundity rate (%)	57.1	108.0	96.2	85.2	67.8	100.0	84.6	108.6	88.4
Prolificacy rate (%)	142.9	158.8	122.0	148.8	117.7	141.0	134.1	141.3	137.7

DISCUSSION

All experimental animals were (as far as possible) subjected to similar management/husbandry practices. This emphasises the validity of results thus recorded. However, not withstanding the fact that Blended goats are superior to indigenous goats with respect to liveweight and average weight gains, this study shows that the general performance of the Blended goats is almost on par with the purebred Galla. Mean birth and weaning weights of Blended and Galla kids were within the range of values reported by others (Wilson, 1987; Das et al, 1989; Das and Mkonyi, 1990).

Mean birth weights of kids were lower than those reported in Botswana for Boer, Tswana and Boer x Tswana kids (APRU, 1984) and Boer x indigenous kids in Zimbabwe (Khombe, 1985). In this study, birth weights were higher than the 2.2 kg reported by Adel and Saanan x Adel kids of Sudanese goats (Awgichew et al, 1989), 2.1 kg for Sudanese goats (Wilson, 1976) and 1.9 kg for Swazi goats (Lebbie and Manzini, 1989). Blackburn and Field (1990), working with Galla goats in Kenya, and Karua (1989) working with indigenous goats in Malawi, reported lower birth weights than those reported in the present study.

The oldest females gave birth to heavier kids. This may be due to the weight of dams at mating. Likewise, heavier kids at weaning age probably was due to higher mothering ability. With ages beyond 24 weeks, the effect of season on growth performance was insignificant. It may be reasonable to assert that there is a "compensatory effect" with mature animals. This is partly evidenced by the tendency of reduced variances in mean daily gains as per singles *vis* twins and males *vis* females. The numerical superiority of liveweight daily gains for wet season treatment group over dry season kids prior to weaning age is seemingly a function of doe milk production potential. Average milk production per doe per day during the wet season is higher than that for does kidding during the dry season (Das and Sendalo, 1990).

The effect of birth type, sex and season on birth weight, weaning weight and mature weight is in agreement with that reported by Chawla and Bhatnagar (1983) on Barbari and Beetal goats in India and by Das and Sendalo (1990) on improved meat goats in Tanzania. ADG from birth to weaning was 76.8 g. This declined to 69.82 g, 50.39 g and 45.56 g as per respective reporting periods of 24 weeks, 48 weeks and 72 weeks of age. Wilson (1976) reported average daily gains of 87 g per day to three months of age in Sudanese goats. This declined to 67 g per day from birth to six months. In Ethiopia, the growth rate of indigenous goats declined from 104 g at three months to 44 g at 24 months (Mukasa-Mugerwa et al, 1986). From meteorological data, adverse weather/climatic conditions during the period 1985-1987 shows the poor reproductive performance of our experimental animals during that period, irrespective of breed. However, there was a "carrying forward effect" for the Galla breed as opposed to Blended goats.

The reproductive parameters of the meat goats in the present study were in agreement with those reported by Das (1989) and Das and Mkonyi, (1990). These values were higher than those reported by Wilson (1976) in Sudanese goats.

CONCLUSION

From results of this study, birth weights are dependent on birth type, sex, season, breed and age of dam. Singles are significantly and consistently superior to twins with respect to liveweight. Sex is an important aspect in meat goat production in Tanzania to the effect that males are superior to females. Age of dam is likewise an important aspect whenever birthweight is a main inventory of management/husbandry practices. Season of birth is an important factor at early stages of life, with kids born in the wet season superior to those born in the dry season.

It is apparent that the growth rates and reproductive performance of meat goats are comparable to the known meat goats found elsewhere in the tropics, thus indicating that these animals can perform well in the semi-arid region of northern Tanzania. Improvement in feeding practices, especially during the dry season and other managerial practices, such as housing and disease control measures, are important in improving goat performance.

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PERFORMANCE OF INTRODUCED DAIRY GOATS UNDER ZERO GRAZING SYSTEM: A CASE STUDY OF HEIFER PROJECT INTERNATIONAL DONATED GOATS IN ARUMERU DISTRICT, ARUSHA, TANZANIA

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SUMMARY

In 1987, two livestock centres in northern Tanzania (Tengeru and West Kilimanjaro) received 89 dairy goats from Heifer Project International for distribution to farmers and for multiplication both on-farm and at the livestock centres. Since then, dairy goat numbers have increased and distribution has continued using the famous system of "get one and give two". Other expected benefits were increased milk supply to families, job creation and other socio-economic benefits which were reported at the 1991 workshop.

In previous years, it was not possible to measure milk production. In this study, the extent that milk production has increased and hence the anticipated changes in rural lives are reported. Kidding intervals, litter size and other benefits which neighbours were able to share such as crossbreeding their local goats with project bucks which stayed at the village are also presented. In this study, ten goats in second lactation and nine goats in third lactation were used in the investigation. Milk production was measured and recorded on the spot for a period of seven weeks. This was done twice a week for both morning and evening milking.

Forty seven litters since 1987 were observed from the farmers' records and from these the average litter size was calculated. Project and non-project farmers were interviewed formally in meetings and informally on individual visits. From information gathered, A summary of benefits was extrapolated.

Results indicate that since the introduction of dairy goats in the village around the Institute, considerable interest has developed for grazing goats. The original 18 goats have increased to 85 with only 27 loses. With average litter size of 1.72 kids per litter, a further increase is anticipated.

Different breeds were found to have different capacities in milk production. (Table 1). While kidding interval appears high (Table 2), this is thought to be due to management of breeding bucks.

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Table 1. Average Milk Production/day (collected over seven weeks)

Village	Farmer	Goat breed	Milk Production	Lactation
Akheri	Afitwa Nyiti	Anglo Nubian	2.2	II
	Afitwa Nyiti	Anglo Nubian	2.1	III
	Stephen Moses	Saanen	2.4	II
	Peter Jacob	Saanen	2.4	II
	John Ainea	Saanen	2.4	III
	Joel Bonifatic	Saanen	2.5	II
	Peter Samboti	Saanen	2.6	II
	Peter Samboti	Saanen	2.2	III
	Moses Jacob	Saanen	2.2	III
Nguruma	Ndelakwa Mika	Anglo Nubian	1.8	II
	Ndelekwa Mika	Anglo Nubian	2.2	III
	Japhet Susalingi	Anglo Nubian	2.1	II
	Japhet Sumalingi	Anglo Nubian	2.1	II
Sing'isi	Nicodemu Kitomari	Saanen	3.3	II
	Eliakunda Palangye	Saanen	3.2	III
	Linghtness John	Saanen	3.3	III
	Sarah	Saanen	3.1	III
	Charles Nyiria	Saanen	3.5	III

Table 2. The Average Kidding Interval for the Project Goats[1]

Village	Farmer	Breed	Lactation	Interval I	Interval II
Akheri	Afitwa Nyiti	Anglo Nubian	II	360	-
	Afitwa Nyiti	Anglo Nubian	III	367	392
	Stephen Moses	Saanen	II	377	-
	Peter Jacob	Saanen	II	360	-
	John Ainea	Saanen	III	374	398
	Joel Bonifatic	Saanen	II	356	-
	Peter Samboti	Saanen	II	370	-
	Peter Samboti	Saanen	III	383	390
	Moses Jacob	Saanen	III	372	382
Nguruma	Ndelakwa Mika	Anglo Nubian	II	372	-
	Ndelekwa Mika	Anglo Nubian	II	340	415
	Japhet Susalingi	Anglo Nubian	II	392	-
	Japhet Sumalingi	Anglo Nubian	II	384	-
Sing'isi	N. Kitomari	Saanen	II	377	-
	E. Palangye	Saanen	III	400	359
	Linghtness John	Saanen	III	373	372
	Sarah	Saanen	II	370	-
	Sarah	Saanen	III	354	361
	Charles Nyiria	Saanen	III	387	350

[1]80 kids; 47 Kiddings; 1.72 average

Pneumonia and poisoning were the known causes of deaths to adult goats. Pneumonia is common with poor hygiene and poor ventilation during the wet season. Poisoning resulted from poor disposal of agrochemical containers. In one case, plant poisoning was the cause of death.

Generally, this project has been successful. Farm Africa and World Vision have expressed an interest to collaborate on this exercise of increasing goat milk production. Given suitable facilities and resources, it is believed that the project area population can be enlarged.

ACKNOWLEDGEMENT

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STUDIES OF OESTRUS SYNCHRONISATION

Abebe Girma[1]

ABSTRACT

Fifty nine Somali does with an average body weight of 27.9 kg and aged between 2-4 years were synchronised by using sponges containing 30 mg Cronolone (Flurogestone acetate) with or without PMSG injection at sponge removal. Thirty animals served as a control group. Sponges were retained in 51 does. Oestrus was exhibited by 80% of the animals treated with sponge alone, while 96% of the animals treated with sponge and injected with PMSG at sponge withdrawal showed oestrus. Most does exhibited behavioural oestrus 25-48 hrs. following sponge removal. Fertility of synchronised oestrus as confirmed by latter kidding is poor as compared to the control group. It is concluded that oestrus in local goats can be fairly synchronised by progestagen. Nevertheless, since fertility of synchronised oestrus is poor, its practical application and economic benefits are questionable.

INTRODUCTION

A brief literature study on incidence of kidding reveals that most tropical goats are seasonal, i.e they can be bred and kid at any time of the year. However, there are distinct seasons when most animals conceive. Such seasonal variation is perhaps due to seasonal variation in feed supply. For instance, Mukassa-Mugerwa et al (1986) made a survey of small ruminant production in the Ethiopian Highlands and reported that most conception occurred during or following the short rains in March-May. This mating season forces the young to be weaned during the dry season when feed supply is limited. In such cases it can be advantageous to synchronise kidding to make the best use of available forage and to reduce the need for supplementary feed as much as possible.

Synchronisation of oestrus in goats may be achieved hy the male effect (Chemineau, 1987) or by hormonal treatment (Corteel, 1975). Progesterone or progestagen can be administered orally, by injections, subcutaneous implants or vaginal pessaries. Vaginal pessaries have become widely accepted in many countries. The purpose of this experiment is to study the response of local goats to progestagen treatment.

MATERIALS AND METHODS

Animals

Eighty nine Somali does with an average body weight of 27.9 kg and aged between 2 and 4 years were used. Each doe showed at least one oestrus before it was included in the study. Does were randomly allocated to three experimental groups as shown below.

Group	Number of Does	Treatment
I	30	Control
II	29	Progestagen
III	30	Progestagen + PMSG

All does grazed natural pasture during the day. Supplemental feed and mineral lick were provided at mid-day in confinement.

Synchronisation and Detection of Oestrus

Sponges containing 30 mg Cronolone (flurogenstone acetate) were inserted deep into the vagina of each of group II and III does using a lubricated plastic speculum, and left in place for 17 days. At

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sponge withdrawal, half the does that carried sponges for 17 days were injected with 400 IU pregnant mare serum gonadotrophin (PMSG) subcutaneously. Detection of oestrus was carried for 30 minutes in the morning between 8:00 and 9:00 hrs and in the afternoon between 16:00 and 17:00 hrs using an intact buck fitted with an apron to prevent intromission. A doe is considered to be in oestrus if she stands still when mounted by a buck.

Mating

Does detected to be in oestrus (natural or synchronised) were bred in order to study fertility status of synchronised and natural oestrus. Adult Somali bucks or AngloNubian bucks were used for breeding. The duration of mating for the control group lasted from May 9 1991 (the day of sponge insertion for groups II and III does) to May 31 1991. It was planned to mate does twice daily using the same buck with two natural matings approximately 12 hrs apart. While this plan has worked for the control group, it was not possible to adhere to it for group II and III does.

Blood Sampling

Ten does of each group (II and III) were used to obtain blood samples. Sampling started two days before sponge withdrawal. Venous blood (about 10 ml) was collected at 24 hours intervals before sponge withdrawal and at 8 hour intervals, starting at the time of sponge withdrawal for an observation period of 120 hours. Serum was recovered by centrifugation and stored at -20°C until assayed for serum progesterone concentration.

RESULTS

Synchronisation

Sponges were retained in 51 does for the full period of 17 days. One case of sponge adhesion was observed. Animals that did not retain sponges for the full period of the experiment and the one case of adhesion were excluded from data analysis. Thus, 50 does half of which received PMSG and the other half that did not receive PMSG injection were available for analysis. Vaginal sponges did not cause any health hazard. Even the doe with the reported case of adhesion was bred successfully after removal. Figure 1 illustrates the percentage of animals that exhibited oestrus during different time periods following sponge withdrawal.

Fertility

Of the 30 does in the control group, 26 showed oestrus. Four does failed to show any oestrus signs. Of the 26 bred does, 21 became pregnant as confirmed by later kiddings. Others had to be rebred. Nineteen does of group II came into heat and were bred successfully. Of these, 17 became pregnant as confirmed by later kiddings. Of the does that received PMSG at sponge withdrawal and bred, only five (23.8%) became pregnant. Three animals of this group neither returned to heat nor conceived. Repeat breeders were observed in the control group as well as in both synchronised groups. But, as shown in Figure 2, the number of repeat breeders was much higher in does that received PMSG.

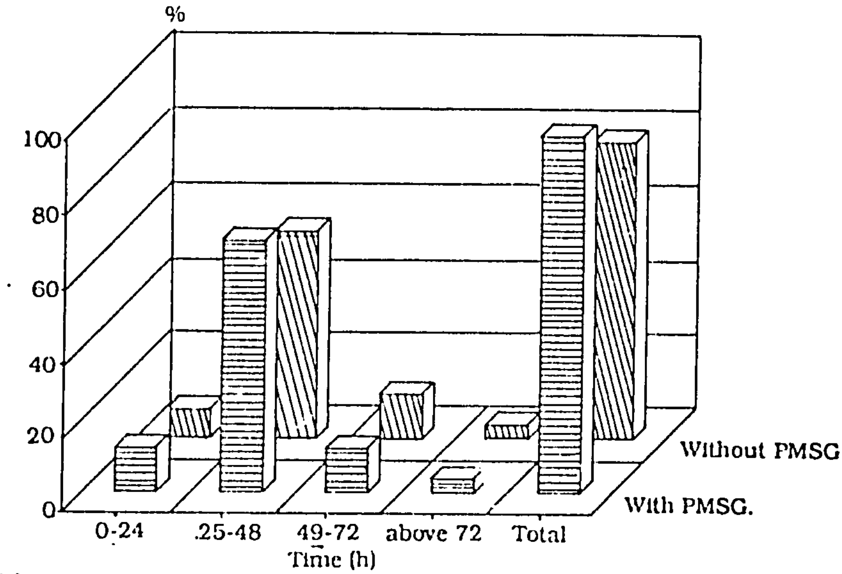

Fig. 1. Percentage of Does in oestrus after sponge withdrawal

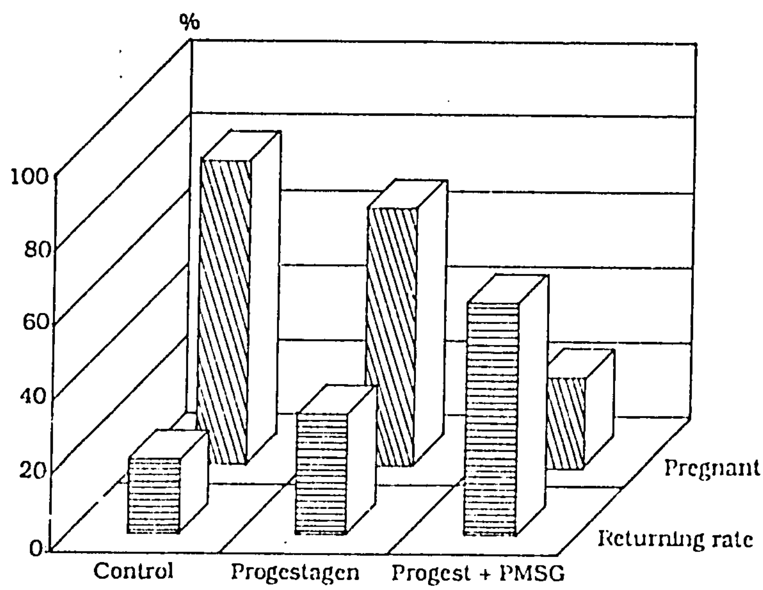

Fig. 2 Percentage of repeat breeders and pregnant Does

DISCUSSION

Sponge loss in this experiment is relatively higher when compared to other reports. Most experimental animals were maiden does, i.e animals that had never kidded before. Narrow reproductive tract of young does might have hindered proper insertion of sponges. Another possible reason is perhaps the management system. Does grazed outdoors had to be confined at night in groups. It was noted that some does developed a habit of pulling down the nylon strings (attached to sponges) of other does.

Synchronised oestrus is shown by 80% of group II and 96% of group III does. PMSG gave better results as compared to the sponge alone. Corteel (1975) used 45 mg FGA and 400 IU of PMSG to synchronise oestrus during the breeding season. He reported that 95% of the treated females came into oestrus. This finding confirms his report. It has been shown that gonadotropins play an important role in estrogen production. Increase in estradiol 17_{β} has been observed by Taminin et al (1985). Estrogen production has not been determined in this experiment. Nevertheless, it is safe to assume that PMSG has caused increased estrogen production, hence giving better results as compared to animals treated with progestagen only. It is difficult to explain why PMSG increased the number of repeat breeders.

In both groups (II and III), most does came into heat within 24-48 hours following sponge removal. Taminin et al (1985) found that all treated goats exhibited behavioural oestrus 18-24 hours after sponge removal. The frequency of heat detection in their experiment was every six hours for an observation period of 96 hours. Reduced frequency of heat detection in this experiment might have caused at least some of the experimental does that might have exhibited early oestrus to be recorded in later hours.

Fertility, as confirmed by later kiddings is poor in both synchronised groups, although does that did not receive PMSG were better than those that did receive PMSG. Progestagen or progestagen + PMSG lowered fertility. The main reason for lowered fertility of does following regulation of oestrus with a progestagen is failure in sperm transport and consequently to a reduced rate of ovum fertilisation (Allison and Robinson, 1970). According to Crocker et al (1975), "progestagen insufficiency" and sperm transport seem to be related. Ewes in which the oestrus cycle has been prolonged with relatively low amounts of progestagen have tended to have less efficient sperm transport and lower fertility at the onset of oestrus than ewes treated with larger amounts of progestagen (Allison and Robinson, 1975). It may be argued that the amount of progestagen used in this study was low (30 mg FGA). But it is still difficult to explain why PMSG reduced fertility. In fact, this finding is contradictory to many other results (Bongaso et al, 1982).

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A REVIEW OF GENETIC RESISTANCE TO ENDOPARASITES IN SMALL RUMINANTS AND AN OUTLINE OF ILCA'S RESEARCH PROGRAMME IN THIS AREA

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INTRODUCTION

Helminthiasis is of considerable significance in a wide range of agroclimatic zones in sub-Saharan Africa and constitutes one of the most important constraints to small ruminant production. The widespread occurrence of infection with internal parasites in grazing animals, the associated loss of production, the costs of anthelmintics and death of infected animals are some of the major concerns. There is also increasing awareness of environmental issues which may influence anthelmintic usage through consumer demand for animal products and pastures free of chemical residues. Current control methods for internal parasites outside Africa focus on reducing contamination of pastures through anthelmintic treatment and/or controlled grazing. In Africa, these control methods are limited by the high costs of anthelmintics, their uncertain availability, increasing frequency of drug resistance and limited scope in many communal pastoral systems for controlled grazing. It appears unlikely that new broad-spectrum anthelmintics will be available in the near future because of the major costs incurred in development of new products. To date, no commercial vaccines have been developed. Alternative approaches to control internal parasites are therefore being considered. One such approach is utilisation of host genetic variation for resistance.

Evidence for genetic variation of the host for resistance or tolerance to internal parasites was first documented 40-50 years ago (e.g Stewart et al, 1937; Gregory; 1937, Emik, 1949; Warwick et al, 1949; Whitlock, 1955). In the developed world, there has been a renewed interest in this area in the last 10 to 20 years, particularly in Australia and New Zealand, due mainly to the problems of rapidly increasing drug resistance and increasing costs of anthelmintic treatment.

This paper reviews the evidence for genetic resistance to endoparasites both within and between breeds of sheep and goats and assesses the possibilities of breeding for increased resistance. In light of this evidence, ILCA has developed a Pan-African research programme to investigate and characterise genetic resistance to endoparasites in sheep and goats. The experimental design and research protocol is briefly outlined.

CRITERIA OF RESISTANCE, RESILIENCE OR TOLERANCE

Clunies-Ross (1932) was the first to recognise the need for the distinction between "resistance to infection" and "resistance to the effects of infestation". There is some confusion in the literature about how to define these effects, but the following definitions are commonly used (Albers et al, 1987; ILCA, 1991).

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RESISTANCE, defined as the initiation and maintenance of responses provoked in the host to suppress the establishment of parasites and/or eliminate parasite load;

RESILIENCE, defined as the ability of the host to maintain a relatively undepressed production level under parasite challenge;

TOLERANCE, defined as the ability of the host to survive in the face of parasite challenge.

For a number of reasons, measurement of resistance appears more useful than resilience or tolerance. For example, tolerance or resilience do not imply control of the parasite and therefore contamination of pasture will increase because faecal egg output of the animals is not being reduced. With resistant animals, however, the contamination of pasture by infective larvae gradually decreases (Windon, 1990). However, if parasites can adapt to anthelmintics, they can probably also adapt to resistant hosts. It has therefore been suggested that until it is known what occurs in parasite adaptation, it is better to select for resilience because there is no pressure being exerted on the parasite for genetic adaptation. Currently, it appears that genetic adaptation of parasites to resistant hosts may not be a major problem (e.g Windon, 1991), but further research in this area is underway.

In Australia, resilience has been measured in terms of depression of liveweight gains (LWG), wool growth (WG) and fibre diameter assessed from young lambs (3-6 months of age) infected and uninfected with parasites (Albers et al, 1987). The heritability of resilience was low and not significantly different from zero ($0.09 \pm .07$ and $0.08 \pm .07$ for LWG and WG, respectively). In contrast, heritability of resistance measured as faecal egg counts (FEC) or haematocrit (packed cell volume - PCV) following artificial infection with *Haemonchus contortus* ranged from 0.26 to 0.45. The genetic correlations between resistance (FEC and PCV) and resilience (LWG) assessed in this study were in the desirable direction (0.31 to 0.37), but had high standard errors. It appears that this genetic correlation may be less than unity. Therefore, the genetic control of resilience is partially independent of that for resistance.

As will be documented later, most published reports on within-breed differences in host responses to endoparasites have concentrated on measures of resistance. In breed characterisation studies, it is usually not difficult to also measure production traits (e.g. growth, wool, reproduction). To measure 'true resilience' is more difficult since it involves an experimental design which includes infected and uninfected animals (e.g Albers et al, 1987). This also has important implications for estimating genetic parameters as is discussed later.

The consensus appears to be to concentrate most effort on resistance but assess resilience when this is practical and feasible.

Mode of Infection

Both natural pasture challenge and artificial (experimental) infections have been used in assessing resistance to endoparasites. There is a wide diversity of internal parasites and under natural challenge small ruminants usually harbour more than one species (Gruner, 1991a). These include the three major orders (Nematodes, Cestodes and Trematodes) and a range of genera within orders (Hansen and Perry, 1990). The life cycle, population biology and pathogenicity of the different species are not the same, but in most cases are relatively well known.

Nearly all the research to date on resistance to endoparasites has concentrated on the Nematodes and particularly the *Trichostrongyles* (e.g *Haemonchus, Ostertagia, Trichostrongylus* and *Nematodirus* spp). There have been relatively few reports of resistance of sheep to Trematodes (*Fasciola hepatica* and *Fasciola gigantica*). Wiedosari and Copeman (1990) recently documented relatively high resistance to *F. gigantica* in Javanese thin-tailed sheep. There is need for further work on host genetic resistance to Trematodes (flukes) and Cestodes (tapeworms), both of which are important in many areas of Africa.

In order to obtain meaningful results with natural infection, it is first important to assess which are the most economically important parasites in any particular agroclimatic zone. When there is a diversity of parasites present, then natural infection is preferred, particularly to assess breed differences. In assessing within-breed genetic variation to obtain heritability and genetic correlation estimates, then artificial infection is often preferred (Woolaston et al, 1991) since it should help control some of the environmental effects. Usually, artificial infection is with a single parasite species (e.g *Haemonchus contortus* or *Trichostrongylus colubriformis*), although sometimes a mixed infection is given (Gruner et al, 1986; Watson and Hosking, 1992a,b). When artificial infection is used, it is important to assess how this relates to resistance under natural challenge. There is some encouraging evidence that the genetic association between artificial infection with *H. contortus* or exposure to *H. contortus* contaminated pasture is positive (Gray 1991; Woolaston et al, 1990a). Similarly, positive correlations between resistance to *H. contortus* and *T colubriformis* have been reported (Gray et al, 1991; Woolaston et al, 1990a).

Piper and Barger (1988) noted that artificial infection excludes any expression of genetic resistance due to the grazing behaviour of the host. They suggested that selection for resistance based on natural infection is to be preferred, as it makes fewer assumptions about the basis of host resistance. However, in those climates where there is marked variation between years in intensity of larval challenge on pasture, artificial infection may need to be included in conjuction with natural infection.

Parameters to be Measured

The most common trait measured to predict resistance has been faecal egg count. FEC is usually a good indicator of worm burden (especially in young animals) but this can depend on the parasite species. For example, FEC during *Ostertagia* infection bears little or no relationship to worm burdens, even in young sheep (Piper, 1987). However FEC can be considered a trait of importance in its own right since it is closely related to the level of contamination of the pasture and therefore the level of infection to which grazing animals are exposed (Gray, 1991). PCV is another important parameter to determine the level of parasitism, particularly for blood sucking parasites such as *H. contortus*. Ideally, at each time FEC or PCV is measured, larval culture should be undertaken to provide an approximate indication of which parasite species are present. Larval differentiation will be indicative only of the actual number of worms of each species because different parasite species have different rates of egg output.

The periparturient rise in FEC in ewes (i.e. from birth and while lactating) has been measured in both between-breed and within-breed studies. Because of its relationship with pasture contamination at a time when young animals are very vulnerable to infection, it is another interesting and important parameter.

Worm counts are the best measure of resistance but involve slaughtering the animal. They have often been used in breed characterisation studies but cannot easily be used in within-breed selection studies. Similarly, a number of other parasitological parameters reflect different aspects of resistance (e.g rate of establishment of newly ingested larvae; rate of development into adult stages, survival of adults, prolificacy and size of females, etc.) but these also involve slaughtering animals sequentially over time.

A number of immunological parameters are being investigated as potential criteria for resistance and are discussed in a later section of this paper.

Tolerance is measured in terms of mortality, while resilience should be assessed in terms of all economically important production traits. In many experiments, production is measured over a relatively short period (e.g liveweights of lambs over 3 to 6 months). There is need for further evaluation over longer periods, particularly for reproductive parameters.

GENETIC VARIATION IN RESISTANCE

Between-breed Variation

There is a substantial body of evidence for between-breed variation in resistance to trichostrongyle nematodes in sheep, beginning with the report of Stewart et al (1937). Table 1 summarises many of the publications that have been reported to date and is an amalgam of similar summaries produced by Gruner and Cabaret (1988) and Gray (1991) with the addition of some further publications. Table 1 illustrates a number of important points such as:

Table 1. Sheep breed comparisons for resistance to internal parasites

Resistant Breed(s) (n)[1]	Comparison Breeds (n)[1]	Trait[2]	Type of infection[3]	Parasite Species[4]	Age (Months)	Reference
Romney	Rambouillet Southdown Shropshire Crosses	E	N	Oc	6-20	Stewart et al (1937)
Rambouillet	Romney, Cheviot	S	N	Hc	Rams	Warwick (1949)
Targhee (32) Panama (21)	Rambouillet (27) Hampshire (35) Suffolk (95)	E,W	N	Osp,Nsp	4-7	Scrivner (1964)
Florida Native	Rambouillet Hampshire	E,W,S	N	Hc	Lambs & ewes	Loggins et al (1965)
Targhee (8)	Suffolk (8)	E	A	Osp+Hc	3-11	Scrivner (1967)
Merino	Targhee	E,P,W	N	Hc,Str	2-7	Colglazier et al (1968)
Florida Native (120)	Rambouillet (60)	E,P	N	Hc	Ewes	Jilek & Bradley (1969)
Scottish Blackface	Dorset	W,Bw	A	Ta	Lambs	Ross (1970)
Florida Native(19)	Rambouillet (8)	E,W	A	Hc	5	Rhadakrishnan et al (1972)
Florida Native(33)	Rambouillet (8)	E,W	A	Hc	5	Bradley et al (1973)
Cigaja (10)	Merino (10)		N	Str	12	Cvetkovic et al (1973)

Table 1 Contd.

Resistant Breed(s) (n)[1]	Comparison Breeds (n)[1]	Trait[2]	Type of infection[3]	Parasite Species[4]	Age (Months)	Reference
Navajo (24)	Suffolk (11) Rambouillet (23) Targhee (15) Corriedale (15)	E,W	A	Hc	4-5	Knight et al (1973)
Scottish Blackface (24)	Finn Dorset (22)	E,W,P	A	Hc	7-10	Altaif & Dargie (1978)
Red Maasai (16)	Merino (16) Corriedale (16) Hampshire (16)	E,W	A	Hc	24-36	Preston & Allonby (1978)
Merino (5)	Awassi (5)	E,P,W	A	Hc	5-6	Al-Khshali & Altaif (1979)
Columbia Crosses (50)	Suffolk Crosses (50)	E	N		ewes	Norman & Hohenboken (1979)
Red Maasai (10)	Merino (60)	E,W,S	N	Hc	ewes	Preston & Allonby (1979)
Red Maasai (10)	Black-head Persian (10) Merino (10) Dorper (10) Corriedale (10) Hampshire (10)	E,W,S	N	Hc	ewes & wethers	Preston & Allonby (1979)
Barbados x Dorset (69)	Dorset (50) Crossbred (15)	E,W	N/A	Cooperia Tsp, Osp	ewes & lambs	Yazwinski et al (1979)
Barbados (8) BxDorset (14)	British crossbred (15)	E,W	A	Hc	3-5	Yazwinski et al (1981)
West African Dwarf W.A. Long-legged	Nungua Black-Head	E	N	Mixed (Oc,Tsp,Hc)	Ewes & lambs	Assoku (1981)
Border Leicester x Merino (66)	Merino (66)	E,W	N	Osp	ewes	Donald et al (1982)
Florida Native (13) St. Croix (10) Barbados (14)	Domestic (14) St. Croix-cross(8)	E,P_p	A	Hc,Tsp Osp	Ewes	Courtney et al (1984)
Florida Native (30) St. Croix (29)	Barbados (27) Domestic (41)	E,P,W	A	Hc	5-6	Courtney et al (1985a)
Florida Native (5)	Barbados (9) St. Croix (4) Domestic (5) Domestic-cross (12)	E,P,W	N	Hc,Tsp	Ewes	Courtney et al (1985b)
3/4 East Friesian	Corriedale	E,W,Bw	N	Mixed		Suarez (1985)

Table 1 Contd.

Resistant Breed(s) (n)[1]	Comparison Breeds (n)[1]	Trait[2]	Type of infection[3]	Parasite Species[4]	Age (Months)	Reference
Lacaune (50)	Romonov (50) RxL (50)	E,W	N	Osp,Nsp	Ewes	Gruner et al (1986)
Laucaune (5)	Romonov (5)	W	A	Mixed Osp,Tc	5-6	
Merino d'Arles	Romanov Merino x Romonov	E	N	Mixed	Ewes	Gruner et al (1987)
Florida Native (21)	Dorset x Rambouillet (45)	E,P_p,W	N	Hc,Tsp	Ewes Osp	Zajac et al (1988)
Horro (32)? Arsi (32)	B.H. Somali (32) Adal (32)	E,P,W S,Bw	N	Hc	6-12	Asegede (1990)
Merino d'Arles (30)	Romanov (30)	E,W	A	Oc	Ewes & lambs	Gruner (1991a)
Perendale(216)	Romney(221) RxP (342)	E,B,W	N	Mixed (Osp)	4-8	Watson & Hosking (1992a)
Red Maasai (15)	Dorper (15) B.H. Somali (15) Romney (15)	E,P,W,S	N/A	Hc	Ewes	KARI/ODA (1992) (unpublished)
Red Maasai (27)	Dorper (15)	E,P,W,S	N/A	Hc	Ewes	KARI/ODA (1992) (unpublished)

1. Number of sheep of each breed
2. E = Eggs per gram; P = Packed cell volume; W = Worm count;
   S = Survival; Bw = Body weight; P_p = Periparturient rise in epg
3. N = Natural; A = Artificial
4. Hc: *Haemonchus contortus*
   Tsp: *Trichostrongylus species*
   Ta: *Trichostrongylus axei*
   Tc: *T. colubriformis*
   Oc: *Ostertagia (Teladorsagia) circumcincta*
   Osp: *Ostertagia (Teladorsagia)* species
   N.sp: *Nematodirus* species
   Str: *Strongyloides*

- Resistance to *H. contortus* has been most commonly assessed, but there is also evidence for resistance to *Ostertagia* sp. and *Trichostrongylus* sp.

- Resistance has been demonstrated both with artificial infection and natural challenge. Usually with natural challenge this involves a number of parasite genera with one or two predominating.

- In nearly every case, FEC has been used to measure resistance but worm counts are also commonly recorded. Production traits and survival rates have been recorded less commonly.

- Resistance has been demonstrated in both lambs and mature animals (ewes, rams and wethers).

- Many of the breeds identified as being relatively resistant are native or 'unimproved' breeds. This presumably makes sense since these breeds have been under a reasonable degree of natural selection with little or no treatment with anthelmintics. The question of how best to utilise resistant breeds is discussed later.

- The experimental design used in nearly all these breed comparisons is poor. In particular, the number of animals evaluated for each breed is small, very few studies take account of variation among sires within breeds and how the animals were sampled is not given. Requirements for adequate experimental designs for breed evaluation have been comprehensively reviewed and discussed by Dickerson (1969). How animals are sampled and the family structure (i.e. number of sires and progeny per sire) are critical factors.

- While any one publication can be criticised in terms of experimental design, it is reassuring to note that some breeds have been identified as resistant in a number of independent studies. This applies particularly to the Florida Native and Red Maasai breeds. It is very likely these breeds have some real resistance characteristics.

Table 2 summarises the evidence for genetic variation for resistance between goat breeds. The number of publications are limited and suffer from most of the shortcomings discussed for sheep. It is possible that the mechanisms or level of resistance may be different in sheep and goats, since as goats are predominantly browsers, they are likely to have been under less natural selection for resistance. Indeed, it is usually reported that goats are more susceptible to nematode parasites than sheep, but the degree of susceptibility can differ for different parasite species (Gruner, 1991a). More research on resistance of goats to internal parasites is needed, especially in view of their numbers and importance in Africa and other developing countries.

Table 2. Goat breed comparisons for resistance to internal parasites

Resistant Breed(s) (n)[1]	Comparison Breeds (n)[1]	Trait[2]	Type of infection[3]	Parasite Species[4]	Age (Months)	Reference
Saanen (12)	East African(12) Galla(12)	E,W,S	A	Hc	24-36	Preston & Allonby (1978)
Alpine	Saanen	E	N	Mixed		Cabaret & Anjorand (1984)
East African (17)	Galla (13) Toggenburg x EA(19)	E,P,W S,Bw	A	Hc	10-14	Shavulimo et al (1988)
Alpine	Saanen	E	N	Oc	Does	Richard (1988)
Alpine(44)	Saanen(30) Crossbreds(26)	E	N	Osp,Tsp Hc	Does	Richard et al (1990)

Table 2 Contd.

Resistant Breed(s) (n)[1]	Comparison Breeds (n)[1]	Trait[2]	Type of infection[3]	Parasite Species[4]	Age (Months)	Reference
East African (8) and E.A. x Galla	Anglo Nubian-cross(8) Toggenburg-cross (18) DPG (16)	E,P	N	Mixed (mainly Hc)	10-12	Rohrer et al (1991)

1. Number of goats of each breed
2. E = Eggs per gram; P = Packed cell volume;
   W = Worm count; S = Survival; Bw = Body weight
3. A = Artificial; N = Natural
4. Hc = *Haemonchus contortus*; Oc = *Ostertagia (Teladorsagia) circumcincta*
   Osp = *Ostertagia (Teladorsagia)* species;
   Tsp = *Trichostrongylus* species

Within-breed Variation

The first evidence for within-breed genetic variation for resistance to internal parasites in sheep was reported by Gregory (1937), Gregory et al (1940), Emik (1949), Warwick et al (1949) and Whitlock (1955, 1958). Both Warwick and Whitlock dealt with *H. contortus* infection and compared the performance of offspring from parents selected for increased resistance (determined by FEC or PCV depression) with offspring from unselected parents or parents selected for decreased resistance. Larger-scale studies to estimate genetic resistance to nematode parasites (particularly *H. contortus*, *T. colubriformis* and *Ostertagia* sp.) in the Australian Merino were initiated in the early 1970's (Piper, 1987). This has resulted in a number of publications which have provided reasonably precise estimates of heritability both in the Australian Merino and subsequently the New Zealand Romney (studies initiated in the early 1980s, Baker et al, 1991).

These heritability estimates are summarised in Table 3. Resistance is assessed in terms of either FEC or PCV and functions of these traits. For example, FEC is usually transformed to normalise the skewed or 'over-dispersed' distribution. Logarithm, square root or cube root transformations are commonly used. In large data sets, heritabilities of transformed or untransformed FEC do not vary much (Woolaston et al, 1991). In addition, maximum FEC, average FEC, PCV decline and minimum PCV have been defined as measures of resistance. The heritabilities of these different functions of FEC or PCV are all very similar.

Table 3. Heritability estimates for measures of resistance to internal parasites in sheep

Trait[1]	Heritability[2]	Type of infection[3]	Age (months)	Parasite species	Reference (Breed)
FEC	0.29±.12(phs)	N	3-4	Mixed (mainly *Ostertagia*)	Piper et al (1978)
FEC	0.11±.12(phs)	N		*Nematodirus*	(Merino)
FEC(Max)	0.29±.12(phs)	A	3-6	*Haemonchus*	Albers et al (1984) (Merino)
FEC(Av)[4]	0.39±.27(R)	A	4-8	*Trichostrongylus*	Windon & Dineen (1984)
	041±.10(phs)				(Merino)
Log FEC	0.34±.19(Resm)	N	4-8	Mixed *(Trich & Ost)*	Watson et al (1986)
	0.57±.24(Resm)	N		*Nematodirus*	(Romney)
FEC(Max)	0.27±.13(phs)	A	18-20	*Haemonchus*	Piper (1987)
LogFEC(Max)	0.23±.13(phs)				(Merino)
PCV(decline)	0.25±.13(phs)				
FEC(4 wk)[5]	0.34±.10(phs)	A	3-6	*Haemonchus*	Albers et al (1987)
FEC(5 wk)[5]	0.26±.09(phs)				(Merino)
PCV(4 wk)	0.45±.12(phs)				
PCV(5 wk)	0.35±.11(phs)				
LogFEC	0.35±.12(Resm)	N	5	Mixed	Baker et al (1991)
	0.39±.13(Resm)		7	*(Trich & Ost)*	(Romney)
	0.66±.18(Resm)		11		
LogFEC(Av)	0.53±.15(Resm)		5 & 7		
FEC(4 wk)[5]	0.22±.04(Ream)	A	3-6	*Haemonchus*	Woolaston et al (1991)
FEC(5 wk)[5]	0.21±.04(Ream)				(Merino)
FEC(Max)[5]	0.20±.04(Ream)				
FEC(Av)[5]	0.24±.04(Ream)				
LogFEC(Max)	0.33±.03(Ream)	A	5-7	*Haemonchus*	Woolaston et al (1991)
Square root FEC(Max)	0.31±.03(Ream)				(Merino)
Square root FEC(Av)[4]	0.44±.04(Ream)	A	4-8	*Trichostrongylus*	Woolaston et al (1991)
Cube root FEC(Av)[4]	0.41±.04(Ream)				(Merino)
LogFEC(Av)	0.42±.14(phs)	N	3-8	Mixed (maily *Ostertagia*)	Cummins et al (1991)
LogFEC(Av)	0.38±.08(So)				(Merino)
LogWBLC(Av)	0.29±.13(phs)				
Square root FEC	0.30±.22(phs)	N	10	Mixed (mainly *Trich)*	Karlsson et al (1991)
Square root FEC	0.44±.26(phs)		13		(Merino)
Log FEC	0.13±.07(phs)	N	4-5	Mixed	McEwan et al (1992)
LogFEC	0.25±.09(phs)			*Nematodirus*	(Romney)

Table 3 Contd.

Trait[1]	Heritability[2]	Type of infection[3]	Age (months)	Parasite species	Reference (Breed)
FEC	0.34 ± .08(Resm)	N	7-8	Mixed	Bisset et al (1992)
Log FEC	0.27 ± .07(Resm)			(mainly *Trich)*	(Romney)

1. FEC = Faecal Egg Counts (eggs per gram of faeces); PCV = Packed Cell Volume
   WBLC = Whole Blood Culture Assay to measure *in vitro* lymphocyte stimulation to trichostrongylid worm antigens
2. phs = Paternal half sib estimates; R = Realized heritability; Ream = Restricted maximum likelihood estimates (animal model); Ream = Restricted maximum likelihood estimates (sire model), So = Sire offspring regression
3. N = Natural; A = Artificial
4. Mean of 5 egg counts at 2 week intervals from 3 weeks post infection
5. Square root tranformation of FEC taken 4 or 5 weeks post infection

It is clear that heritability of resistance, at least in the relatively susceptible Merino and Romney breeds, is moderate to high. The average heritability for a single FEC measurement following natural or artificial infection is 0.32. Heritabilities are similar for both modes of infection, and infection with a number of different parasite genera (both single genus infection and mixed infection). The heritability of PCV (average of 0.35) is similar to that for FEC. It is important to note that all the heritability estimates in Table 3 are for young sheep ranging in age from three to 20 months. This was a deliberate strategy to try and identify heritable selection criteria for young animals so that they could be used in breeding programmes prior to the first breeding at about 16 months.

The advantage in taking more than one measurement of FEC depends on the repeatability estimate. This depends in turn on the type of infection and experimental protocol used and may also be influenced by the FEC level (Karlsson et al, 1991). The repeatability within a single artificial infection with *H. contortus* is high (0.60) and relatively little is to be gained from selecting on the average of two FECs (Woolaston et al, 1991). On the other hand, using natural challenge in New Zealand, and two separate infections separated by an anthelmintic treatment, the repeatability is lower at about 0.30 to 0.40. This results in a heritability of about 0.35 for a single FEC measurement, but a heritability of 0.53 for the average of two FECs taken at about 5 and 7 months of age (Baker et al, 1991).

Similar differences in repeatability estimates for both FEC and PCV between (0.30) and within (0.60) artificial infections with *H. contortus* in Merino lambs was reported by Barger and Dash (1987). It is important to note that the relatively high heritability of responsiveness to vaccination and artificial challenge with *T. colubriformis* (0.44 ± .04) reported by Windon (1991) is based on the mean of 5 egg counts taken at 2 week intervals from 3 weeks post infection. Woolaston et al (1991) suggested that if these repeated measurements are assumed to have a genetic correlation of unity with a repeatability of 0.60, then it is likely that the heritability of one egg count is about 0.30.

There is one heritability estimate in Table 3 for a measure of immune response. This is a whole blood microtitre culture assay to measure *in vitro* lymphocyte stimulation indices to third stage larval *Trichostrongylus* spp. and *Ostertagia* spp. antigens and has a heritability of 0.29 ± .13 (Cummins et al, 1991). FEC was also measured in this study and it was suggested that FEC may reflect the direct outcome of infection (i.e. worm establishment), while the lymphocyte assay is a measure of the immune response of the host to parasite challenge. The genetic correlation between these two measurements looked to be less than unity although with relatively high standard errors, which suggests that they may be at least partially genetically different characteristics.

Few reports on genetic parameters for resistance to endoparasites in goats are available and these estimates are given in Table 4. The only published heritability estimates we could find (i.e. for FEC and PCV) were similar to those for sheep (Rohrer et al, 1991). Studies are also being undertaken to estimate heritabilities for resistance to natural challenge (mainly *Haemonchus* and *Trichostrongylus*) in goats in Fiji (Woolaston, per comm.) Preliminary results were not encouraging with low heritabilities (less than 0.10). This may have been influenced by the inability to adequately adjust for management constraints in this environment.

Table 4. Heritability (h^2) and repeatability (R) estimates for measures of resistance to internal parasites in small ruminants in Africa

Trait[1]	Parameter	Estimate	Species (Breed)	Age (Months)	Parasite[3]	Infection[4]	Reference
LogFEC	h^2	0.40	Goats	10-12	Mixed	N	Rohrer et al (1991)
PCV	h^2	0.22	(DPG)		(mainly Hc)		
LogFEC	R	0.07±.03	Goats	Does	Mixed	N	Baker et al
PCV	R	0.42±.04	(Galla)	Does	(Mainly Hc)		(unpublished)
PCV	R	0.32±.09		28			
LogFEC	R	0.09±.01	Sheep	Ewes	Mixed	N	Bekele et al
PCV	R	0.44±.01	(Ethiopia)		(mainly Tc)		(1992)
LogFEC	R	0.14±.05	Sheep	3-5	Mixed	N	Baker et al
PCV	R	0.42±.06	(D/RM)		(mainly Hc)		(unpublished)
LogFEC	R	0.05±.02	Sheep	2-12	Mixed	N	Reynolds et al
PCV	R	0.22±.03	(D/RM)		(mainly Hc)		(unpublished)
FEC	R	0.15±.05	Sheep	Ewes	Hc	A	KARI/ODA (1992)
LogFEC	R	0.32±.06	(D/RM)				(unpublished)
FEC	R	0.27±.04	Sheep	Ewes	Mixed	N	KARI/ODA (1992)
LogFEC	R	0.19±.03	(D/RM/R/BHS)		(mainly Hc)		(unpublished)

1. FEC = Faecal Egg Count (eggs per gram of faeces); PCV = Packed Cell Volume
2. DPG = Kenyan Dual Purpose Goat, D = Dorper, RM = Red Maasai; R = Romney; BHS = Black Head Somali
3. Hc = *Haemonchus contortus*; Tc = *Trichostrongylus colubriformis*
4. N = Natural; A = Artificial

These are also a few repeatability estimates for both FEC and PCV for some sheep and goat breeds in Africa which are summarised in Table 4. The repeatability estimates for PCV are similar to those reported in Australian Merino sheep (e.g. Barger and Dash, 1987). Those for FEC are consistently quite low and much lower than the heritability estimates shown in Table 3. Since repeatability estimates the proportion of additive genetic variance plus permanent environmental variance relative to total phenotypic variance, it is expected to be as high or higher than heritability estimates. Somewhat higher repeatabilities for FEC are reported in the recent KARI/ODA experiments in the Kenyan highlands relative to the much lower estimates in the study with similar sheep breeds at Diani on the Kenyan coast (Reynolds and Baker, unpublished). This could be due to an age effect (e.g lambs vs ewes), the relatively low FEC levels at Diani or the methodology used to assess faecal egg counts. The improved modified McMaster counting technique (MAFF, 1977) was used by KARI/ODA while the McMaster technique was used at Diani. The correlation between FECs from the same faecal samples counted at each location was not significantly different from zero. This illustrates the need to standardise and document the egg counting technique used in any particular study. There appears to be few published reports on the magnitude of within-laboratory sampling error which would help such assessment.

Selection Experiments

Many of the heritability estimates in Table 3 were derived from divergent selection experiments in sheep for resistance and susceptibility to a number of different parasite genera. There are eight such selection experiments being undertaken in Australia and New Zealand and another has recently been initiated in France. Some details of these selection studies are summarised in Table 5. Both artificial infection and natural challenge is being employed for resistance to a number of different parasite genera.

Successful response to selection has now been reported in three of these studies (Woolaston et al, 1991; Windon, 1991; Baker et al, 1991) and this confirms the moderate to high heritabilities summarised in Table 3. The only realised heritability reported to date was from the early stages of the CSIRO *Trichostrongylus* selection experiment and the estimate of 0.39±.27 was similar to the paternal half sib estimate of 0.41±.10 (Windon and Dineen, 1984).

Table 5. Selection experiments for resistance to internal parasites in sheep

Location[1]	Date started	Selection lines[2]	Selection criteria[3]	Type of infection[4]	Parasite species[5]	Breed	Reference
Armidale (CSIRO) Australia	1975	R,S,C	FEC (+ vaccination)	A	Tc	Merino	Windon (1991)
Armidale (CSIRO) Australia	1978	R,S,C	FEC	A	Hc	Merino	Woolaston et al (1990a)
Wallaceville, New Zealand	1979	R,S	FEC	N	Tsp,Osp	Romney	Baker et al (1991)
Armidale (UNE) Australia	1980	R,C	FEC	A	Hc	Merino	Albers et al (1987)
Ruakura, New Zealand	1985	R,S,C	FEC	N	Tsp,Osp	Romney	Baker et al (1991)
Ruakura, New Zealand	1986	R,S	FEC	A	Hc+Tc	Perendal	Watson & Hosking (1992b)
Rylington Park West Australia	1987	R,C	FEC+ Production	N	Tc+Oc	Merino	Karlsson et al (1991)
Hamilton, Victoria Australia	1988	R,S	FEC+LSA	N	Oc	Merino	Cummins et al (1991)
France	1990	R,S	FEC+NIL	N+A	Oc	Romanov	Gruner (1991b)

1. CSIRO :- Commonwealth Scientific and Industrial Research Organisation; UNE : - University of New England
2. R = Resistant; S = Susceptible; C = Control (random bred unselected line)
3. FEC = Faecal Egg Count (eggs per gram of faeces), LSA = Lymphocyte Stimulation Assay; NIL = Number of Infective Larvae ingested
4. A = Artificial, N = Natural
5. Tc = *Trichostrongylus colubriformis*, Hc = *Haemonchus contortus*, Oc = *Ostertagia (Teladorsagia) circumcincta*; Tsp = *Trichostrongylus* species
Osp = *Ostertagia* species

The expected rate of genetic progress from selection is dependent not only on the heritability, but also on the phenotypic variation, selection intensity and generation interval. The coefficient of variation (phenotypic standard deviation/mean) for logarithm transformed FEC is about 40% while that for PCV is about 15%. Let us assume a flock structure with 5% of the males selected and 30% of the replacement females and a generation interval of 4 years. Then, the expected rate of genetic progress by selecting on

FEC (heritability of 0.30) is 4.8% per year (i.e reduction in egg count), while it is 2.1% per year from selecting for increased PCV (heritability of 0.35).

It is difficult to precisely estimate the rates of genetic progress for FEC actually achieved from the currently published reports. However, they appear to range from 3.5 to 5% per year reduction in FEC in lines selected for resistance (low FEC) versus randomly-bred controls, which is in reasonable agreement with the expected value of 4.8% per year.

Major Genes

Whitlock and Madsen (1958) found some evidence for a putative major gene which conferred resistance to *H. contortus* in sheep. This was not confirmed because of the death of Violet, the ram who was the reputed carrier of the gene.

The progeny of one of the 61 sires evaluated in the study of Albers et al (1984, 1987) at the University of New England (UNE) in Australia exhibited an extremely high level of resistance to *H. contortus* in terms of FEC. This sire become known as the 'Golden Ram' and a dominant gene with an effect of approximately two standard deviations was hypothesised to account for the extremely high level of resistance displayed by the progeny. Segregation experiments designed to test the major gene hypothesis were set up, although in the meantime the Golden Ram died (Piper, 1987). An analysis of backcrosses to the Golden Ram and his sons did not show any clear evidence for segregation (Woolaston et al, 1990b). A major gene index was tested using this data and also did not provide clear evidence for a single gene with large effect. While the offspring of this ram are highly resistant to *H. contortus* and possibly more resistant than the CSIRO resistant line (Gray et al, 1991), the basis of resistance in the UNE flock is currently considered to be polygenic.

GENETIC CORRELATIONS

Among Resistance Traits

There are few estimates of genetic correlations among different measures of resistance. Albers et al (1987) assessed resistance to an artificial infection to *H. contortus* in terms of FEC and haematological parameters. The haematological parameters measured were haematocrits (to measure the degree of anemia), erythrocyte potassium content (indicator of erythropiesis) and serum iron concentrations (indicator of iron supply). High genetic correlations (-0.76 to -0.88) between faecal egg count and haematocrit (PCV) were found, suggesting a high degree of common genetic control. The genetic correlations between PCV and the other two haematological parameters were lower (0.42 to 0.54).

Production Traits

Between-breed comparisons (Table 1) have indicated high resistance levels in sheep breeds with reputedly low productivity such as the Red Maasai and Florida Native. This negative association between productivity and resistance is not supported by within-breed associations (Table 6). The genetic correlation estimates in Table 6 are mostly close to zero, but have large standard errors (0.2 to 0.3).

Table 6. Genetic (rg) and phenotypic (rp) correlation estimates between faecal egg count (FEC) and production traits in sheep

Source[1]	Trait1	Trait2[2]	rg±se	rp	Reference
Merino random bred flock (UNI) Hc infection	Sqrt FEC (5 wk)	LWG(UNI)	-0.29±.26		Albers et al (1987) (Sire model)
		WGR(UNI)	-0.02±.32		
		FD(UNI)	-0.26±.27		
		LWG(INF)	-0.68±.34		
		WGR(INF)	-0.66±.28		
		FD(INF)	-0.41±.24		
Merino random bred flock (CSIRO) Hc infection	LogFEC	CFW	0.10±.31	0.12	Piper (1987) (sire model)
		FD	-0.15±.26	-0.05	
		HBW	-0.42±.46	0.03	
Same as above (more relatives)	LogFEC	CFW	0.14	0.03	Woolaston (1990) (Animal model)
		FD	-0.14	-0.08	
		HBW	-0.15	0.01	
Merino Hc selection lines (CSIRO)	Sqrt FEC (Control line)	CFW	-0.05	-0.06	Woolaston et al (1991) (Sire model)
		FD	0.11	-0.05	
		HBW	0.08	-0.08	
All lines, animal model		EL/EJ	-0.22		
Merino Random Bred Flock (Victoria) Osp Natural infection	Log FEC	CFW	0.22	-0.05	Cummins et al (1991) (sire model)
		FD	0.00	-0.09	
		WW	-0.20	0.02	
		HBW	-0.02	-0.17	
Romney lambs in New Zealand Natural Infection (Tsp, Osp)	Log FEC	LWG(INF)	0.02±.25	-0.09	Baker et al (1991) (Sire model)
		Dag Score	-0.70	-0.08	
		Dag Score	-0.26±.24	-0.09	
Romney lambs in New Zealand Natural Infection (Tsp, Osp)	Log FEC	WW	-0.05±.22	0.01	Bisset et al (1992) (Sire model)
		BW (8mo)	-0.29±.22	-0.05	
		LWG(INF)	-0.36±.23	-0.05	
		HFW	-0.15±.18	-0.02	
		Dag score	0.41±.19	0.11	

1. Hc = *Haemonchus contortus*; Osp = *Ostertagia* species; Tsp = *Trichostrongylus* species
2. CFW = Clean Fleece Weight; FD = Fibre Diameter; HBW = Hogget (yearling) Body Weight;
   WW = Weaning weight; LWG = Live Weight Gain; WGR = Wool Growth;
   (UNI) = Uninfected with parasites, (INF) = Infected with parasites;
   BW = Body Weight; HFW = Hogget Fleece Weight; EL/EJ = Ewes lambing/Ewes joined (mated)

There are some special problems of estimating genetic correlations which include disease resistance as pointed out by the chicken breeders some time ago (Gavora and Spencer, 1978). Unless the production trait is measured in the absence of the disease, the decrease in production caused by the disease (i.e. the environmental correlation) will bias the genetic correlation estimate. To overcome this problem, experimental designs are needed where the production and the disease traits are measured on different but related groups of animals (e.g. Schaeffer et al, 1978). The group of animals on which the production traits are measured need to be maintained in a disease-free state. In chickens, the two groups can be established by splitting full-sib groups. In sheep, goats and cattle splitting half-sib groups is usually more feasible, although it is possible to create full-sib groups by multiple ovulation and embryo transfer. Another option to break this environmental correlation is a parent-offspring design, where resistance/susceptibility to disease is assessed in the sires and production traits recorded on their progeny in a disease-free state.

All the genetic correlation estimates in Table 6 are potentially biased, expect for those reported by Albers et al (1987). They estimated the genetic correlation between resistance and production measured over a relatively short period (5 months) in Merino lambs. Half-sib groups were split and lambs were maintained infected and uninfected by frequent anthelmintic treatment in a cross-over experimental design. Genetic correlation of resistance (FEC) with production traits of lambs maintained uninfected were not significantly different from zero, but were larger and negative (i.e. favorable) with production traits recorded in infected lambs.

Woolaston et al (1991) suggested that the bias in genetic correlation estimates may not be very great when production traits, such as body weights and fleece weights, are measured 6-9 months after the relatively short artificial infection period and the animals are maintained under regular drenching over the post-infection period. However, the same authors also provided an illustration of an instance where the bias can be considerable. In the CSIRO selection lines for resistance and susceptibility to artificial infection with *H. contortus*, the fertility of ewes (EL/EJ; ewes lambing/ewes joined) declined significantly in the susceptible line relative to the resistant line between 1981 and 1988. This could easily be interpreted as a correlated response to selection. However, prior to the 1989 and 1990 mating seasons, all young sires were fed supplements and the differences between the lines disappeared. It was concluded that the decline in EL/EJ was probably not related to ewe fertility but more likely a ram failure caused by higher than normal levels of parasitism. This effect may be at least partially responsible for the negative genetic correlation (-0.22) with EL/EJ shown in Table 6.

In due course, realised genetic correlations should be forthcoming from correlated responses in the selection experiments for resistance (Table 5). Again, care will need to be taken that the production traits are measured on disease-free animals. Those estimates reported to date support little or no correlation between resistance and production. For example, in the selection lines at Ruakura in New Zealand, there have been no significant differences between the resistant and susceptible lines for liveweight gain or hogget fleece weight (Baker et al, 1990; 1991). There is some evidence in New Zealand for a negative (unfavourable) genetic correlation between dag score and FEC (Baker et al, 1991). Dags are the accumulation of faeces on the wool around the tail-end of sheep and is a trait of significance in wool sheep in that it predisposes to flystrike and is costly and time-consuming to shear off (crutching). It is a moderately heritable trait (0.3). It is commonly considered by farmers that dirty sheep (high level of dags) indicated that a worm burden existed and therefore drenching was required. Current New Zealand evidence does not support this. This trait is of minor importance in Africa where hair sheep predominate. It could be important in those areas where wool sheep are farmed, such as the highlands of Kenya.

Resistance at Different Ages

No estimates of genetic correlations between resistance measured at different ages are currently available, but there is strong evidence that the correlations are high. This evidence comes from the selection lines for resistance and susceptibility, where the selection criterion was the response to acute infection in young sheep (Table 5). The ewes in these selection lines are now being monitored for resistance, particularly over the period just before lambing and during lactation (the periparturient rise in FEC). In all cases, the ewes in the resistant lines maintained significantly lower FECs than those in the susceptible line (Woolaston et al, 1991; Gray 1991; Watson and Hosking, 1992b; Baker et al, unpublished). These differences have been shown for both lactating and non-lactating (dry) ewes (Woolaston et al, 1991). Gray (1991) showed that the difference disappeared at 7 years of age, which in Australia is about the end of a ewes' useful life. It seems clear that resistance measured in weaned lambs is a good indicator of resistance levels for most of their productive life as ewes.

This phenomenon has also been found in between-breed studies. For example, Florida Native ewes have not shown a periparturient rise in egg count when compared with Rambouillet crosses (Courtney et al, 1984), but non-lactating ewes of similar age were equally resistant (Courtney et al, 1985b; Zajac et al, 1988).

Resistance to Other Diseases

Gray (1991) discussed some of the evidence for lack of positive genetic correlations among response to different diseases which involve immune mechanisms, particularly in mice and chickens. Based on this evidence, it has been suggested that conventional selection methods for improving the genetic level of disease resistance are not appropriate (Rothschild, 1989). For example, Hohenboken et al (1986) suggested that some form of stabilising selection for disease resistance may be most appropriate to select for intermediate optimum rather than try to maximise resistance and/or immune responses.

Some limited evidence for genetic relationships among resistance to different sheep diseases of commercial importance are just beginning to become available. In Australia, the responsiveness to several sheep diseases has been assessed in the Merino lines selected for resistance to *H. contortus* (Gray et al, 1991). In both the CSIRO and UNE resistant flocks, there are favourable correlations between resistance to *H. contortus* and *T. colubriformis*. Preliminary studies with the CSIRO lines indicate that the correlated responses in resistance to fleece rot, a natural outbreak of footrot, vaccination against footrot and clostridial disease were neutral. In the UNE resistant flock, based on one highly resistant founder sire (the Golden Ram), some relationships were not favourable or neutral. Resistance to *Haemonchus* and to fleece rot were unfavourably correlated in two years as was resistance to *Haemonchus* and clostridial infection in one year. There was also some evidence of a negative relationship between resistance to *Haemonchus* and the long-term effectiveness of footrot vaccination. The differences in relationships in these two flocks highlights the need for further study in this area and the risk of drawing conclusions from a single selection experiment. It also suggests that genetic basis of resistance could be different in these two flocks.

There are number of diseases of importance to sheep farmers in New Zealand and these include facial eczema, footrot, flystrike and ryegrass staggers as well as internal parasites. To date, only some preliminary information is available on the relationship between resistance to internal parasites and facial eczema (Baker et al, 1991). Selection lines exist in New Zealand for resistance and susceptibility to both facial eczema and internal parasites. In the facial eczema lines, the relationship with FEC appears neutral.

However, in the internal parasite selection lines (high and low FEC) there is some evidence for a positive relationship between resistance to internal parasites and facial eczema.

MECHANISMS OF RESISTANCE IN THE HOST

Well-defined genetic differences either between resistant and susceptible breeds or resistance and susceptible selection lines within breeds are extremely useful for critical and in depth studies on mechanisms of resistance. Mechanisms of resistance include both parasitological and immunological components. It is hoped that increased knowledge in this area may identify predictive markers or indicator traits and hence candidate resistance genes and may also assist in the development of vaccines. A

comprehensive review of this subject is beyond the scope of this paper but some comments will be made to identify the areas currently be investigated.

Terminology

At a recent research planning workshop (ILCA, 1991) the participants made the distinction between predictive markers and indicator traits.

A PREDICTIVE MARKER was defined as a trait which does not require the presence of disease and is not influenced by environmental or physiological factors that may produce transient effects.

AN INDICATOR TRAIT need not be totally independent of environmental contraints but needs to have a heritability higher than the resistance trait being used (e.g. FEC) and be favourably genetically correlated with resistance.

Some examples of each of these will be discussed.

Parasitological Mechanisms

Considerable reservations have been expressed by parasitologists about the use of FEC and PCV as measures of resistance to internal parasites (e.g. Dargie, 1982; Gruner, 1991a). In particular, it has been noted that FEC is not always closely related to worm burdens and that FEC is affected by an array of host-parasite relationships such as level of host immunity, age of host, species of parasite, stage of infection, parturition, consistency of faeces and accuracy of faecal egg counting. Despite these reservations it is also now clear that FEC is both a repeatable and heritable trait (Table 3 and 4) and does respond to selection. As noted earlier, FEC can also be regarded as a trait of interest in its own right, regardless of its degree of relationship with actual worm burdens (Gray, 1991).

It is important, however, that when the opportunity exists, parasitological mechanisms should be measured and compared in resistant and susceptible animals. Usually this means slaughtering animals to measure parameters such as rate of development of the different level stages into adults, the survival of adults, the prolificacy and size of females, the number of adult and immature parasites, etc. Increased knowledge of the parasite biology and host-parasite relationships may help identify indicator traits such as PCV or serum pepsinogen which can be measured on live animals. A recent report from New Zealand (McEwan et al, 1992) indicated that some blood parameters (albumin, total protein and pepsinogen) were all moderately to highly heritable, but phenotypic and genetic relationship with FEC, liveweight gain and wool growth were all close to zero and therefore were of limited value as indicators of resistance.

Resistance to infectious agents may depend upon innate mechanisms (e.g. inflammatory responses) and/or acquired immune responses (Powell, 1987). Under field conditions it is difficult to distinguish between effects of innate and acquired resistance, but this can be done under controlled experimental conditions (e.g. Gill, 1991). The evidence for innate resistance to internal parasites in sheep is equivocal at present but should not be dismissed as possible mechanisms (Gill, 1991; Gogolin-Ewens et al, 1991; Outteridge, 1991).

There is unequivocal evidence, however, that acquired immune response is an important mechanisms in controlling internal parasites in sheep, other domestic animal species and laboratory animals (Miller, 1984; 1987; Watson, 1986; Barger, 1987; Wakelin, 1985, 1987; Smith, 1988; Douch, 1990; Windon, 1990, 1991; Gill et al, 1991; Yong et al, 1991).

Douch (1990) pointed out that the immune response of sheep to nematode parasites involves a cascade of events beginning with the recognition of nematode antigen(s), followed by stimulation of the immune system to elicit the appropriate cellular responses at the gut mucosa and finally the release of products which promote the elimination of the parasite from the gut. This process is complex and still not fully understood.

Smith (1988) suggested that in immune sheep, worm exclusion or expulsion is probably brought about by a combination of immunologically specific (e.g. parasite specific T cells and antibodies) and non-specific components (e.g. mucus and inflammatory mediators) interacting in concert. This response is influenced by the age and genotype of the sheep as well as by nutritional and hormonal status. Smith (1988) also noted that relatively little is known about the antigens of the nematodes and stated that it was important to identify and characterise those antigens which stimulate protective immune responses. There has been progress in this area (e.g. Douch, 1990; Jasmer et al, 1992) which might eventually lead to the development of a vaccine, particularly against *H. contortus*.

In the selection study for high and low responsiveness after vaccination with *T. colubriformis* there has been elevated reactivity in the high responders (i.e. resistant sheep) across all three major immunological functions, that is, cellular, humoral and phagocytic (Windon and Dineen, 1984; Windon, 1990, 1991). These include humoral and cellular recognition of parasite antigen, levels of the complement component C3 and increased activity in the affector arm of immunological activity. Of particular interest in the latter category is the regulation and function of most cells/globule leucocytes and eosinophils resulting in the release of mediators having an antiparasitic effect (e.g. histamine, LTB4, LTC4). In sheep infected with *T. colubriformis*, the numbers of circulating eosinophils after infection reflect immunological responsiveness rather than degree of parasitism. Most of the examinations in these experimental sheep has been limited to peripheral responses (e.g. blood or skin) because the animals are required for breeding. Further research at the level of the gut mucosa may be required to fully explain mechanisms of resistance.

It has also been shown that genetic resistance of sheep to *H. contortus* is an expression of an acquired immune response (Gill et al, 1991). Comparison of immune and inflammatory responses between resistant and susceptible genotypes showed that resistance is associated with mucosal mastocytosis, eosinophilia and anti-*Haemonchus* antibody responses. There is some limited evidence that resistance to *H. contortus* in sheep may not necessarily be controlled by the same mechanisms for resistance to *T. colubriformis* (Gray et al, 1991).

None of the immunological mechanisms investigated to date have identified a clear-cut predictive marker or indicator trait for resistance to internal parasites in sheep or goats which would replace the need to measure FEC or PCV. Given the complexity of immunological responses, perhaps this is not surprising. There are, however, two encouraging possibilities in this area. In Australia, an *in vitro* lymphocyte stimulation test (Riffkin and Yong, 1984) is moderately heritable (0.29±0.13) but has little genetic association with FEC (Cummins et al, 1991). This trait is being considered as another measure of resistance (i.e. immune responsiveness) and is being used in conjunction with FEC to select resistant and susceptible lines of sheep with some encouraging initial responses (Cummins et al, 1991).

In New Zealand, an ELISA assay has been developed to measure antibody response to a number of parasitic genera including *T. colubriformis* and *H. contortus* (Douch and Green, unpublished). Preliminary estimates of the heritability of this antibody response were encouraging and ranged from 0.37 to 0.56 (Baker et al, 1991). The genetic correlation estimates between the antibody response and FEC was also favourable (ranging from -0.37 to - 0.88) and in this case the antibody test might be a useful indirect predictor of FEC. Even if this was not the case it could be still considered as another measure of resistance and included in a selection index for resistance if it was found to be relatively easy and not too expensive to measure.

Molecular Mechanisms and Markers

There is a continuing search for DNA markers which may be associated with disease resistance. Considerable effort has been put into looking for markers within the major histocompatibility complex (MHC) region of the genome. The MHC is a set of closely linked, highly polymorphic loci which has been shown to have a number of important roles in relation to the immune response in chickens and other mammalian species (Wakelin, 1985; Nicholas, 1987, 1991a; Rothschild, 1989). Some useful associations between MHC loci and disease resistance have been established in chickens (e.g. see Nicholas, 1987 for a review). However, it is now becoming increasingly clear that other non-immune, biochemical and physiological mechanisms must also be considered as potential candidates for genetic control of disease (Gogolin-Ewens et al, 1991; Outteridge, 1991).

Despite the intense effort in looking for associations of the MHC with disease resistance, in domestic livestock there are not yet any associations that can be exploited in practical breeding programmes (Nicholas, 1991a). Even when associations with substantial effect are found (as with Marek s disease in chickens), there is need for considerable caution before recommending that homozygous populations be created for what might appear to be a favourable MHC allele if natural selection favours heterozygosity at the MHC (Nicholas, 1991a).

Most of the studies looking for genetic associations with resistance to internal parasites in sheep are at an early stage and involve MHC markers. Although the ovine lymphocyte antigens (OLA) appear closely associated with the MHC and influence responsiveness to vaccination against *T. columbriformis* (Outteridge, 1991), OLA type has yet to be shown to be useful as a selection criterion. Cooper et al (1989) were unable to find any association between OLA type and resistance to *H. contortus*. Both Hulme et al (1991) and Wetherall et al (1991) have reported some evidence for MHC associations with resistance of Merino sheep to internal parasites in Australia. The importance of appropriate sampling and the occurrence of spurious correlations because analyses were not carried out within sire families were highlighted. The pitfalls in searching for such associations are well documented but often ignored (see Nicholas, 1991b, for an excellent review).

Rohrer et al (1991) used two Randomly Amplified Polymorphic DNA (RAPD) markers to search for associations with resistance/susceptibility to *Haemonchus* and coccidia in Kenyan dual purpose goats. One locus showed some degree of relationship with PCV and the study clearly illustrated the potential of these markers for determining genomic polymorphisms.

MECHANISMS OF RESISTANCE IN THE PARASITES

There is often concern expressed that genetic selection for host resistance may be futile because of the capacity of the parasite to adapt to the host resistance mechanisms. This must be a very real concern since there is clear evidence of the ability of pathogens to develop genetic resistance to chemicals and drugs (Nicholas, 1987) and, in particular, resistance of internal parasites to anthelmintics (Waller, 1990). Resistance by internal parasites to some anthelmintics has been shown to follow simple mendelian inheritance in some cases while in other cases, polygenic inheritance was implicated. Some progress has been made in modifying the genome of resistant pathogens using both classical genetic techniques (e.g. genetically sterile individuals) or molecular genetic techniques. Le Jambre and Royal (1980) reported the production of a hybrid *Haemonchus* with meiotic abnormalities which resulted in substantial sterility.

Barger and Sutherst (1991) noted that the introduction of tick resistant breeds into the Northern-Australian cattle industry 20 years ago has almost eliminated the need for acaricides with no evidence of any adaptation by ticks that lessens the effective resistance of *Bos indicus* based breeds. They suggested that development of parasite-resistant sheep should have a similar impact on anthelmintic use.

Very few experimental studies of responses of nematodes to host resistance have been carried out. Windon (1991) reported a small but statistically significant increase in the ability of *T. colubriformis* to infect sheep with acquired resistance to this parasite after one generation of selection in vaccinated resistant sheep. Other investigations yielded very different results. Adams (1988) and Albers and Burgess (1988) did not find any adaptation of *H. contortus* to resistant hosts after 5-6 parasite generations of serial passages through resistant hosts. Recently, studies commenced to examine adaptive responses over 30 generations of *H. contortus* and *T. colubriformis* in the resistant and susceptible *Haemonchus* selection lines (Woolaston, 1990). Results after 7 parasite generations showed no evidence for adaptation in *H. contortus* (Barger and Sutherst, 1991). Even if experimental studies demonstrate the ability of the parasite to adapt to host resistance, Barger and Sutherst (1991) consider this would probably be delayed considerably by a number of factors acting under natural pasture challenge.

BREEDING PROGRAMME FOR PARASITE RESISTANCE

As it has been amply demonstrated that breeding for resistance to internal parasites and other diseases of sheep is a feasible goal (Morris, 1991; AWC, 1991), there is now an urgent need to develop acceptable strategies for accommodating disease resistance traits in industry breeding programmes. This is already occurring in New Zealand where industry sheep breeding programmes have been developed to accommodate resistance to facial eczema (Towers et al, 1990) and internal parasites (Baker et al, 1991; Parker, 1991).

A number of important issues still need to be resolved in this area. For example, to include disease traits in multi-trait selection indexes for within-breed genetic improvement programmes, research is still required on the best way to assign economic values to disease traits and more precise estimates of the genetic correlations between disease traits and production traits are required (Piper and Barger, 1988; Carrick and Ponzoni, 1991). Another important issue farmers have to face is the requirement of withholding drugs or chemicals controlling disease from animals so that genetic variation for host resistance can be manifested (Baker, 1991). In this context, the identification of a predictive marker (e.g.

a DNA probe) which could screen animals for resistance without the presence of the disease may make breeding for disease resistance simpler and more acceptable.

In Africa, it is highly likely that the first question to be asked is how to utilise breed variation most efficiently. Most breed evaluations carried out to date (Table 1) have just compared purebred populations. While this will yield estimates of additive genetic variation among breeds, it does not yield estimates of heterosis and/or epistatic effects which are required to formulate optimum cross breeding strategies (Dickerson, 1969). If, however, some indigenous African breeds are found to be relatively resistant to diseases, then one option will be to carry out multi-trait genetic improvement programmes within that breed or population. If crossbreeding strategies are indicated (e.g. because the performance levels of the resistant breed are very low), then the ranking of resistance in purebred performance is useful in predicting average transmitted effects in crosses but the correlation between purebred and crossbred performance is limited by breed differences in level of inbreeding, in epistatic interaction and by sampling errors of estimation of breed means. If crossbreeding strategies are to be employed, then it will be important to estimate the appropriate parameters and one cannot dismiss the possibility of heterosis for disease resistance (Zijpp et al, 1990).

ILCA'S RESEARCH PLANS

ILCA's major research effort in the area of the genetics of disease resistance over the past 10 years has been in the field of trypanotolerance. Trypanotolerant breeds of cattle, such as the taurine N'Dama and West African Shorthorn, have been identified and extensively characterised, not only for criteria of trypanotolerance but also for production traits.

Research with very similar objectives to the trypanotolerance studies with cattle is now being planned with small ruminants. In particular, work is planned that will determine and compare genetic variation in resistance to internal parasites between and within breeds of sheep and goats in a Pan-African, multidisciplinary study. Where other diseases are also of importance, it is planned to characterise genetic variation in resistance to them, as well as the usual array of production traits, e.g. growth, reproduction and mortality.

In February 1991, ILCA held a research planning workshop at its headquarters in Addis Ababa, Ethiopia to develop a Pan-African research programme to investigate genetic resistance to endoparasites in small ruminants. As originally conceived, this experiment involved evaluation studies being carried out at Debre Birhan, Ethiopia; Diani Estate, Mombasa, Kenya and a site in West Africa. The research at Diani started in 1987 and includes Dorper and Red Maasai x Dorper crosses (Reynolds et al, 1992). In the 1992 matings a group of purebred Red Maasai ewes was added to the study and Galla and Small East African goats are being compared.

Currently, research planning has evolved to lay out more-detailed experimental protocols for the Ethiopian and Kenyan components of this work. In Ethiopia, a multidisciplinary research programme has been designed which involves the evaluation of two sheep breeds (Menz and Horro) lambing in three different seasons of the year. This research will involve quantitative genetics (genetics of disease resistance and production traits within and between breeds); parasitology (epidemiology of parasites on the pasture and in the animals); nutrition (measurement of feed intake using chromic oxide slow-release devices); reproductive physiology (effect of ewe physiological state and hormones on levels of endoparasite infection); animal physiology (assessment of fat deposition/metabolism and gut capacity); and economics (economic evaluation of the importance of genetic variation for resistance to endoparasites versus chemotherapy as a means of controlling endoparasites).

In Kenya, plans are progressing to establish a highlands research site, in collaboration with KARI and ODA, to complement the coastal site at Diani. Present plans are proposing the evaluation of three sheep breeds - two Red Maasai strains, Dorper and Corriedale and possibly three goat breeds - Galla, East African and the Kenyan dual purpose goat. Some of the multidisciplinary features of the Ethiopian experimental protocol may be emulated in Kenya.

In West Africa, plans are being formulated to collaborate with ISRA and IEMVT in Senegal to evaluate Djallonke and Peul Peul sheep and West African Dwarf (Djallonke) and Sahel goats.

The initial phase of this study will establish between- and within-breed genetic variation and is expected to take 4-5 years. A second phase is then envisioned where mechanisms of resistance will be studied between animals well characterised as being relatively resistant or susceptible. It is hoped this may identify indicator traits and/or genetic markers for resistance.

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The ILCA research proposal on genetics of resistance to endoparasites in small ruminants was originally conceived by Dr. O.B. Kasali who left ILCA in June 1991. The research planning workshop held in February, 1991 (ILCA, 1991) involved three expert consultants (Dr. L. Gruner, INRA, France; Drs. R. Windon and R. Woolaston, CSIRO, Australia), and their contributions and deliberations did much to develop the research protocols presently being implemented.

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ON-FARM LIVESTOCK RESEARCH WITH SPECIAL REFERENCE TO THE ON-FARM GALLA X EAST AFRICAN GOAT BREED EVALUATION AT MARIMANTI, KENYA

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ABSTRACT

An on-farm Galla x East African goat breed evaluation was conducted at Marimanti Meru in Kenya under the Embu Meru Isiolo (EMI) livestock project using 12 flocks belonging to local farmers. The objective of this particular study was to determine methodological issues affecting on-farm livestock trials.

Results showed that on-farm livestock trials should not be considered an alternative to laboratory and on-station livestock research. On the contrary, they should be seen as a complementary research method which may be used to answer questions concerning livestock interactions with particular farming environments or farmer acceptability of new livestock technologies. Each on-farm trial is unique and therefore requires unique preparation and execution.

INTRODUCTION

The complexities of livestock integration often lead to difficulties in predicting the effects of proposed "improvements". New techniques may be tested in laboratories and research station environments with great efficiency and control. However, for promising research results to reach the goal of economical application by farmers, the results have to be appropriate to the farmer's system and environment. The objective of on-farm research (OFR) is to identify, in cooperation with farmers, new farming practices and materials which will improve the farmer's system and raise its productivity in a sustainable way. Conducting OFR with livestock is one means of designing and testing appropriate livestock technologies for adoption by farmers to enable packages to be designed for farmers needs. However, many researchers feel that on-farm livestock trials have methodological constraints which make them difficult to carry out and that the logistics involved make them more costly than on-station research.

In this paper, the methodologies in on-farm livestock trials are reviewed with reference to the Marimanti on-farm trials. The constraints and rationale for the trials are identified. This is followed by a discussion on if and how livestock on-farm trials can be conducted in the future based on the lessons learned from the Marimanti experience.

MATERIALS AND METHODS

The trial initially began in June 1988 with 12 flocks. This number was decided upon because of available resources. The flocks/sites were selected within a 15 km radius of the project centre using the compass directions of North, South, East and West as the basis for location selection.

Selection criteria for individual farmers were that they must be livestock keepers; have a herd size of 10-50 female goats; be well acquainted with the project activities and have acquired Galla and/or East African flocks.

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All selected farmers attended a one-day seminar in which the purpose and objectives of the trial were fully discussed. The farmers were also shown how to take and record kid birth weights and inventory changes in their flocks. All the selected farmers were provided with portable spring balances and recording sheets. As an incentive, the participating farmers were promised frequent advisory visits by the project technical staff, with free dewormers.

Trial Design

Since the aim of the trial was to evaluate the performance of the Galla X East African goat relative to the pure East African under on-farm conditions, two types of flocks were selected for the trial: flocks with pure East African goats and flocks with both Galla and East African goats and their cross breeds.

Assuming that the farmers were homogeneous in most managements aspects, the two breeds were the treatments while the flocks on different farms were the replicates. On the first visit to each flock, all animals were sexed, identified with ear tags, aged by dentation or by farmer recall for younger animals. Relationships between existing kids and dams were established and the recent reproductive history of all breeding females investigated.

At each subsequent visit, records were taken of flock inventory changes, including births, purchases, deaths, sales and slaughter, together with reasons and causes when known. This information was then used to update the flock list. The performance of the kids from birth to one year was selected as the main response variable. The main parameters to be measured were: monthly weights of all females; kid birth weights and subsequent monthly weights; and inventory changes in the flock.

Data Analysis

The 16 month trial period was not adequate to collect sufficient data for complete analysis given the nature of the trial; hence, only a superficial and general analysis was done. Multiple regression was recommended as the best form of analysis for the existing data.

RESULTS

Results showed no significant difference in the growth performance of the two breeds and their crosses. However, most farmers involved in the trial felt that the survival rate of Galla x East African kids was low compared to that of the East African kids as they were prone to the helminth problem prevalent in the area, despite their initial heavier birth weights. Trial losses and coefficients of variations (CV) were very high due to lack of close supervision of the experiments and different environments on different farms. It was found that trials with animals, especially large ones, are constrained by the number of replications because of the relative high cost, the diverse genetic background, variation in age, condition and past nutritional history. Non treatment error was increased due to animal mobility. Hence there were varying livestock-environment interactions. It was difficult to find comparable units in the trial because of the difficulty of synchronising animal breeding on farms.

It was found that most farming communities are not homogeneous as assumed and are composed of diverse groups of farmers with different levels of power, access to resources and interest in participating in trial programmes. This increased non treatment error and also complicated the management of the trial.

STUDY FINDINGS

Trial Design and Analysis

- There is a need to develop statistical methods for analysis of on-farm trial data, where input levels and environments vary among sites;
- Treatments in randomised block design should be limited, i.e. three to four but with as many replicates as the resources can allow for practical and statistically acceptable results.
- A pre-trial survey and or a pilot trial is essential in order to design a practical on-farm trial which will satisfy the statistical requirements and be relevant and practical to participating farmers.
- The use of farmers/farms as replications at the given number of farms per treatment limits precision and therefore the likelihood of detecting significant treatment effects at conventionally used levels of significance.

Farmer Participation and Cooperation

If farmers are to be actively involved in the management and execution of on-farm trials, then:

- it is vital that objectives, design and hypothesis of a trial be understood in order to sustain interest and cooperation;
- trials should not extend beyond 12 months - farmer interest is enhanced by rapid and dramatic results;
- incentives to farmers participating in on-farm trials to sustain their interest and cooperation is justified by the inconveniences and possible risk involved in using the farmer's own resources. However, the incentives should be in kind rather than in cash as this is likely to influence the results.

CONCLUSION

On-farm livestock trials are unique and therefore their methodology cannot be generalised, neither can they be based on experience with crop on-farm trials or on-station research methodologies.

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THE CONTRIBUTION OF SMALL RUMINANT PRODUCTION TO HOUSEHOLD INCOME, WITH SPECIAL EMPHASIS ON SHEEP PRODUCTION, FOR SMALL SCALE FARMERS IN THE ASAL: A CASE STUDY OF LAIKIPIA WEST

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ABSTRACT

A sample of 65 small scale farms was selected from two of the subdivided ranches in the ASAL of West Laikipia (Ngarua and Rumuruti) to determine, among other things, the economic contribution of small ruminant production to small scale farmers' household income and the importance of sheep production, to these farmers. The study found that small ruminant production significantly influenced household income and that more respondents preferred sheep than goats; indeed sheep outnumbered goats by 2:1.

INTRODUCTION

By 1987, land buying companies in Laikipia had bought 74% of the former European ranches. While 63% of these ranches had already been subdivided into small scale farms, the rest were in various stages of subdivision. The subdivision of Ngarua and Rumuruti was completed in 1976 but the main settlement was between 1973 and 1979.

Considering that 91% of the population in Laikipia lives in rural areas (GoK, 1991), the majority are small scale farmers. Because of the importance of small scale farming, Laikipia Research Programme has oriented its research towards this type of farming and especially towards the Laikipia ASAL, as 80% of the District is in the ASAL. One of the areas of research is small ruminant production. The objective of the paper is to discuss the level of contribution of small ruminant production to household income and whether there is any inclination towards sheep production by small scale farmers in the study area.

MATERIALS AND METHODS

In 1990, there were 33 former European ranches in Laikipia West (including five government settlement schemes) which were in various stages of settlement and/or subdivision. In eight, subdivision was completed and therefore maps were available. For sampling convenience, the two ranches used in the study were from this group. Each selected ranch was subdivided into four equal sub-clusters and the two farthest sub-clusters from each other (one sub-cluster from each ranch) were chosen as the starting point. The farms or sampling units were not sampled randomly within the sub-clusters but systematically from a randomly selected corner of the sub-cluster.

Using this method, 65 respondents who were defined as small scale farmers were interviewed. They represented 9% of the potential respondents in each ranch. No prior appointments were made for visits, but we interviewed the husband or the wife, or in default, the *de facto* head of the farm. Otherwise, the enumerator moved to the next farm. Each respondent interviewed was asked general questions relating to the establishment of the livestock and crop enterprises and the reasons for starting

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each enterprise. Specific questions related to small ruminant production included a) herd composition, b) reasons for keeping small ruminants, c) income accruing from them and d) constraints.

RESULTS AND DISCUSSION

Establishment of the Livestock Enterprises

When comparing the two main livestock enterprises (cattle and small ruminant production), there was a tendency towards starting with small ruminant production rather than cattle production. Table 1 shows that 37% of the respondents who had small ruminants started with them as their first enterprise, either alone or together with maize and/or cattle. But, only 26% of the respondents with cattle had started with cattle as the first enterprise, either alone or together with small ruminants and/or maize. Small ruminant production was the favorite choice as the second enterprise. It was chosen by 53% of the respondents with small ruminants, while cattle production was chosen as the third enterprise (after maize and small ruminants, respectively) by 51% of the respondents with cattle. While five respondents started with small ruminant production alone as the first enterprise, only one respondent started with cattle production alone as the first enterprise. This indicates that cattle production could not be established alone without the support of maize and/or small ruminant production. Thus, small ruminant production was the most important livestock enterprise in the initial years of farm establishment and that cattle production was mainly important as the last enterprise.

Table 1. Order in which small ruminants and cattle were established by respondents

	all respondents with small ruminants		all respondents with cattle	
Choice	frequency	%	frequency	%
1st enterprise alone	5	9.8	1	2.6
1st enterprise with maize	9	17.7	4	10.3
1st enterprise with cattle	1	2.0	-	-
1st enterprise with sr	-	-	1	2.6
Established all three together	4	7.8	1	10.3
Sub total (1) as 1st enterprise	19	37.3	10	25.8
2nd enterprise alone	19	37.3	0	0.0
2nd enterprise with cattle	8	15.7	-	-
2nd enterprise with sr			8	20.5
Sub-total (2) 2nd enterprises	27	53.0	8	20.5
Sub-total (3) as 3rd enterprise	3	5.9	20	51.3
Don't know the starting order	2	3.9	1	2.6
Total (1+2+3)	51	100.0	39	100.0

The Importance of Small Ruminant Production to Household Income

The influence of small ruminant production to household income was determined based on respondents' comments and from calculations of household income based on survey data. Respondents were first asked to indicate their main sources of income used for development (income usually required in a lump sum), for instance, to fence their farms. Responses, ranked according to importance (Graph 1), show that small ruminant production was ranked first (34%) followed by off-farm income (29%) and maize sales (17%). Of the respondents that said net farm income was the most important source of income used for development, 54% indicated that small ruminant production was the most important source (Graph 1B). Even for the respondents who had indicated more than one source of income used for development purposes, small ruminant production was still leading among the second sources. The explanation for the importance of small ruminant production is that they are easier to dispose of when need for cash arises because they can be sold at any time of the year. With cattle, cash may be required when cows are dry yet the mean herd size is too low (2.3 Tropical Livestock Unit) for any sale without jeopardising the enterprise.

Next, respondents were requested to indicate sources of income used for daily expenses, for instance, on food and clothing. When ranked according to importance, it was found that more respondents (31%) still ranked small ruminant production as the leading source (Graph 1). Therefore, of those who said net farm income was the most important source of income used for daily expenses, 50% indicated that small ruminant production was the most important source (Graph 1B).

Respondents were asked to rank, in order of importance, the reasons for keeping small ruminants (Table 2). Results show that the major reason for keeping small ruminants is as a main source of income (45%). Other reasons are ease of disposal in an emergency (25%) and as an investment (16%). Combined, 70% of the respondents kept small ruminants because of the cash income accruing from them. Even among those who gave more than one reason for keeping small ruminants, 42% still indicated that small ruminants were the main source of income.

Table 2. Ranked order of importance of small ruminants

	Ranked 1st in importance		Ranked 2nd in importance	
Reason for keeping small ruminants	Frequency	%	Frequency	%
1) main source of income	23	45	44	3
2) easy to dispose in emergency	13	25	2	14
Source of cash income (1 + 2)	36	70	8	57
3) an investment	8	16	4	29
4) home consumption	6	12	2	14
5) milk	1	2	0	
Total	51	100.0	14	100.0

The results confirm what had been observed by other studies. Small ruminant production is an important source of cash income for the poor pastoralists and small scale farmers alike (Little, 1981; Herren 1990).

Household Income Calculated from Survey Data

1990 household income was calculated for respondents with positive household income. The breakdown of this income is shown in Table 3. The contribution of cattle and small ruminant production to household income is 28% and 11%, respectively, while their contribution to net farm income is 68% and 28%, respectively. Income from maize was low, contributing only 2% of the total household income and only 5% of the net farm income. This was not surprising because 1990 was a drought year in the study area.

Table 3. Distribution of household income across enterprises

Source of income	Amount (KSh)	% contribution to household income	% contribution to net farm income
Off farm	4807	58.9	--
Cattle	2266	27.8	67.7
Small ruminants	925	11.3	27.6
Maize	157	1.9	4.7
Total	8155	100.0	100.0

The results indicate that during a drought year, small ruminant production may be the only source of net farm income for those respondents (23%) who have no other livestock enterprise. Although the income calculated from survey results was at variance with the farmers' perception of the enterprise that is most important as far as household income is concerned, small ruminant production contributed close to one third of the net farm income. This discrepancy may have occurred because respondents did not give all the information about their household income. This is usually a problem in income related studies (GoK, 1977).

Sheep Herd Distribution Within the Livestock Herd

Livestock ownership by species is shown in Graphs 1 and 2. Graph 2 shows that while 78% of the respondents owned small ruminants, 60% owned cattle. More respondents (69%) owned sheep than goats (52%). The small ruminant herd was made up of indigenous stock; only 6% of the respondents owned any exotic crosses (Dorper crosses). A breakdown of the one-species-ownership category shown in Graph 2 indicates that 83% had small ruminants while only 17% had cattle. There were more respondents with only sheep (33%t) than with only goats (28%). The explanation is that when respondents were unable to acquire cattle and small ruminants together, they either preferred or could only afford to keep small ruminants.

Sheep distribution in the study area is shown in Table 4. Small ruminants comprised 36% of the livestock bio-mass. There was significantly more sheep than goats ($P < .05$), making up 70% of the small ruminant bio-mass. Exotic sheep or their crosses were not common. They comprised only 3% of the small ruminant population or 10% of the sheep population.

Table 4. Sheep ownership frequency distribution within the total herd

Species	Respondents	Mean	%[1]	%[2]	SD	Min.	Max.
TLU all cattle	65	2.3	4	-	2.6	0	9.0
TLU indigenous goats	65	0.4	11	30	0.7	0	3.0
TLU dorpers sheep	65	0.1	3	10	0.4	0	3.7
TLU indigenous sheep	65	0.8	22	60	1.0	0	3.7
TLU all sheep	65	0.9	25	70	1.1	0	3.7
TLU all small ruminants	65	1.3	36	100	1.5	0	5.0

[1]Percentage - Livestock bio-mass
[2]Percentage - Small ruminant bio-mass
SD - Standard Deviation
TLU - Tropical Livestock Unit (250 kg)

Fifty-seven percent of the respondents kept more sheep than goats while 35% kept more goats than sheep. Sheep herd sizes were significantly ($P < 0.001$) larger than goat herd sizes. Thirty two percent of the respondents had more than 10 sheep but only half as many had this number of goats. Again, while 20% had more than 20 sheep, only 10% had as many goats. Moreover, herds of more than 30 of any particular small ruminant species were associated with sheep only, because 9% of the respondents had more than this number of sheep but 1.5% only had as many goats. Although this confirms what was found by Kohler (1987a) and Little (1981) in Laikipia and Baringo, respectively, it differs from what was found by Thorper et al (1990) in a similar zone in Coast Province where goats out-numbered sheep by 3:1.

While there is no breakdown of sales indicating whether income was from sheep or goats (farmers had no record of the sales within the year), *ceteris peribus*, sheep contributed at least 70% of the income from small ruminant production or 19% of the net farm income for small scale farmers in the study area.

Reasons for Preferring Sheep

Forty three percent of the respondents said that they preferred sheep, 21% said that they preferred goats and 36% had no preference. However, when looking at the reasons for preferring sheep to goats, it was found that 83% percent of the respondents kept sheep because they were docile and hence could be herded together with cattle. Other reasons given were that they were more resistant than goats to diseases (14%) - because of the incidence of Contagious Caprine Pleuropneumonia (CCPP) in goats in the area - and that goats destroyed trees. The importance of the herding factor is supported by the fact that all respondents who had both cattle and small ruminants grazed them together. The explanation for preferring sheep production is that animals that were less troublesome to herd were favoured. This can be seen by the fact that only 31% of the respondents employed herders while the rest herded the animals themselves. Another explanation is that due to labour constraints, farmers could not afford to keep many goats because this may require keeping a cattle and a small ruminant herd.

Constraints to Small Ruminant Production

The following were the most common constraints to small ruminant production mentioned: mortality through disease infestation (54%), insufficient water for livestock (22%), and lack of sufficient grazing (8%). Pneumonia and CCPP were noted by respondents and the Ministry of Livestock Development as the biggest disease menace to small ruminant production in West Laikipia.

CONCLUSIONS

This study indicates that in West Laikipia:

(a) Most small scale farmers graduated from maize production to small ruminant production and finally to cattle production, in that order.
(b) Small ruminant production contributed about one third to the net farm income, but 30% of the respondents ranked it first among the main sources of cash income.
(c) Sheep out-numbered goats by 2:1 and small scale farmers preferred sheep to goats because of the convenience of herding.
(d) Sheep contributed 70% and 19% to small ruminant income and net farm income, respectively.
(e) Diseases and lack of water were the main constraints to small ruminant production.

Therefore, sheep rather than goat improvement programmes are more likely to succeed because 79% of the farmers (43% of the respondents who preferred sheep plus 36% who had no special preference for either of the species) would be more receptive to sheep improvement programmes. Conversely, only 57% (21% of those who preferred goats plus 36% who had no special preference for either of the species) would be more receptive to goat improvement programmes. As most respondents keeping goats (54%) said that goats survived better in case of drought, programmes aimed at the improvement of small ruminant nutrition would increase the preference for sheep even more. This is especially important because the ranches are now only settled to 60%. As they approach 100% settlement, insufficient grazing will become a more significant constraint.

We were not able to estimate the actual and separate contribution of sheep and goat production to household income. Therefore, the contribution of sheep production to this income is only by inference.

ACKNOWLEDGEMENTS

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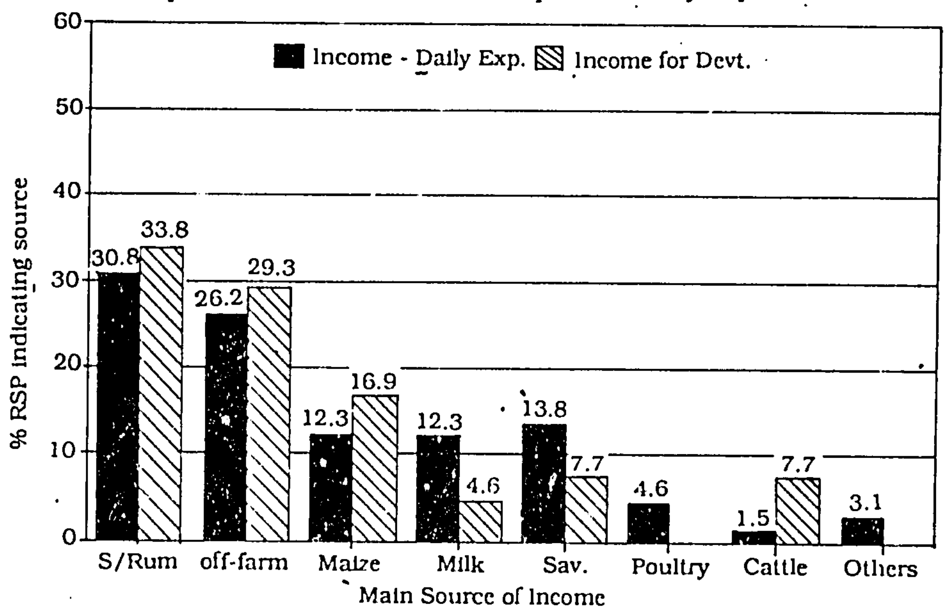
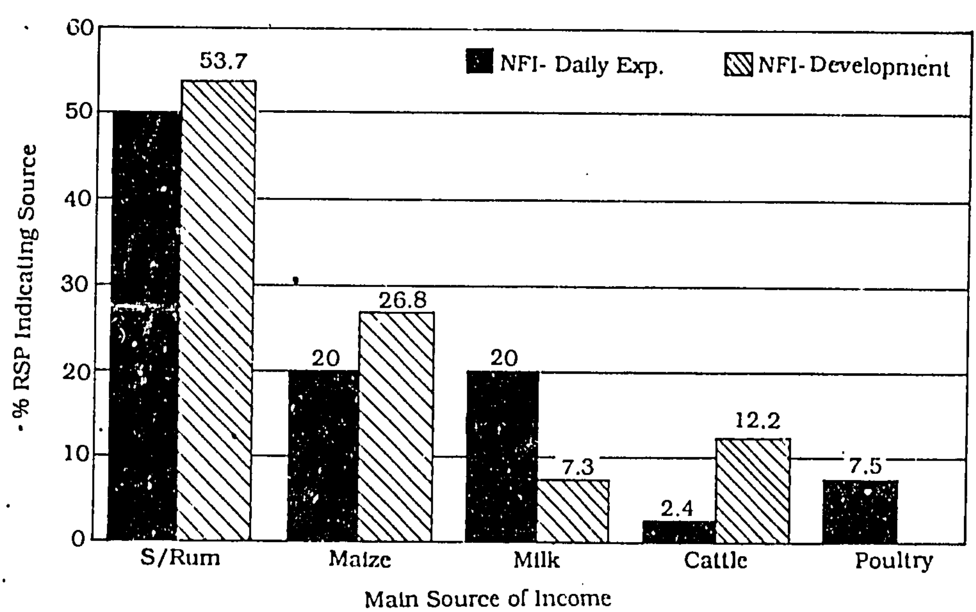
Graph I : Sources of Income Development & Daily Expenses



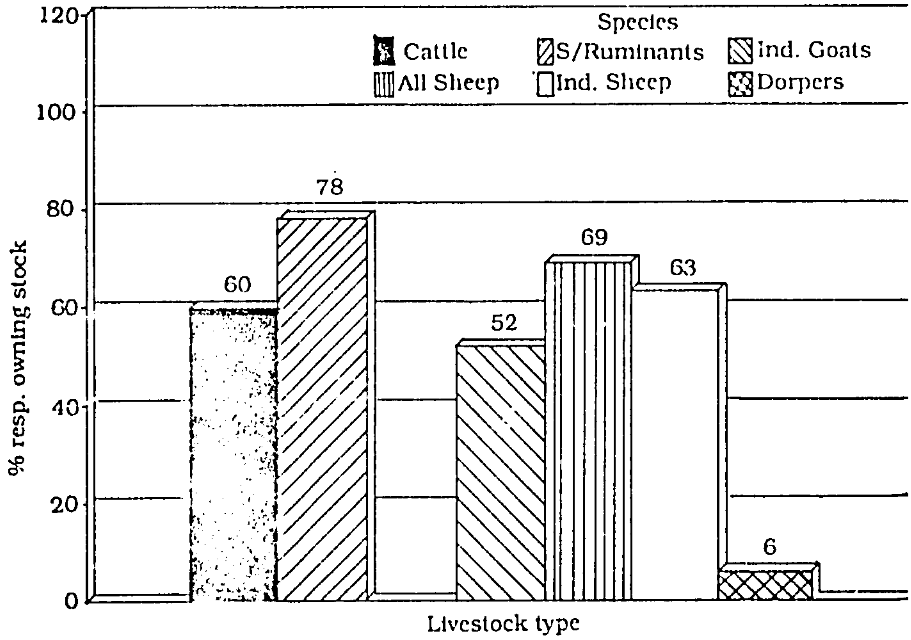
RSP= respondents, NFI- Net Farm Income
S/Rum. = Small Ruminant, Sav. = Savings
SOURCE: Sample data

Graph 1 B Net Farm Income Sources for Development and Daily Expenses



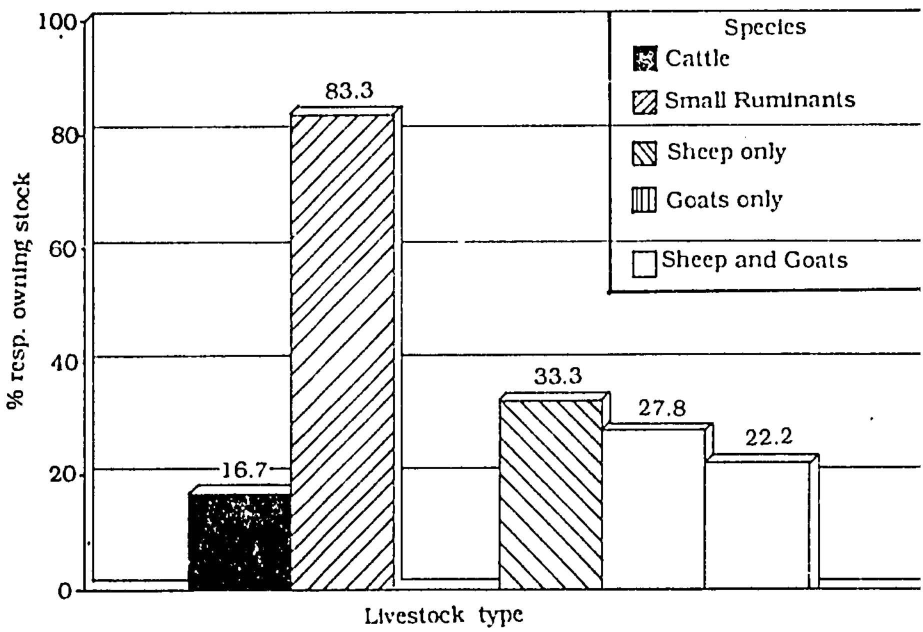
RSP =Respondents, NFI-Net Farm Income
S/Rum = Small Rumin[illegible], Sav. = Savings
SOURCE: Sample dat[illegible]

Graph II Livestock Ownership by species



Resp.= respondent =65
total % not=100 some have species
SOURCE: Sample data 1991

Graph III: Respondents with Cattle or Small Ruminants



Resp. = Responent = 18
SOURCE: sample data

CONTACT EXPOSURE OF GOATS, SHEEP AND CALVES WITH GOATS INFECTED WITH MYCOPLASMA STRAIN F38

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SUMMARY

Twenty sheep, (10 vaccinated and 10 control), ten calves and five goats were housed with four goats artificially infected with Mycoplasma strain F38 for a period of 50 weeks. Both donor and contact goats developed the classical CCPP and those that recovered had complement fixing, growth inhibiting, agglutinating and latex agglutinating antibodies in their sera. Mycoplasma F38 was isolated from dead goats. Out of 10 control sheep, three developed complement fixing antibodies. One of the three sheep had detectable agglutinating (SAST) and latex agglutinating (LAT) antibodies in addition to the complement fixing antibody. The antibody appearance in serum was preceded by pyrexia in the affected animals. Most of the vaccinated sheep had both agglutinating and complement fixing antibodies but none was positive by LAT. No growth inhibiting antibodies were detected in sheep. F38 was not isolated from dead sheep. Only one calf had detectable agglutinating (SAS) antibodies. None of the calves had complement fixing, latex agglutinating and growth inhibiting antibodies.

INTRODUCTION

Contagious caprine pleuropneumonia (CCPP) is an important disease of goats. Several mycoplasmas have been isolated from CCPP cases in Kenya (Kibor, 1983; MacOwan,1976) but Mycoplasma strain F38 has been associated with most of the CCPP outbreaks in Kenya (Kibor, 1983; MacOwan and Minette, 1976). In Kenya and possibly in neighbouring countries goats, sheep and cattle are grazed together. It has been reported that sera from cattle and sheep exposed to infected goats had antibodies to F38 as detected by latex agglutination test (LAT) (Muriu et al, 1990). This communication reports observations made on clinical status and humoral antibody responses mounted by sheep and calves following exposure to goats infected with mycoplasma strain F38 under experimental conditions.

MATERIALS AND METHODS

Sources of Animals

Goats and sheep were purchased from farms with no history of CCPP. Calves (cross breeds 8-12 months old) were from KVRC Muguga. All animals were screened for presence of F38 antibodies by compliment fixation test (CFT) (MacOwan, 1976), slide agglutination serum test (SAST) (Pristley, 1951), growth inhibition test (GIT) (Clyde, 1964) and latex agglutination test (LAT) (Rurangirwa et al, 1987).

Source of Infection

Four adult goats were used as the source of infection. They were infected with 20 mls of Mycoplasma F38 prototype broth culture containing about 1×10^7 colony forming units (CFU) per ml. The broth culture was injected through the tracheas. The animals were fed on hay and water *ad libitum*. Rectal temperature was recorded daily in addition to clinical examination.

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Contact Challenge

Five susceptible goats, ten unvaccinated sheep, ten sheep vaccinated with F38 vaccine (five vaccinated with vaccine stored at 4°C and five vaccinated with vaccine stored at 22°C) and ten unvaccinated calves were housed with the infected goats.

Post Mortem Examination

Gross post mortem examination was carried out on all dead animals.

Bacteriological Isolation

Exudates (peritoneal, pericardial and pleural fluids) and lung tissues of dead animals were examined for presence of bacteria and mycoplasma. Blood agar and tryptose serum agar were used for isolation of these organisms. Nasal swabs and blood were also taken for isolation of mycoplasma.

Detection of Antibodies

Detection of antibodies to Mycoplasma F38 was achieved by use of complement fixation test (MacOwan, 1976). Slide agglutination serum test (SAST) (Priestly, 1951), Latex agglutination test (LAT) (Rurangirwa et al, 1987) and Growth inhibition test (GIT) (Clyde, 1964).

Detection of F38 Antigens in Tissues and Exudates

Double immunodiffusion in agar (Gourlay, 1965) was used to detect presence of F38 antigens in exudates and lung tissues from dead animals.

RESULTS

Clinical Observations

Infected donor goats

Following infection with F38 broth culture, 3/4 disease donors became pyrexic after 3 to 5 days (Table 1). The pyrexia persisted for between 7 and 13 days. Intense coughing was noted after 3 to 5 days following pyrexia. It persisted for 5 to 10 weeks. Occasional coughing continued throughout the experimental period. One of the infected donor goats did not develop pyrexia and no coughing was ever noticed. All animals recovered.

Table 1. Infected Donor Goats - Pyrexia and Coughing

Animal	Pyrexia (Days)		Coughing	
	appearance after infection	persistence	onset after pyrexia (days)	persistence (wks)
G9	3	13	3	10
G161	5	7	4	8
G162	None	N/A	None	0
G165	3	7	5	5

Contact Goats

All 5 contact goats became pyrexic and started coughing after being housed with infected donor goats (Table 2). The pyrexia developed 16 to 51 days after contact with infected donor goats. Pyrexia persisted for 4 to 6 days. Intense coughing was noted 1 to 4 days after the onset of pyrexia and it persisted for 4 to 18 days. Occasional coughing was noted throughout the experimental period. In one animal (G166) both pyrexia and coughing appeared at about the same time. Two animals which died of fibrinous pleuropneumonia died 5 and 6 days, respectively, after onset of pyrexia. One animal (G163) recovered from CCPP but died of other causes three months later.

Control Sheep

Following contact with infected goats 4/10 of the control sheep died (Table 3) after 1,6,7 and 13 weeks. The animals died suddenly without any clinical signs. They continued to eat well until death. The main post mortem observations were a full rumen, lung congestion exudates in the thoracic, pericardial and peritoneal cavities. (Table 4). *Corynebacterium haemolyticum* and *Pseudomonas* species were isolated from two of the sheep (Table 3).

Table 3. Sheep and Calves - Bacteriological Results

Animal No.	Exposure Period (wks)	Group	Organisms Isolated
654 Sheep	1	Contact	-
658 Sheep	2	Vaccinate 4°C	-
655 Sheep	6	Vaccinate room	-
659 Sheep	6	Vaccinate 4°C	-
645 Sheep	6	Contact	Corynebacterium haemolyticum
653 Sheep	7	Contact	Pseudomonas sp.
662 Sheep	10	Vaccinate 4°C	-
663 Sheep	13	Contact	-
652 Sheep	14	Vaccinate 4°C	-
B166 Calf	37	Contact	-
B354 Calf	47	Contact	-

Table 4. Post Mortem Observations

								Increased fluids	
Animal	Vaccinated	Contact	Pneumonia	Bloat	Enteritis	Worms	Pleural	Peritoneal	Pericardial
Sheep 654	-	+	-	-	-	+	-	-	-
Sheep 658	4°C	-	+	+	+	-	-	-	-
Sheep 645	-	+	+	-	-	-	+	+	+
Sheep 653	-	+	+	+	-	-	-	+	+
Sheep 655	Room	-	+	-	+	-	+	+	+
Sheep 659	4°C	-	+	+	-	+	+	+	+
Sheep 662	4°C	-	+	+	-	-	+	+	+
Sheep 663	-	+	+	+	-	-	+	+	+
Sheep 652	4°C	-	+	+	-	-	+	+	+
Goat 164	-	+	Fibrinous pp.		-	-	+	-	+
G2141	-	+	Fibrinous pp.		-	-	+	-	+

Three of the surviving sheep developed both pyrexia and coughing after 10, 37 and 38 weeks, respectively, after contact with infected goats (Table 5). The pyrexia lasted 2 to 3 days. One sheep (X650) was noted to cough but no pyrexia was observed.

Table 5. Control Sheep - Complement Fixing Antibodies

Animal	Contact Period (Wks)	Antibody Persistence (Wks)
X661	9	6
X660	17	7
X650	17	6

Vaccinated Sheep

After contact with infected goats 5/10 vaccinated sheep died at various times after exposure (Table 3). Four of them were vaccinated with vaccine stored at 4°C while one was vaccinated with vaccine stored at room temperature. The animals died suddenly without any signs. A full rumen, lung congestion, increased exudates in thoracic, pericardial and peritoneal cavities were the main post mortem observations (Table 4). No bacteria or mycoplasma were isolated from the dead animals (Table 3). Two of the surviving five animals were noted to cough without increase in rectal temperature (wk 36,40) respectively) while one animal (X657) had both cough and increase in rectal temperature at different times (Wks 37,42) during the experimental period (Table 6).

Table 6. Sheep and Calves: Coughing and Pyrexia

Animal No.	Group	C + T	C	T
Sheep 650	Con	-	+36 wk	-
Sheep 651	V4°C	-	+36 wk	-
Sheep 648	Con	+37 wk	-	-
Sheep 657	Vr	-	+37 wk	+ 42 wk
Sheep 661	Con	+9 wk	-	-
Sheep 619	Con	+38 wk	-	-
Sheep 646	VR	-	+40 wk	-
Calf B149	Con	-	+41 wk	+ 40 wk (ECF)
Calf B354	Con	-	+41 wK	+ 40 wk
Calf B307	Con	-	+36 wk	-
Calf 30 7	Con	-	+37 wk	-

Key

C	=	Coughing only
T	=	Pyrexia only
C+T	=	Coughing and Pyrexia together
Con	=	Contact animal
V4°C	=	Vaccinated with vaccine stored at 4°C
VR	=	Vaccinated with vaccine stored at room temperature
Wk	=	Period in weeks after contact when parameter was observed

Calves

Two calves out of 10 died after 37 and 47 weeks of contact, respectively No significant post mortem observations were made and neither bacteria nor mycoplasma was isolated from their tissues (Table 3).

Two other calves (149 and 354) had pyrexia and cough during the experimental period (Table 6). The high temperature in 149 was associated with theileriosis (ECF) which was treated with Clexon. Coughing which was not associated with increase in rectal temperature was also noted in two other calves (307 and 047) (Table 6).

Humoral Response

Infected donor goats

The donor goats developed complement fixing, growth inhibiting, agglutinating and latex agglutinating antibodies. The antibodies were detectable during or immediately after the onset of pyrexia (Table 7).

Table 7. Goats: Humoral response after infection period (weeks) animals were positive

Animal	CFT	GIT	SAST	LAT
Donor 9	30	12	20	28
Donor 161	30	27	20	10
Donor 162	31	10	20	29
Donor 165	30	20	20	30
Contact 163	18	12	20	18
Contact 166	29	12	13	29
Contact 167	30	11	17	30
Contact 164	-	-	-	-
Contact 214	-	-	-	-

Contact Goats

Contact goats seroconverted after being housed with infected donor goats. Complement fixing, growth inhibiting, agglutinating and late agglutinating antibodies appeared during or immediately after the onset of pyrexia. Animals which died of fibrinous pleuropneumonia had no detectable antibodies before death (Table 7).

Control Sheep

Of the 10 control sheep in contact with infected goats, only three had detectable complement fixing antibodies (Table 5). The first animal seroconverted nine weeks after exposure to infected goats. The other two animals seroconverted after 17 weeks following contact with infected goats. The complement fixing antibodies were detectable for 6-7 weeks. Seroconversion in one animal (X661) was associated with pyrexia (Table 6) which was not the case with the other two animals. Besides complement fixing antibodies, this animal also developed agglutinating antibodies (SAST, LAT) which were detected for six weeks.

When the animal died (10 months later) a small abscess which measured one inch in diameter was noted. The right apical lobe was attached to the thoracic wall at the site of the abscess. No organism (bacteria, mycoplasma) was isolated from the lesion. F38 antigens were not detected in the abscess.

Vaccinated Sheep

All the vaccinated sheep (10/10) developed agglutinating antibodies (SAST) but were negative by LAT. The agglutinating antibodies were detected for 37 weeks. Most of the sheep (9/10) also had complement fixing antibodies which could be detected at varying periods (2 to 19 weeks) after vaccination (Table 8). None of the vaccinated sheep had growth inhibiting antibodies.

Table 8. Vaccinated Sheep - Complement Fixing Antibodies

Weeks after Vaccination	0	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
No. of animals positive	0	0	1	1	2	3	6	6	6	7	7	4	4	4	2	2	2	2	2	2	2	1	0

Contact Calves

None of the calves had complement fixing, latex agglutinating and growth inhibiting antibodies after contact with infected goats. However, one of the calves (B187) had agglutinating antibodies (SAST) which were detected eight weeks after contact with infected goats and persisted for 10 weeks.

Presence of F38 Antigens in Tissues and Exudates

F38 antigens were detected in lung tissues and exudates from the two goats that died of fibrinous pleuropneumonia, but not from tissues from sheep, calves and a goat that had recovered from contagions caprine pleuropneumonia three months earlier.

DISCUSSION AND CONCLUSION

The contact (normal) goats responded in the classical manner following exposure to infected goats; the rectal temperature rose followed by coughing. This was followed by death or by the recovery process in which animals produced antibodies. In the present work, 3/10 control sheep which were seronegative turned seropositive. The sheep, unlike the goats, produced low level antibodies. This may be due to the fact that the sheep is an unnatural host and F38 could not multiply to high levels as in the goat. The rise in rectal temperature followed by seroconversion and coughing is, however, a clear indication that the organism established itself in the sheep. Although F38 could neither be isolated nor antigens detected in the lung lesion of X661, the presence of an abscess adds suspicion that the organism may have been multiplying in the respiratory tract. Unlike goats, sheep had no detectable growth inhibiting antibodies. It would seem high amounts of antigens are required to elicited growth inhibiting antibodies and perhaps the inability of F38 to multiply to high levels in an abnormal host explains why sheep had no detectable growth inhibiting antibodies. Only 1/10 calves had detectable agglutinating antibodies (SAST). This may be an indication that the level of multiplication of F38 in calves was less than in sheep. Although we did not detect complement fixing antibodies in calves, these antibodies have been detected in cattle, buffaloes, camels and impalas (Palling et al, 1978; 1988.)

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HAEMONCHUS AND *TRICHOSTRONGYLUS* SPECIES IN GOATS IN KENYA RESISTANT TO ANTHELMINTICS

N. Maingi[1], E.J. Gichanga and V.M. Gichohi

ABSTRACT

This study was undertaken to elucidate the presence of resistance to thiabendazole (TBZ) and levamisole (LVM) in gastrointestinal nematodes of goats on three farms in Kenya. In an initial field investigation, faecal egg count reductions (FECR) were determined in naturally infected groups of goats after treatment with either of the anthelmintics. Mean FECR for TBZ at 44 mg/kg (recommended dose) on a farm in Nairobi and Kajiado were 51% and 77%, respectively, while mean FECR and LVM at 7.5% mg/kg (recommended dose) was 70% on a farm in Kiambu. This data indicated resistance to the respective anthelmintics. *Haemonchus* (66%) and *Trichostrongylus* (20%) were the predominant nematode species isolated. The isolates were then subjected to an *in vivo* controlled slaughter assay (worm count reduction (WCR)) and an *in vitro* egg hatch assay (EHA). The WCR for TBZ on the isolates from the farms in Nairobi and Kajiado were 75% and 86%, respectively, while LC50 values obtained in the EHA for the isolates were 0.34 and 0.2 μg TBZ/ml, respectively. WCR for LVM on the isolate from Kiambu was 82%, while the EHA LC50 for the isolate was 2.8 μg LVM/ml. WCR and EHA data confirmed resistance to TBZ in goats on the farms in Nairobi and Kajiado, and to LVM in goats on the farm in Kiambu.

INTRODUCTION

Numerous reports of resistance to anthelmintics in nematodes of domestic animals have been documented (e.g. Waller, 1986; Waller and Prichard, 1986). Resistance to anthelmintics in sheep and goat nematodes is now widespread in Australia and is of increasing importance in New Zealand, South America and Europe. On the African continent, anthelmintic resistance has been described in sheep in South Africa (Barger, 1975; van Wyk and Malan, 1988), Kenya (Maingi, 1991; Waruiru et al, 1991) and Tanzania (Bjorn et al, 1991). Information on anthelmintic resistance in nematodes of goats in Kenya is, however, limited to a single report by Njanja et al (1987). Njanja et al (1987), reported decreased efficacy of thiandazole (TBZ) at 88 mg/kg against naturally acquired nematodes in goats at Ol'magogo farm in Naivasha. At present, there are no reports on the prevalence of anthelmintics resistant nematodes in goats in other parts of Kenya. This study was designed to establish whether resistance to anthelmintics was present in nematodes of goats on three large scale farms in Kenya.

MATERIALS AND METHODS

Field Study

A field survey was undertaken in 1991 on Kangati farm in Kiambu district, Mr. Kuria's farm in Nairobi and Mr. Daniel's farm in Kajiado district. These farms will be referred to respectively as farm A-Kiambu, farm B-Nairobi and farm C-Kajiado.

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Farm A-Kiambu is situated 35 km north of Nairobi at an altitude of 2350 m. The area receives an annual rainfall of about 750-1000 mm while the mean monthly temperature varies from 10°C to 25°C. Febantel (FB) (Rintal[R], Bayer, Germany), LVM (Wormicid[R], Cosmos, Nairobi, Kenya) and LVM and oxyclozanide combination (Nilzan[R], ICI, Middlesex, UK) had been used on the farm at one time or another during the previous five years. Farm B-Nairobi is situated 15 km southwest of Nairobi at an altitude of 1750 m. The area has an annual rainfall of 750-1250 mm and mean monthly temperatures of 10°C to 26°C. TBZ (Thiabenzole[R], Merck and Co. Inc., NJ, USA), LVM and albendazole (ALB) (Valbazen[R], Smith Kilne, Beecham, UK) had been used on the farm during the previous five years. Farm C-Kajiado is situated 60 km southwest of Nairobi at an altitude of 1950 m in a semi-arid region. The annual rainfall is about 600-700 mm while the mean monthly temperature varies from 10°C to 30°C. TBZ and LVM had been used on the farm during the previous three years. Anthelmintics were used at an interval of about three months on all three farms. At initiation of the study, thirty 6 to 12 month old goats on each farm, having high faecal strongyle egg counts, were assigned at random to three groups of 10 animals each and weighed. Goats in group 1 were each treated with TBZ at 44 mg/kg and those in group 2 were treated with LVM at 7.5 mg/kg. Group 3 represented the untreated controls. The anthelmintics were administered orally using a calibrated syringe. Faecal samples were collected directly from the rectum of each goat on day 0, 7 and 10 after treatment. Faecal strongyle egg counts were determined using a modified McMaster technique (Whitlock, 1948) and recorded as eggs per gram (EPG) of faeces. These counts were used to calculate the percent efficacy of each drug based on the percent faecal egg count reduction (FECR%). This is corrected for changes that occur in the control group by the equation: FECR% = 100 [(1 -(XT2/XT1) (XC1/XC2)] (Presidente, 1986), where XT and XC are geometric mean EPG for the treated and control groups, respectively, while 1 and 2 refer to geometric mean EPG before and after treatment, respectively. Althelmintics showing less than 90% FECR% are considered ineffective and indicate anthelmintic resistance in the nematode population (Riffkin et al, 1984). Samples were also pooled for each group, cultured and larvae isolated and identified on each of the three days according to standard procedures (MAFF, 1971). An estimate of the efficacy of the anthelmintics against individual nematode species was calculated using the same formula as for FECR%. This was done for *Haemonchus* and *Trichostrongylus* spp, whose group mean egg counts exceeded both 30 epg and 5% of the total EPG both before and after treatment, based on larval identification.

Controlled Slaughter Assay and Egg Hatch Assays (EHA)

In the second part of the study, 24 worm-free 6 to 9 months old male goats were separated at random into three groups of eight animals each. Group 1 goats were infected with larvae isolated from farm A-Kiambu, group 2 received larvae from farm B-Nairobi while group 3 received larvae from farm C-Kajiado. Each goat was infected orally with approximately 10,000 larvae in distilled water. The 24 experimental goats were housed in pens that were cleaned every day until the experiment was terminated. After patency, faecal samples were collected from the goats and pooled for each group for isolation of eggs which were used in the *in vitro* EHA. The eggs were isolated from the faecal samples using a floatation technique (LeJambre, 1976). The EHA was then performed in triplicate according to the method of LeJambre (1976) and Dobson et al (1986) for TBZ and LVM, respectively. Concentrations of TBZ used in the assay ranged from 0.04 to 0.36 μg TBZ/ml, while those of LVM ranged from 0.3 to 30 μg LVM/ml in distilled water. The percentages of eggs failing to hatch at each drug concentration were then calculated and the data subjected to probit analysis (Finney, 1971). This gave the drug concentration, which, on average, inhibited 50% of the eggs for each isolate from hatching or Lethal Concentration 50% (LC50) and the 95% confidence interval.

On day 28 post-infection, faecal samples were collected from the goats and the EPG determined. These were recorded as the EPG on day zero of the experiment. On the same day, goats in each group were separated at random into two groups of four animals each based on faecal egg counts of individual animals. This was to ensure that the level of infection did not differ significantly between the groups. The goats were then weighed and treated. One of the groups infected with the isolate from farm A-Kiambu was given LVM at 7.5 mg/kg. One of the groups infected with the isolate from farm B-Nairobi and one of the groups infected with the isolate from farm C-Kajiado were treated with TBZ at 44 mg/kg. The drugs were administered orally using a calibrated syringe. The other groups remained as the untreated controls.

On day 0 and 10 post-treatment, all goats were killed and total worm counts determined using established techniques (MAFF, 1971). The percent efficacy (PE) defined as the difference between the geometric mean worm counts in the control and treated group, expressed as a percentage of the geometric mean worm counts in the control group (Presidente, 1986), was then calculated for each anthelmintic. Anthelmintics showing less than 90% PE are considered ineffective.

RESULTS AND DISCUSSION

Table 1 gives the geometric mean faecal egg counts and percent efficacy (FECR%) for TBZ and LVM in naturally infected goats on the three farms.

Table 1. EPG and FECR% for TBZ and LVM in goats on 3 farms

Farm	Treatment Group	Geometric Mean EPG Day 0	Day 7	Day 10	%Efficacy (FECR%*) Day 7	Day 10
A-Kiambu	Control	1400	950	1012	-	-
	TBZ	1240	76	65	90.97	92.95
	LVM	1050	224	204	68.56	71.37
B-Nairobi	Control	700	435	650	-	-
	TBZ	1184	326	591	55.65	46.24
	LVM	1146	57	70	92.0	93.42
C-Kajiado	Control	2157	1900	1055	-	-
	TBZ	1386	286	153	76.57	77.43
	LVM	1542	82	60	93.96	92.04

*FECR% = 100 [1 - (XT2/XT1)(XC1/XC2)]

On farm-A Kiambu TBZ at 44 mg/kg had an efficacy of 90.97% on day seven and 92.95% on day 10 post-treatment. LVM at 7.5 mg/kg had an efficacy of 68.56% and 71.37% on the respective days. On farm B-Nairobi, TBZ at 44 mg/kg had an efficacy of 55.65% and 46.24% on day seven and 10 post-treatment respectively, while LVM at 7.5 mg/kg had an efficacy of 92.00% and 93.42%.

Efficacy for TBZ on Farm C-Kajiado was 76.57% on day seven and 77.43% on day 10 post-treatment, while LVM had efficacies of 93.96% and 92.04% on the respective days. This data indicates resistance to LVM on farm A-Kiambu and resistance to TBZ on farm B-Nairobi and C-Kajiado, based on the interpretation of previous workers (Riffkin et al, 1984).

The numbers and percentage distribution of genera of nematode larvae identified from cultures of faecal samples obtained from goats on all three farms before treatment are given in Table 2

Table 2. Percentage distribution of genera of gastrointestinal nematodes isolated from cultures of faecal samples from goats on three farms

Farm	Nematode Genera					
	Haemonchus	Trichostrongylus	Cooperia	Oesophagostomum	Nematodirus	Strongyloides
A-Kiambu	72	17	5.0	3.0	2.0	1.0
B-Nairobi	68	22	6.0	3.0	0	1.0
C-Kajiado	59	21	10	5.0	3.0	2.0
Mean %	66.33	20.00	7.00	3.67	1.67	1.33

Nematode larvae encountered were *Haemonchus* spp (66.33%), *Trichostrongylus* spp (20%), *Cooperia* spp (7.0%), *Oesophagostomum* spp (3.67%), *Nematodirus* spp (1.67%) and *Strongyloides* spp (1.33%). The predominance of strongylid nematodes observed in this study is similar to that previously reported in ruminants in Kenya (Allonby, 1975; Omara-Opyene, 1985; Gatongi et al, 1987; Maingi and Gichingi, 1992). The percentage reduction in egg counts for *Haemonchus* and *Trichostrongylus* spp, the predominant species in the goats, on day 7 and 10 after treatment with either TBZ or LVM, are given in Table 3.

Table 3. Percentage reduction of group mean Haemonchus and Trichostrongylus spp. egg counts in goats on three farms after treatment with either TBZ or LVM

Farm	Anthelmintic	Percentage Reduction (*FECR%)			
		Haemonchus spp. Day 7	*Haemonchus* spp. Day 10	*Trichostrongylus* spp. Day 7	*Trichostrongylus* spp. Day 10
A-Kiambu	LVM	61.36	69.46	70.40	75.50
B Nairobi	TBZ	44.20	50.40	51.00	56.80
C-Kajiado	TBZ	71.50	65.00	78.10	80.45

*FECR% = 100[1 - (XT2/XT1)(XC1/XC2)]

On farm A-Kiambu, LVM failed to reduce *Haemonchus* and *Trichostrongylus* spp by more than 90%, indicating resistance based on the interpretation of Riffkin et al (1984). Similarly, EPG reduction for the two species on farm B-Nairobi and C-Kajiado was less than 90% for animals treated with TBZ.

Table 4 gives the LC50 values and their 95% confidence intervals for TBZ and LVM in nematodes isolated from the three farms. The LC50 values for LVM were 2.8, 0.24 and 0.35 μg LVM/ml for isolates from farm A-Kiambu, B-Nairobi and C-Kajiado, respectively. For the respective isolates, LC50 values for TBZ were 0.05, 0.34 and 0.20 μg TBZ/ml.

Table 4. Lethal concentration 50% (LC50) and the 95% confidence interval detected in the egg hatch assay using TBZ and LVM on Haemonchus and Trichostrongylus spp isolated from three farms

Isolate	LC50 in ug/ml (95% confidence interval)	
	LVM	TBZ
Farm A-Kiambu	2.80 (2.72 - 2.84)	0.05 (0.02 - 0.08)
Farm B-Nairobi	0.24 (0.22 - 0.27)	0.34 (0.28 - 0.40)
Farm C-Kajiado	0.35 (0.33 - 0.39)	0.20 (0.16 - 0.24)

LC50% = Concentration of anthelmintic (micrograms/ml) required to inhibit 50% of incubating eggs from hatching

Results of the EHA indicate resistance to LVM for the isolate from farm A-Kiambu, based on the interpretation of others (Dovson et al, 1986). These workers observed that LVM-susceptible strains' eggs do not hatch in concentrations above 5 μg LVM/ml and have LC50 values of about 0.3 μg LVM/ml. LVM-resistant isolates have LC50 values ranging from 1 to 5000 μg LVM/ml. The data also indicates that farm B-Nairobi and C-Kajiado isolates are resistant to TBZ. TBZ-susceptible isolates do not hatch in concentrations higher than 0.1 μg TBZ/ml, and have LC50 values of about 0.06 μg TBZ/ml, while those for resistant strains are higher than 0.1 μg TBZ/ml (LeJambre, 1976; Hall et al, 1978; Presidente, 1986).

The FECR% for TBZ at 44 mg/kg and LVM at 7.5 mg/kg for groups of goats artificially infected with larvae isolated from farm A-Kiambu, B-Nairobi and C-Kajiado are presented in Table 5.

Table 5. Geometric mean faecal egg counts (EPG) and percent efficacy (%FECR) for TBZ and LVM in goats artificially infected with nematodes isolated from three farms

Isolate	Treatment Group (dosage)	Geometric Mean EPG (minimum - maximum) Day 0	Day 10	* F E C R %
A-Kiambu	Control	3,700 (100 - 10,120)	5,200 (300 - 12,400)	
	LVM (7.5mg/kg)	2,542 (200 - 5,800)	1,250 (0 - 2,850)	65.01%
B-Nairobi	Control	944 (150 - 9,400)	642 (200 - 10,000)	
	TBZ (44mg/kg)	1,200 (600 - 2,000)	300 (0 - 800)	63.24%
C-Kajiado	Control	4,300 (2,000 - 14,000)	6,100 (1,800 0 12,300)	
	TBZ	3,600 (400 - 9,100)	1,532 (100 - 2,200)	70.00%

*FECR% = 100 [1 - (XT2/XT1)(XC1/XC2)]

LVM failed to reduce faecal egg counts in goats infected with the isolate from farm A-Kiambu by more than 90%, indicating resistance. Similarly, FECR% for the isolates from farm B-Nairobi and C-Kajiado were less then 90% after treatment of artificially infected goats with TBZ.

Geometric mean worm burdens for control and treated groups of goats and percent efficacy for LVM and TBZ in goats artificially infected with nematodes isolated from goats on farm A-Kiambu, B-Nairobi and C-Kajiado are given in Table 6.

Table 6: Geometric mean worm burden and percent efficacy for TBZ and LVM in goats artificially infected with nematodes isolated from three farms

Isolate	Treatment Group (dosage)	Geometric Mean EPG (minimum - maximum)	*FECR%
A-Kiambu	Control	1,945 (362 - 3,200)	
	LVM (7.5mg/kg)	342 (10 - 532)	82%
B Nairobi	Control	930 (450 - 1,046)	
	TBZ	231 (100 - 360)	75.16%
C-Kajiado	Control	1,0440 (620 - 1,440)	
	TBZ (44mg/kg)	146 (25 - 250)	86%

$$\text{*\% Efficency} = \frac{\text{Geometric mean worm burden in control group} - \text{Geometric mean worm burden in treated group}}{\text{Geometric mean worm burden in control group}}$$

The reduction in worm burdens by LVM in goats infected with the isolate from farm A-Kiambu was 82%, while those for TBZ on isolates from farms B-Nairobi and C-Kajiado were 75.16% and 86%, respectively.

Data from both the EHA and controlled slaughter assay confirmed resistance to LVM on farm A-Kiambu and to TBZ on farms B-Nairobi and C-Kajiado as had been detected in the initial field trials. The use of these anthelmintics on the respective farms should be discontinued to prevent production losses that may occur as a result of failure of the anthelmintics. Anthelmintics with different modes of action should be used.

CONCLUSIONS

Resistance to TBZ and LVM was detected in *Haemonchus* spp. and *Trichostrongylus* spp. in goats on three farms in Kenya using the FECR and confirmed using the EHA and a controlled slaughter assay. Selection of the goat farms used in this study was not random. Therefore, the results of the survey do not give a true impression on how widespread resistance to anthelmintics may be on goat farms in Kenya. The results of the present study and those of Njanja et al (1987), however, support that resistance may be widespread. The levels of nematodiasis observed in this study were high, and the species found, especially *Haemonchus*, causes severe disease. The presence of anthelmintic resistance on goat farms in Kenya may therefore be causing enormous losses. A large scale and comprehensive survey is therefore needed and management measures for the problem of anthelmintic resistance instituted.

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RESISTANCE TO GASTRO-INTESTINAL PARASITES IN DORPER AND RED MAASAI-DORPER CROSSBRED SHEEP

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INTRODUCTION

Sheep and goats are widely owned by small scale farmers at the Kenyan coast; 60% of households keep smallstock, while only 20% keep cattle. The annual value of sheep and goat production in Kenya is estimated at K Pounds 118 million (KARI, 1991). Information on direct and indirect losses caused by helminth infection is not available, but various estimates have been made, ranging from USD 25 million (Preston and Allonby, 1979) to K pounds 22.5 million (Murray, unpublished).

Much of the work on selection of sheep for resistance against internal parasites comes from Australia. Early studies in an unselected Merino flock revealed moderate genetic variation in resistance to *Haemonchus contortus*. Two divergent selection lines were established in 1978. After 11 years, the resistant flock had a mean faecal egg count of around 2500 epg, while the susceptible flock had around 13000 epg (Woolaston, 1990), showing that selection is feasible.

The study reported here started in 1987, preliminary results from which have been reported at the 7th and 8th SR-CRSP meetings (Bullerdiek, 1989; Bullerdiek et al, 1990). The objectives are to determine within- and between-breed differences in resistance to natural infection with gastro-intestinal parasites and to identify genetic markers to aid in the selection of resistant animals. Results are reported for the 1990 lamb crop.

MATERIALS AND METHODS

The study was carried out at Diani Estate of Baobab Farms, 20 km south of Mombasa. Rainfall is bimodally distributed with rainy seasons in March-June and October-December. Rainfall figures were collected daily. The soils in the area are sandy and well to excessively well drained. These soils are characterised by very low levels of macronutrients, especially nitrogen and phosphorus, low organic matter, low cation exchange and water holding capacity. Vegetation on the research site is natural pasture and bush. The predominant grass species are *Heteropogon contortus* and *Hyparrhenia rufa*.

In March 1990, 297 ewes, 242 Dorper and 55 F_1 Red Maasai X Dorper, were bred in single sire groups of around 11 animals to 12 Dorper and 12 Red Maasai rams. Ewes were blocked by breed and age, and allocated at random to sire groups. Ewes were herded separately from rams on natural grazing during the day. Ewes and rams were penned in breeding groups over night in a boma, where mineral blocks and water were available. Lambs were weighed as soon after birth as practical (usually within 24 hours) and then weekly to weaning at 3 months, and fortnightly up to 12 months. Adults were weighed monthly. Blood and faecal samples were collected from all animals at weighing time. Blood was analysed

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for Packed Cell Volume (PCV) using a haematocrit centrifuge, and trypanosomes using the buffy coat method (Murray et al, 1983). Faecal egg counts were taken and faecal samples were cultured and the larvae identified (Hansen and Perry, 1990).

Animals were treated with an anthelmintic (Ivomectin) when PCV level dropped below 21, if blood was negative for trypanosomes. When trypanosomes were detected, animals were injected with Berenil, and PCV rechecked one week later. If the PCV level had started to recover, anthelmintic treatment was deemed unnecessary. All lambs were treated with anthelmintics at weaning.

Data were stored in Dbase files and analysed using SAS programmes. Weight, PCV and FEC were determined at 30 day intervals by interpolation and analysed using a General Linear Model. Independent variables used were sire breed, sire within sirebreed, dam breed, sex and number of drenches up to the age in question. Interactions between the independent variables were included when preliminary analyses showed them to be significant. Faecal egg counts, because of a skewed distribution, underwent a logarithmic transformation prior to analysis to determine levels of significance. Values reported below are least square means unless otherwise stated.

RESULTS

Monthly rainfall figures for 1990 and 1991 are shown in Figure 1. The area was relatively dry after lambing until the short rainy season October to December 1990. The long rains in 1991 started in March when lambs were around 7 months old, faltered in April and continued wet from May until lambs were 12 months old in August. Total rainfall between August 1990 and July 1991 was 959 mm, with 6 months receiving less than 50 mm/month.

Two hundred and fifty one lambs were born in August 1990, 98 pure Dorper, 101 F_1 crosses, 25 back crosses to Dorper rams and 27 back crosses to Red Maasai rams. There were 10 sets of twins. Lamb mortalities were high (0.27) in the first month after birth. The ewe flock contained a number of animals 7 years and older and many of the deaths were of lambs from these ewes. By weaning, 76 lambs had died (0.30), with pure Dorpers proving more susceptible (0.36) than the cross breeds (0.27). Over the following 9 months, a further 15 animals died so that overall mortality to 12 months was 0.36. Dorpers proved less hardy with a mortality of 0.47 compared to 0.29 for crosses.

Statistical analysis showed that sire breed, sire within sirebreed, dam breed, sex and number of drenches had significant effects on many of the parameters studied, but interactions between these independent variables were not significant except for FEC at 270 and 360 days. Interactions were therefore excluded from the model, except at 270 and 360 days.

Lamb weight, as shown in Table 1, was significantly affected by sire breed (higher for Dorper sired lambs), by sex (higher for males), number of drenches received (higher up to 270 days of age for animals with the fewest drenches). After 180 days of age when the number of drenches had increased for some animals, there was no difference between those that had received one or two treatments, but weights were lower for those that had needed three or more drenches. At 240 days, lambs that had received a single drench weighed 14.8 kg, compared to 11.6 kg for those with three or more drenches. By 360 days, the differences in weight related to breed and sex had disappeared, and had reversed for number of drenches so that animals with the most drenches weighed the heaviest. Sire within sirebreed had a significant effect on liveweight only at 60 days.

Table 1. Least squares means of liveweight (kg) lambs from birth to 360 days, and significance of factors on liveweight

		Age (days)								
		Birth	60	90[a]	120	180	240	270	300	360
Weight		2.8	8.3	10.6	12.7	14.5	13.9	16.5	18.1	18.7
Sire breed		***	**	NS	*	*	**	*	NS	NS
Dam breed		NS	NS	NS	NS	NS	*	NS	NS	*
Sex		NS	NS	NS	*	*	NS	*	NS	NS
Number of drenches		-	-	***	**	*	***	***	NS	NS
Sire breed:										
Dorper		2.9	8.7	10.4	12.8	15.1	14.3	17.1	18.8	19.7
Red Maasai		2.6	8.0	9.7	12.0	14.2	13.2	16.0	18.0	19.2
No. of drenches	0	-	-	11.0	-	-	-	-	-	-
	1	-	-	9.1[b]	13.2	15.2	14.8	17.2	18.8	19.1
	2	-	-	-	11.5[c]	14.1[c]	14.8	17.5	19.2	19.5
	3+	-	-	-	-	-	11.6	14.9	17.3	19.8

a all lambs were drenched at weaning
b one or more drenches
c two or more drenches
NS Not significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

PCV levels (Table 2) decreased with age across all breed groups, from 35.6% at birth to 25.2% at 360 days. PCV up to 330 days of age was significantly affected by number of drenches (higher for animals with the fewest drenches). Sire breed had a significant effect at 120 and 300 days with heavier weights for lambs with Red Maasai sires. At 240 days of age, lambs that had received one drench had mean PCV levels of 26.2%, compared to 21.5% for three or more drenches ($P<0.001$). From 240 days onwards, there was no difference in PCV level between lambs that had received 1 or 2 drenches. Sire within sirebreed was approaching significance ($P<0.1$) at 270 and 300 days. By 360 days, none of the factors in the model had a significant effect on PCV.

Table 2. Least square means of PCV % of lambs from birth to 360 days and significance of factors on PCV

		Age (days)								
		Birth	60	90[a]	120	180	240	270	300	360
n		197	189	168	164	160	150	145	130	105
PCV		35.6	30.5	28.4	28.8	29.5	25.3	27.2	25.6	25.2
RSD		4.31	4.88	3.63	3.28	3.16	2.55	2.34	2.41	3.75
Sire breed		NS	NS	NS	**	NS	NS	NS	***	NS
Sire (sirebreed)		NS	NS	NS	NS	NS	NS	NS	NS	NS
Dam breed		NS	**	**	NS	NS	NS	NS	NS	NS
Sex		NS	NS	NS	NS	NS	*	NS	NS	NS
No. of drenches		-	-	***	NS	**	***	**	*	NS
No. of drenches	0	-	-	29.5	-	-	-	-	-	-
	1	-	-	25.9[b]	29.2	29.6	26.2	27.4	26.6	26.4
	2	-	-	-	28.8[c]	28.1[c]	25.1	27.2	25.3	24.4
	3+	-	-	-	-	-	21.5	25.0	24.7	25.2

RSD Residual Standard Deviation
a all lambs were drenched at weaning
b one or more drenches
c two or more drenches
NS Not significant; * $P<0.05$; ** $P<0.01$; *** $P<0.001$

Faecal egg counts (Table 3) showed a skewed distribution across all breed groups, with a high coefficient of variation (CV) when compared to the CVs for weight and PCV, but Logarithmic transformation of FEC reduced the CV to around 50%. FEC values were affected by number of drenches from 150 to 270 days of age (higher for animals with the fewest drenches), but were not significantly affected by sire breed, nor by sire within sirebreed. At 270 days, lambs that had received a single drench had FEC values of 682, compared to 418 for those with three or more drenches (P<0.05). Interaction effects of sire and dam breeds were significant at 360 days, and of sex and dam breed at 270 days.

Table 3. Least square means of faecal egg counts EPG of lambs from 60 to 360 days, and significance of factors on FEC

	Age (days)							
	60	90[a]	120	180	240	270	300	360
n	115	121	138	142	123	121	106	83
FEC	358	393	218	263	392	548	976	620
RSD	305.6	594.0	230.5	333.0	503.1	537.4	748.4	816.0
Sire Breed	NS	NS	NS	NS	NS	NS	NS	NS
Sire (sirebreed)	NS	NS	NS	NS	NS	NS	NS	NS
Sex	NS	NS	NS	NS	NS	**	NS	NS
No. of drenches	-	NS	NS	*	NS	*	NS	NS
Sire X dam	-	-	-	-	-	NS	-	**
Sex X dam	-	-	-	-	-	*	-	NS

RSD Residual Standard Deviation
a All lambs were drenched at weaning
NS Not significant; * P<0.05; ** P<0.01

At 240 days, weight was positively correlated with PCV across all breed types (P<0.001), with correlation coefficents ranging from 0.22 for Dorper lambs to 0.56 for the three quarter Red Maasai. At 270 days, there was a positive correlation between weight and FEC across all breed types (P<0.01), with correlation coefficients ranging from 0.28 for pure Dorper to 0.76 for three quarter Dorpers. However, correlations between PCV and FEC were neither significant nor consistently in the same direction.

Lambs with Red Maasai sires needed fewer drenches than those with Dorper sires. By 270 days, 66% of Red Maasai crosses and 54% of Dorper lambs had received only the mandatory drench at weaning. The difference between breeds persisted to 360 days.

A culture of faecal samples was undertaken in April, May, July and August for the purpose of larval identification. There were no differences across time in the species composition of the larvae. Almost half of the larvae were *Haemonchus* and the other half were *Oesophagostomum*. A few *Trichostrongylus* larvae were found, accounting for 2% of the total.

DISCUSSION

When the main gastro-intestinal parasite challenge comes from *Haemonchus*, anaemia will occur, and in the absence of other anaemia causing factors, PCV levels can act as an indicator of challenge. Albers et al (1984) used PCV decline as a reflection of the *Haemonchus* burden using artificial challenge, although interpretion of results is unclear under field conditions with multiple species challenge. The challenge in the present study was from *Haemonchus* and *Oesophagostomum*. This needs to be borne in mind in the interpretation of PCV and FEC data. There is clear evidence from Barger (1988) that untreated Merino lambs on naturally contaminated pasture had acquired substantial resistance to infection with *Haemonchus* by 4 months of age, whereas lambs given one or more anthelmintic treatment, had not.

Protection against further challenge with *Haemonchus* is more effective if a moderate worm burden remains (Donald et al, 1969), but is lost after an anthelmintic treatment (Benitez-Usher et al, 1977). Immune animals without antigenic challenges still have good protection against challenge at 42 days, but had lost the immunity completely by 84 days (Jackson et al 1988). Barger (1988) concludes that anthelmintic treatment of lambs during an outbreak of haemonchosis may be particularly dangerous unless the treated lambs are moved to a clean pasture.

Over the period of the study, only 5 cases of trypanosomiasis was detected, and it is therefore assumed that anaemia was primarily related to *Haemonchus* infection. The present study showed that PCV was highest in animals that had received the fewest drenches. This is consistent with the findings of Barger (1988) that drenching removes acquired immunity. Animals that did not require drenching retained immunity, and were able to control parasite challenge. PCV tended to be higher in Red Maasai crosses, but the differences were only occasionally significant. Bullerdiek et al (1990) also reported that Red Maasai X Dorper lambs had higher PCV level than pure Dorpers, but found that PCV level was positively correlated with the number of drenchings received.

High PCV levels would be of practical value to farmers if they were consistently correlated to superior animal performance. Significant correlations between FEC and PCV under field conditions would be expected if *Haemonchus* is consistently the predominant specie. Faecal culture suggest that two species, *Haemonchus* and *Oesophagostomum*, predominate at the study site, but this needs to be confirmed across animal breed types and seasons. Post-mortem reports indicate that the numbers of *Oesophagostomum* in the intestinal tract is more varied than the numbers of *Haemonchus*. With single species challenge, interpretation of results is straight forward, but it is more difficult under field conditions with mixed challenge.

Faecal egg counts showed high coefficients of variation when compared to weight and PCV data. The independant variables used in the model had little consistent effect on FEC. Sire breed and sex had no effect and dam breed was only a significant factor at 270 days. Surprisingly, number of drenches had a significant effect on only two occasions and then FEC was lowest in those animals that had received the most drenches. If drenching removes acquired immunity, after drenching when lambs are returned to the same infected pasture (as would happen under smallholder management), they could be expected to be more susceptible to reinfection. This does not appear to have happened.

Results from the present study confirm the influence of breed on weight, and show that differences persisted up to 270 days, when the long rains were established. This confirms the preliminary results reported by Bullerdiek (1990) that Dorper lambs gained weight faster than Red Maasai X Dorper up to weaning at 90 days. Bullerdiek (1990) reported that up to 150 days, lambs grew faster with more frequent drenching. The present study reverses that finding, at least up to 270 days of age. From 270-330 days, weights were not affected by number of drenching, but at 360 days, animals that had received the highest number of drenches were heaviest. This may however be due to a commercial decision to sell males from the herd for the Id ul Fitr market.

Limited work is available on the economic value of improving resistance to parasites. A number of Australian studies have looked at the correlations between resistance, as indicated by FEC, and various production parameters. Albers et al (1989) quantified the effect of a single infection with *H. contortus* larvae on liveweight gain and wool growth over a relatively short period in young Merino sheep on pasture. Liveweight gains were reduced by 38% over an 8-9 week period beginning at the time of infection. Woolaston (1991) shows that there is little genetic association between FEC and production traits. In New Zealand, Baker et al (1991) showed that the phenotypic correlations between liveweight gain and FEC are consistently slightly negative, as would be expected for lambs left undrenched, but genetic correlations were more variable and in general not significantly different from zero.

Little published material is available for African conditions. In a field trial with 783 does in 64 flocks over a 2 year period in southern Tanzania, Hendy (1988) showed that responses in liveweight and growth traits to anthelmintic treatment were positive only in the rainy season. The predominant species from faecal culture were *Haemonchus contortus* and *Oesophagostomum columbianum*. Location effects were noted with significant effects of treatment occuring in one district but not in another. In one district, anthelmintic treatment increased survival rate of kids born in the rainy season by up to 27%, and the productivity index for dams kidding in that period by up to 64%. Set against this, the trends in the dry season were in the opposite directions. Muenstermann and Tome (1989) in a small trial at Transmara Livestock Research Station, found that improved survival after drenching had the largest influence on economic benefits from drenching and that responses with sheep were greater than in goats.

In New Zealand, individual farmers are benefiting from resistant sheep largely due to reductions in the number of drenchings required (Baker et al, 1991). On a wider scale, reduction in the frequency of application of drenches will slow the rate of development of drug resistance in parasites. The present on-station study showed that Dorper sheep need more drenches than Red Maasai crosses, but this will be of limited relevance to African smallholder farmers because veterinary inputs are minimal. Changes in reproductive performance of resistant ewes and survival rates of offspring are more important, and the economic benefits from these need to be determined.

CONCLUSION

There are differences between breeds in susceptibility to gastro-intestinal parasites, as indicated by PCV levels and the need for drenches. Red Maasai crosses require fewer drenches than Dorper and have a higher survival rate to 360 days. Although the number of drenches required was positively correlated with weight for the first nine months, the significance of this in older animals, and eventually through to breeding performance, remains to be established.

Although the number of animals was relatively low, the influence of sire within sirebreed on PCV suggests that further investigation of heritabilities may be profitable. The data has not revealed a clear association between the variables liveweight, PCV and FEC that could be used as an indicator of resistance to gastro-intestinal parasites.

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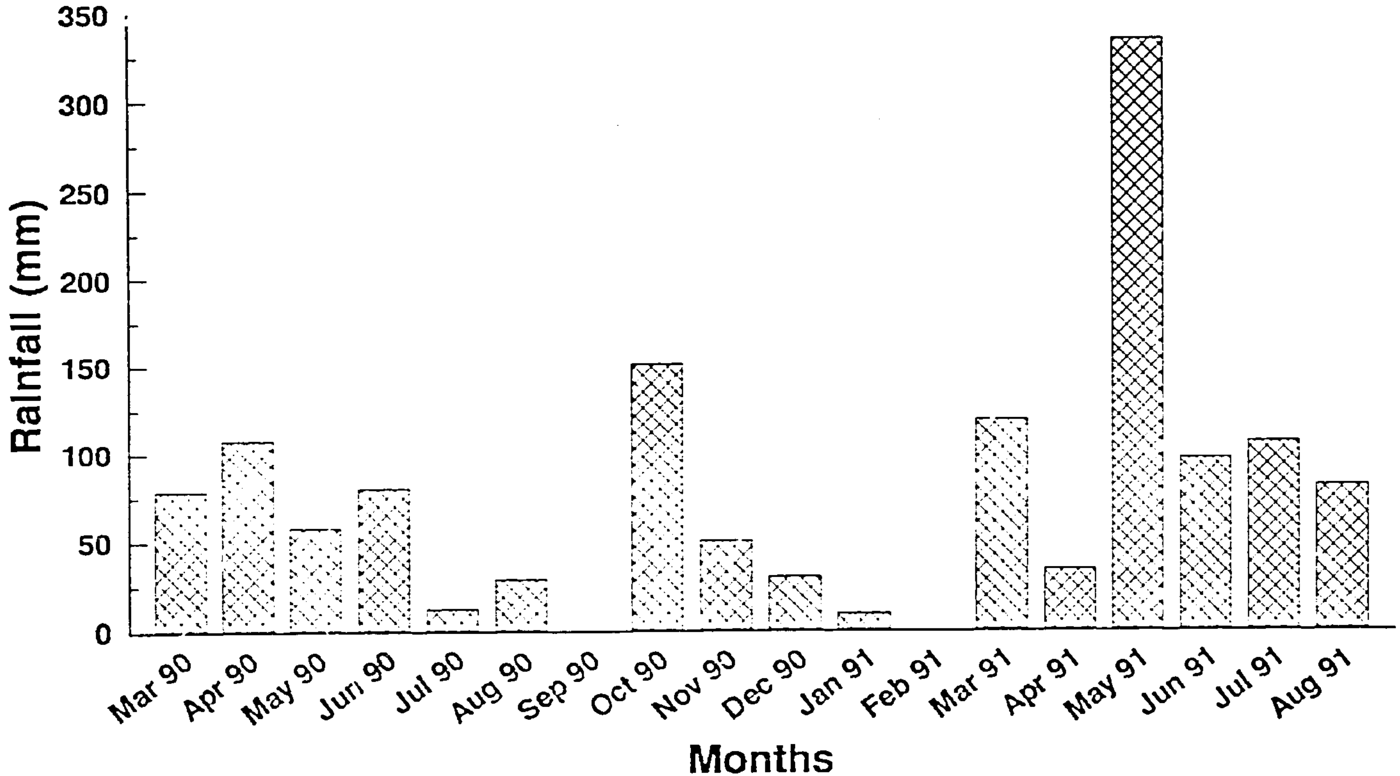
MONTHLY RAINFALL (mm) AT DIANI ESTATE FROM MARCH 1990 TO AUGUST 1991



EXPERIENCES OF GOAT DEVELOPMENT IN ETHIOPIA

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ABSTRACT

A dairy goat project has been implemented in Ethiopia for the last 3 years by a British NGO, Farm-Africa, the Ministry of Agriculture, Alemaya University of Agriculture, Awassa College of Agriculture and several NGOs. The project now works with nearly 1000 families in the south and the east of the country. The project aims to improve the milk production and growth rates of local goats and is implemented by selecting the poorest families in a community and providing local goats on credit, together with a package of forage and health improvements. Crossbreeding of Anglo-Nubian with Somali goats is carried out and the offspring are being tested on farm. In addition to the extension programme, a unique national survey of indigenous goats in Ethiopia is being undertaken. To date 35,000 goats have been surveyed in two thirds of Ethiopia. The current operation and performance of the project is described in the paper. After three years experience of project implementation, several issues emerge as being vital to the success of such projects and these are discussed.

INTRODUCTION

Prior to the initiation of the Dairy Goat Development Programme in 1989, little attention had been paid to goats in Ethiopia by researchers and development workers. The Dairy Goat Development Programme was initiated by the British non-governmental organisation (NGO), Farm-Africa and the Ministry of Agriculture, Environmental Protection and Development (MoA). It was agreed that goats had been almost totally neglected by government organisations in Ethiopia and lagged far behind other domestic species in research and development resources allocated to them. In fact in recent times there has been a certain amount of adverse publicity concerning goats because of Ethiopia's problems of environmental degradation. However, there are 18-20 million goats in the country, kept by some of the poorest members of Ethiopian society and from research undertaken as part of the project, it is clear that goats are widely milked by poorer families in Ethiopia. Workneh and Peacock (1991) report that 78% of goatkeepers in the south of Ethiopia milk their goats and they are also milked in the east and north of the country. It follows, therefore, that if attention is directed towards goats, then the poorest in Ethiopian society will benefit.

With an average GNP of about 120 US dollars per head per year, Ethiopia is one of the poorest countries in the world. Population density is very high in the highlands where farms sizes are small, 0.5-0.25 ha/family. It is well known that the highlands of Ethiopia are under extraordinary pressures from an increasing population attempting to maintain itself on degraded and degrading resources. Soil erosion is severe as cultivation is extended to the most extreme margins possible. The cycle of drought, famine and distress is widely known. The opportunities for farmers to improve the nutrition and income of their families are limited. The introduction of a more intensive goat management system in combination with forage development presents one option for improving this situation.

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Ethiopia's goat population is widely distributed through the country, with approximately 27% found on mixed farms in the highland areas. The remainder are kept in large flocks by pastoralists in the lowland, rangeland areas.

The project aims to increase rural incomes and nutrition in the highlands of Ethiopia by improving the productivity of goats managed by women. The project is directed towards those areas of the country where increasing population pressure is leading to diminishing landholdings and where rainfall limits reliable production from cereal crops. It is aimed at the poorest members of the community - the families with no livestock and particularly the women in those families. It sets out to help these women improve the welfare of their families by increasing milk supply which may be used for home consumption or sale, and increase income from the sale of males.

The project is a collaborative programme involving government and non-government organisations in Ethiopia. During its first three years, the programme has already stimulated a wide range of activities related to goats among the programme's collaborators, which include the Ministry of Agriculture, Alemaya University of Agriculture, Awassa College of Agriculture, the Institute of Agricultural Research and seven collaborating NGOs.

During the first phase, approximately 800 women in 4 regions (Hararge, Bale, North Omo and South Shoa) benefitted from the project. It was understood that in the context of Ethiopia's environmental problems, it was important to encourage a rational use of goats by growing forage and encouraging a cut-and-carry feeding system. Therefore, emphasis is placed on planted forage crops in order to practise a cut-and-carry feeding system.

Although the focus of the project is the field extension programme, it was also planned that the project would stimulate a wide range of activities related to goats in different government and non-government organisations. This includes such wide-ranging activities as goat AI, vaccine production, curriculum development and information provision.

The project is also making a major contribution to the information needs of the country through the national goat breed survey. This survey is carried out by graduate students and aims to characterise the indigenous goats of Ethiopia by making a detailed physical description of them as well as describing the management under which they are kept. By mid 1991, about 25,000 goats have been handled and described in 8 regions of the country.

In summary, the Dairy Goat Project has the following components and achievements after its first three years:

- The establishment up of 26 goat groups in 10 districts involving 800 families and disbursement of credit funds for the purchase of 1600 goats;
- The planting of about 40,000 forage trees and other forages in these groups;
- The establishment of two crossbreeding flocks at Alemaya University of Agriculture and Awassa College of Agriculture;
- The training of farmers, extension staff, undergraduate students, postgraduate students and professional staff in aspects of goat production;
- The involvement of the agricultural credit bank (AIDBANK) in providing credit for women for the first time;
- The production of extension materials and a public awareness campaign;

- The surveying of over 50% of Ethiopia to identify different goat types and management systems;

- The monitoring of the epidemiology of goat diseases, producing new information on goat diseases and their control;
- The training of personnel to collect, process and use goat semen.

Programme Components and Experience of Implementation

The components of the programme and an outline of the experience of implementing each component is briefly described.

Women's Goat Groups - The Extension Programme

At the heart of the programme is the establishment and subsequent supervision of women's goat groups in different regions of the country. Goat groups are normally established under the auspices of Service Cooperatives. Service Cooperatives were established after the 1974 revolution to supply inputs to individual farmers and assist with marketing of products. As such, credit has to be channeled through these Service Cooperatives who borrow funds on behalf of their members. Generally, Service Cooperative management has been rather poor under the Dergue regime. It is hoped that under the current democratisation process, Service Cooperatives will become more democratic and accountable and that management will improve.

The programme has adopted a stepwise approach to improving goat production. After an appropriate site has been selected, the programme is implemented as follows:

(1) The idea of improving goat production is explained and the terms of participation in the programme are clearly explained at a meeting of both women and men;
(2) Selection of women to participate takes place by the Peasant Association committee and MOA/NGO staff. Emphasis is placed on women-headed households who have sufficient labour to allocate to goat production. The main criteria for selection is lack of livestock ownership.
(3) The selected women are required to plant some forage, however small an area, before they receive their goats.
(4) The women then receive 2 local goats on credit. They are required to pay an insurance premium of about 5% of the initial value of the goat. Repayment may be in cash or kind according to the economic status of the community in question.
(5) Women receive training in forage development, husbandry and health care.
(6) Participants receive either a crossbred doe or exotic buck for mating at group level;
(7) Further training is provided in the care of the crossbred animal, emphasising the rewards from increased use of livestock inputs e.g. anthelmintics, vaccinations, minerals etc. Once milk production has increased, improved methods of milk hygiene, handling, butter and cheese making will be taught.
(8) Assistance may be provided in marketing the milk and/or dairy products.

After 3 years, the project is about to begin distribution of crossbreds to the most outstanding women. So far, project participants have benefitted from the project through income derived from the sale of male offspring, increase in the capital value of the flock itself, availability of a small quantity of milk and increased security from livestock ownership. There have been a few fortunate women who received goats with a high twinning rate and whose flocks have spectacularly increased in number, causing the family's previous income to be doubled, and in some cases trebled, within two years.

Credit Arrangements

Supplying credit to women and for goats are both new interventions for Ethiopia. Funds for credit were supplied by Farm-Africa but recently Ethiopia's agricultural credit bank, the Agricultural and Industrial Development Bank (AIDBANK), has agreed to supply credit to women and for goats. This is an important step in the institutionalisation of the project. To support AIDBANK's involvement, the Ethiopian Insurance Corporation (EIC) has also become involved with goat insurance for the first time and has set 3% as the insurance premium for a local goat and 4% for a crossbred.

Although AIDBANK is now involved in supplying credit to women it is only to women who meet certain criteria, such as Service Cooperative membership, that credit is actually given indirectly through the woman's husband, thus precluding widows from access to such inputs. It is hoped that with the recent change in government, new agricultural policies will allow a more liberal approach to the definition of legally acceptable bodies for the receipt of credit. This would enable the women to form themselves into a recognised group and to manage their own credit funds and breeding buck station, assist their members to buy inputs, e.g. anthelmintics, and ultimately market products. This enhanced role of the women themselves will be a major emphasis in the next phase of the project.

In areas of the project where families are extremely poor and there is little cash in the society, credit may be repaid in kind, by returning a weaned female kid to the project who then passes it on to new families.

Veterinary Care

Few farmers in Ethiopia have easy access to veterinary services. And although veterinary staff are well trained, they have only rudimentary equipment and a very poor supply of drugs. It is hoped that the supply of drugs will improve in the near future. In the meantime, the project supplies drugs and equipment. In the future, it is hoped that simple drugs such as anthelmintics, acaricides etc, will become available to farmers through private traders.

In line with MOA policy, it is intended to train paravets to attend goats in each group. It is now widely agreed that in developing countries in Africa, a decentralised animal health care system is likely to be the most cost-effective means of preventing and controlling livestock diseases. The use of bare foot' or paravets is the key to such a system. It is the policy of MOA to train such people and to try to have one per SC. It is therefore planned to train one paravet per goat group who will be responsible for supplying simple veterinary service to goats in the group.

Monitoring the health of goats in the project is carried out and a much better picture of goat diseases in the highlands of Ethiopia is now available than at the start of the project. The most economically important diseases are Haemonchosis, Fascioliasis and Sarcoptic mange. It is hoped to make anthelmintics even more widely available to farmers and to control internal parasites through the more widespread use of a cut-and-carry feeding system. A form of what appears to be almost epidemic mange has been encountered with a seasonal incidence. The contributing role, if any, of sub-clinical levels of other diseases known to exist in the area, e.g. Contagious Caprine Pleuropneumonia and Peste de Petit Ruminants needs understanding.

Forage Development

In the densely populated environments in which the project operates, forage has to be grown in areas of the farm that do not compete with grain crops - around the house, along the edges of fields, undersown in maize/sorgum etc. If it is then fed to an income generating livestock enterprise, then farm incomes can be increased and some environmental protection afforded. The project is fortunate to work closely with the World Bank-funded Fourth Livestock Development Project. The forage strategies promoted for goats are backyard pasture, forage strips and undersowing annual/perennial crops. The main species used are *Chamaecytisus prolifer, Leucaena leucocephala, Sesbania sesban, Desmodium intortum, Macrotyloma axillare, Cajanus cajan, Medicago sativa* and *Pennisetum purpureum*. Greater emphasis is given to legumes in order to improve the quality of the natural diet which may have a high proportion of poor quality crop residues.

Growing plants to feed to livestock is a very new technology for farmers in all areas in which the project works, indeed in all areas of the country. Although farmers will nearly always voice lack of grazing as one of their most important problems, the technology has not, until recently, been available to them to enable either individual or communal efforts to alleviate this chronic problem. Forage development is a new technology and it will take time before the benefits of growing forage and controlling livestock are perceived to outweigh the labour and supervision costs. All participants understand the need for more and better feed for their goats but not all are convinced enough to allocate the labour necessary to establish and protect the forage. In Hararge, where villagisation first began, house compound areas are in most instances quite small. Problems were found in controlling neighbours' livestock which may wander uncontrolled through the village. Some limited success was achieved by the most determined women through vigilance and by cutting their trees above the feeding level of cattle and smallstock about 2 metres height, which shows it can be done. Most success was achieved in Hararge in areas less severely villagised, where more space was allowed between houses, even large enough to cultivate crops. Rows of elephant grass can be plated around these areas together with tree legumes.

The break-up of many villages has, to a certain extent, disrupted backyard forage development but ultimately will lead farmers to have a greater interest in planting trees around the house compound of their choice. In the future, it is planned that more field-based forage strategies will be used, such as undersowing and forage strips. This will require the cooperation of the husband and this must be sought.

Breeding Strategy

Crossbreeding is carried out between British Anglo-Nubian stock and Somali does at Alemaya University and Awassa College. F_1 does with a 50% kid in *utero* will be distributed to the most outstanding women in the project. They will be evaluated on-farm for satisfaction/attitude of women recipients, milk yield, lactation length and sale age. Due to the shortfall in the supply of F_1's, it is also intended to establish buck stations on a trial basis. Farmers would be encouraged to upgrade their goats to no more than 75% exotic blood and less if the management is not adequate. The initial performance of the crossbreds indicate superior growth rates of 103 ± 36.1 g/day compared to 55.1 g/day of local goats.

It is also vital to consider now the long-term sustainability of the project in supplying breeding stock to an ever increasing number of families. With the recent changes in policy, it is now more attractive for private investors to invest in agricultural enterprises. Several individuals have approached Farm-Africa with interest to invest in goats either for milk production or breeding stock production. It is hoped to be able to assist these individuals invest in goat production.

Farm-Africa in collaboration with the National AI centre, organised a course on goat semen collection, processing and use. The Centre now proposes to train an increasing number of inseminators in goat insemination. In this way, at little extra cost, goat AI could 'piggy-back' on the existing cattle insemination system and reach a large numner of producers.

Training

Training of all levels of participants is vital to the success of the programme. A goat extension package has been developed for use in group meetings. It covers forage development, feeding, breeding management and health. The package is used in regular group meetings where a different topic is covered. As the project works predominantly with women, the preferred approach is one of regular monthly afternoon meetings. Apart from instruction in goat husbandry, assistance should also be provided in record keeping and financial management. As more goats' milk becomes available, methods of milk preservation and processing will also be discussed.

However, training is not just about imparting 'know-how'. There will he an increasing emphasis in the next few years on the social development of the women themselves. This is perceived as essential, not for any radical political purposes, but for the technical and social success and indeed sustainability of the project itself. For example, it buck stations are to be established, this must be done on a 'group' basis. The buck station or crossbreds are likely to become a focus for the women and this will encourage the development of a group identity. Once established, this group could then be further developed to encompass such things as the control of credit funds, purchase and supply of inputs (anthelmintics, mineral licks, etc), training of paravets and possibly the eventual marketing of products. Different modes of cooperation are likely to succeed in different areas according to traditional systems of cooperation. The development of cooperation among the group will require careful nurturing.

To date training of extension staff been in the form of short in-service training courses. It is now that more extended courses in goat husbandry, health and breeding management are organised on a routine basis for both extension staff currently involved in the project and for those wishing to become involved.

It is planned that professional staff receive more formal training in goat production. It is only when professionals become identified as 'goat specialists' within their institutions that future work on goats is assured. This is seen as crucial to the future sustainability of goat development and research in Ethiopia.

National Goat Breed Survey

The National Goat Breed Survey aims to make a physical description of all the goat types of Ethiopia and to describe the management systems in which they are kept. As such, it is a major contribution to knowledge about goats in Ethiopia and forms the basis of a unique study of a nation's goat resources. It is planned that by the end of 1992, the whole country would have been surveyed and that in 1993, an illustrated monograph will be published. The survey is carried out by a series of post-graduate students who each survey several regions of the country. They follow an altitude transect taking samples of goats at 500 m strata. When sampling, they take a wide range of physical measurements of whole flocks, carry out a survey of the local farming system, record lactation data and engage in interviews on the socio-economic role of goats in that area. Each student surveys about 10,000-12,000 goats and the data is analysed at the International Livestock Centre for Africa where multivariate analyses are possible.

CONCLUSIONS

The project has already shown the potential for goats to dramatically improve the welfare of the poorest families in Ethiopia. Expertise is being developed in goat production in many institutions in the country and it is hoped than an increasingly firm foundation is being laid that will allow the expansion of goat development activities far beyond the scope of the Dairy Goat Project itself. In this way, Ethiopia's goat resources can make an increasing contribution to the welfare of families and the economy of the country.

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POTENTIAL BROWSE SPECIES AS FEED FOR SMALL RUMINANT PRODUCTION IN UGANDA

E.N. Sabiiti and J.S. Mugerwa[1]

INTRODUCTION

The natural grasslands of Uganda contain several browse species which constitute an important feed for small ruminants (about 2.5 million goats and 0.8 million sheep) throughout the year. They remain relatively green through the dry seasons and are known to be a high quality feed when compared to grasses whose percent crude protein may fall below the limiting level of 7% that inhibits intake. Goats and sheep normally browse on leaves, young twigs, flowers, pods and seedlings.

However, browse management in these ecosystems is poor due to lack of management decisions based on scientific data. Yet goats and sheep play an important role in the economy of rural traditional farmers. They provide meat, hides and skins and are also used in various traditional ceremonies.

Although some browse species play an important role in small ruminant production and in sustaining grassland stability, there is still limited data on their productivity and nutritive value and how they can be optimally managed to sustain high productivity. Furthermore, there is no detailed information on the status of all potential browse species in different agro-ecological zones and how browsing affects their production.

The objective of the study was to determine the productivity and nutritive value of potential browse plants which were commonly browsed by small ruminants in the natural grasslands.

MATERIALS AND METHODS

The study was conducted in 1988 in the *Acacia*/savanna grassland ecosystem in Mbarara District, southwestern Uganda. The area is important for livestock grazing is facing feed scarcity due to mismanagement of the grazing resources. Goats and sheep are free ranging, often grazing with large cattle herds. The vegetation and climate of the area has been described by Langdale-Brown et al (1964) and Sabiiti and Wein (1991).

Biomass Production and Nutritive Value

The dominant species investigated were *A. sieberiana, A. hockii* and *A. gerrardii*. Ten saplings (young trees) of each *Acacia* species of similar sizes were randomly located in an area of about 10 ha and then felled in June 1988 at a height of 50 cm. Young twigs and leaves were sampled from each sapling and oven-dried at 70°C for two days for nitrogen analysis.

The stumps were allowed to coppice in order to determine biomass of the shoots/stump. The regrowth shoots were all pruned from each stump after attaining an average height of 1.5 m - this being taken as the range at which browse was easily available to goats and sheep. They were separately oven-dried as above to estimate fodder yield and nutritive value. A similar number of seedlings of each species

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was sampled in an area that had been burned in February 1988 (dry season) and the seedlings were used to estimate biomass and nutritive value. Mature pods containing seeds were sampled and divided into pod with seeds, seed only and empty pods in order to determine nutritive value.

For the shrubby species of browse, namely *Sesbania sesban, Securinega virosa, Solanum incanum, Indigofera errecta* and *I. hirsuta*, only their %CP was determined in twigs and leaves.

Percentage crude protein of the ground samples was determined by the MacroKjeldal method (AOAC, 1980).

RESULTS AND DISCUSSION

Biomass Production and Crude Protein Content of Acacia Browse Species

Table 1 shows that *A. sieberiana* produced significantly ($P \leq 0.05$) higher biomass from coppice shoots and seedlings than the other two species. This was the most dominant browse tree species in the study area. *Acacia gerrardii* is another productive browse tree that is very much browsed by goats and sheep.

Table 1. Biomass production: DM g/stump, percentage crude protein of coppice leaves, twigs from parent trees and seedlings of Acacia browse species in South Western Uganda

Species	DM Coppice shoots	CP% Coppice leaves	CP% Young twigs	DM Seed-lings	CP% Seed-lings
A. sieberiana	2965^{a}[1]	22.5^{a}	18.8^{a}	90^{a}	27.4^{a}
A. hockii	1675^{b}	20.3^{a}	16.9^{ab}	61^{b}	25.6^{ab}
A. gerrardii	1942^{c}	18.2^{a}	15.2^{bc}	69^{bc}	23.5^{bc}

[1]Means with similar letters within columns are not significantly ($P < 0.05$) different using Duncan's multiple range tests.

Regeneration of the cut stumps started within two weeks and the shoots grew vigorously, attaining an average height of 1 m in about four months of growth in the dry season. Pellew (1983) and Sabiiti and Wein (1988) have reported high rates of growth of *Acacia* species in national parks in East Africa where they form an important diet for game animals.

All *Acacia* species had a high percentage crude protein. This would supplement dry grasses that are grazed by sheep and goats in the dry season as well as by cattle. It is not surprising that goats, in particular, avidly browse *Acacia* leaves, twigs and seedlings most of the year. However, there is still limited information and the response of *Acacia* to browsing by goats or sheep (Sabiiti and Wein, 1991).

Uncut trees produced few new shoots or none at all below 2 m. As such, they would not provide sufficient highly nutritive browse during the dry season for goats and sheep. Thus, selective cutting before the dry season starts would provide productive browse within easy reach by small ruminants. Fire, which has been reported to stimulate germination and emergence of *Acacia* seedlings (Harrington 1974; Sabiiti and Wein, 1988), is another practical management practice to improve the quality of the natural grasslands through increased protein content in seedlings that was generally higher but much so when compared with young twigs sampled from the saplings in this study.

Chemical Composition of Pods

Table 2 indicates that seeds were superior to pods in crude protein content. *A. hockii* was the best followed by *A. siebariana* and *A. gerrardii* which had similar protein levels. Comparable levels of crude protein have also been reported for other *Acacia* species in East Africa (Dougall and Bogdan, 1958; Dougall et al, 1964).

Table 2. Mean chemical composition of pods and seeds of Acacia browse species in South Western Uganda

Species	Components	CP%
A. sieberiana	Pods + seeds	14.8
	Seeds	24.8
	Pods	10.6
A. gerrardii	Pods + seeds	18.1
	Seeds	24.8
	Pods	5.3
A. hockii	Pods + seeds	15.4
	Seeds	35.3
	Pods	9.5

However, the main problem with *A. hockii* and *A. gerrardii* is that the pods dehisce and many seeds (which are small) are scattered and are not easily picked by stock. *A. sieberiana* pods are indehiscent and on maturity fall to the ground where they are easily picked and eaten by the goats and sheep. The seeds are also large. In the case of *A. hockii* and *A. gerrardii*, farmers could collect the pods before they dehisce and use them for supplementation during the dry season.

It is clear from the results that the three *Acacia* species are potentially high in nitrogen and could alleviate dry season feed shortages if the trees are properly managed. It should also be noted that since they are leguminous species, they could have a potential for fixing atmospheric N which would later be available to the grasses for the grazers. However, this has not yet been fully documented. Similarly, the contribution of pods and seeds to ruminant productivity (liveweight gain, lambing rates etc.) was not studied here.

Chemical Composition of Shrubby Browse Species

The shrubby browse species were equally high in crude protein (Table 3), thus revealing a very high production potential of browses in this natural grassland ecosystem. What is now required is to evaluate them for biomass production and how it is affected by different browsing pressures of goats and sheep. There is also a need to evaluate all these browse species under cultivation where their potential could be higher than under natural conditions.

Table 3. Mean chemical composition of shrubby browse species in South Western Uganda

Species	Components	CP%
Capparis tomentosa	Twigs	17.4
	Leaves	25.3
Securinega virosa	Twigs	16.2
	Leaves	22.4
Solanum incanum	Twigs	17.2
	Leaves	18.8
Indigofera arrecta	Twigs	16.5
	Leaves	23.7
Indigofera hirsuta	Twigs	16.2
	Leaves	24.6
Sesbania sesban	Twigs	20.5
	Leaves	27.5

CONCLUSION

This short-term study has provided useful data on the potential of *Acacia* and other browse species as feed for small ruminant production. *Acacia sieberiana* was superior in biomass production (2965 DM g/individual stump) and leaves and seeds of all the browse species outyielded twigs in crude protein content. Management practices like selective felling of saplings should be used to increase available browse of high nutritive value.

Further research is required for long-term evaluation studies in order to determine browse productivity and feeding value for various small ruminant production systems, e.g. free ranging, tethering, intensive or mixed grazing. Such studies will be made much easier since we have already collected some of the germplasma of the potential browse species from different agro-ecological zones in the country.

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EFFECTS OF FEEDING CRUSHED LUPIN SEED ON INTAKE, GROWTH PERFORMANCE AND LIVER ENZYMES IN LAMBS

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Lupin (*Lupinus albus* cv. ultra) is a grain legume with an excellent capacity to fix nitrogen, and capable of improving the organic matter of soils. These agronomic attributes have led, recently, to much interest in lupin as a field crop and as a protein supplement for animals.

Lupin seed has been investigated, to a limited extent, for its protein value to ruminants but studies show that alkaloids in lupin may restrict voluntary intake and nutrient utilisation.

The present study, conducted in Kenya, was designed to determine the effects of detoxification of crushed lupin seed (CLS) on voluntary dry matter intake (DM), growth performance and liver enzyme activity in growing lambs.

Thirty corriedale weaning wether lambs, about 5 months of age and weighing 11.8-3.3 kg, were assigned, according to a randomized complete block design, to 5 dietary treatments. The trial lasted for 105 d. Diet A served as the control and represented a diet containing ground sunflower seed; diet B and C contained 15% and 30% of intact CLS, respectively, and diet D and E contained detoxified CLS at 15% and 30%, respectively. Diets were formulated to be isonitrogenous and contained varying quantities of Napier grass (*Pennisetum purpureum*), lucerne hay, maize bran and urea/vitamin/mineral mixture. Table 1 shows the chemical composition of the diets.

Table 1. Ingredient Chemical[1] and Alkaloid[2] Composition of Experimental Diets

	DIET				
Item	A	B	C	D	E
CLS(%)	0	15	30	15	30
DM(%)	88.5	90.4	90.1	91.2	92.1
CP(%)	16.0	16.1	16.3	15.8	16.4
ADF(%)	31.6	18.1	25.4	23.2	26.6
NDF(%)	52.2	44.5	44.8	49.1	49.1
Lupanine(%)	nd	.187	.424	.166	.366
13-OH lupanine (%)	nd	.078	.160	.044	.138
Ca (ppm)	.39	.23	.27	.27	.47
P (ppm)	.39	.28	.29	.28	.38
Mn (ppm)	70	456	913	1244	1409

nd - not detected
[1]n=7
[2]n=2

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Lambs were maintained in individual pens, and fed *ad libitum*, twice daily. The animals were weighed two times per week and blood samples collected every two weeks from the jugular vein of each lamb. Blood plasma was analysed for Glutamic oxaloacetic transaminase (GOT), γ-Glutamyl transferase (γ-GT), Glutamic pyruvate transaminase (GPT) and Alkaline phosphatase (ALP).

The procedure for removing soluble, toxic quinnolizidine alkaloids from CLS involved boiling whole lupin seed in water for 1 h and steeping it in running cold water for a minimum of 24 h followed by 12 h of oven-drying at 65°C. Total alkaloids were analysed by Gas chromatography with mass spectometry detection (GC-MSD). Specific alkaloids, lupanine and its derivative 13-hydroxylupanine were also analysed. This procedure appeared to reduce the content of total as well as specific alkaloids in diets D and E (Table 1).

Lambs fed detoxified diets (D and E) had higher ($P<.05$) DMI (75.6 $g/w^{.75}$ and 74.9 $g/w^{.75}$, respectively) than lambs fed the intact diets (B and C) (70.6 $g/w^{.75}$ and 71.8 $g/w^{.75}$). Lambs fed the control diet (A), which contained ground sunflower seed, had the least ($P<.05$) DMI (53.7 $g/w^{.75}$). Lambs fed diet B,C,D and E had higher ($P<.05$) ADG (70, 120, 130 and 110 g/d, respectively) than those fed diet A (40 g/d)). Results of enzyme assays showed no relationship between diet and activity of SGOT, γ-GT, SGPT and ALP. The Pearson correlation coefficient procedure revealed negative, though nonsignificant relationship ($r=-.3086$, $P>.05$) between DMI and total alkaloid content of the diets. The trend in voluntary intake is consistent with the change in total alkaloid content, and suggests that alkaloids could be responsible for limiting appetite.

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FEEDING BEHAVIOUR OF GOATS AND CATTLE UNDER EXTENSIVE MANAGEMENT ON SMALLHOLDER FARMS IN THE COASTAL SUB-HUMID ZONE OF KENYA

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INTRODUCTION

The study was conducted in Kaloleni division, Kilifi district, in coastal lowland Kenya. The rainfall in the region is bimodal, with a long rainy season from April to June and a short rainy season from November to December. The mean annual rainfall is 1100 mm, but is variable and often poorly distributed (Jaetzold and Schmidt, 1983). The soils are sandy, free draining and infertile, poor in organic matter, nitrogen and essential nutrients. The area is densely populated, mainly by mixed crop/livestock smallholder farmers. Coconut, cashewnuts, and citrus are the major tree crops found in the area. Maize, cassava and cowpeas are major food crops grown for subsistence use.

Smallholders own between 3-4 plots, varying in total area from 3 to 5 ha. Livestock owners have larger plots than non livestock owners and tend to own more plots. Sixty percent of farmers own small ruminants, mainly goats, and 20% own cattle, mainly Zebu. Grade cattle for dairy are kept on a small number of farms. Most ruminants rely on natural grazing for the major part of their nutrient requirements. However, little or no information is available on feed availability for systems based on natural pasture in this area. This study was therefore designed as a rapid survey to identify the most important plants in the pasture and to determine the feeding behaviour of cattle and goats.

METHODS

The study on animal feeding behaviour was conducted during three seasons in three contrasting farms in the Kaloleni division in the Coastal lowlands in the short dry season (August), the short rainy season (December) and the long dry season (March). The three farms that were investigated were located in coconut-cassava (CL3), transitional cashew-cassava (CL4) and transitional livestock millet (CL5) zones. Each farm was selected based on the availability of grade cattle, Zebu cattle and goats. Three animals in each category were followed on each farm, except for the CL3 farm where the Zebu group was reduced to two, and the CL5 farm where the goats were stolen before the final study period. In each season, three days were spent collecting data on time spent grazing, walking, browsing and resting for three of each animal species, in three sessions during each day. The precise timing of the three sessions depended on management decision of farmers, but were early morning, late morning and late afternoon.

Each farm was surveyed prior to commencement of data collection to assess the distribution of plant species, classified as either abundant, common, present, rare or absent. Plants were then grouped as grasses, non-woody herbaceous, woody herbaceous or shrubs. Each individual animal was observed for five minutes in each session, broken into ten-second intervals. At the end of each interval, the activity was recorded at that precise moment. The proportion of times animals spent grazing, browsing, walking and resting were obtained. During the same five-minutes periods, data were also collected on plant species grazed or browsed, together with a bite count number for each animal and plant specie. Bite counts were used to determine rank order of species preference.

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Bite count data were analysed for the short rains and long dry season by a least square means procedure, using SAS. The independent variables in the model were season, farm, animal species and plant type. Interactions between season and animal specie, season and plant type, season and farm, animal specie and plant specie, farm and animal specie, farm and plant type were included in the model. Preliminary statistical analysis also included animal type (Grade, Zebu, goat) but this was excluded from the final model when no difference between cattle types was apparent. Levels of significance were determined from a square root transformation of the data to minimise the skewed distribution of bites taken.

RESULTS

Farmers in CL3 and CL4 herded their livestock a distance away from the homestead in the morning sessions and near the homestead during the late afternoon session. Normally, animals were herded on pasture near the homestead in CL5 farm throughout the experimental period. Location of grazing was similar across seasons except for CL3 farm where animals were herded to a pasture close to the homestead throughout the long dry season.

Plant Availability

High diversity was found in all farms, with a total of 69 different plants being identified. Considerable differences were observed between farms, reflecting the ecological zone in which the farm was located (Table 1). Only two plants were rated as 'abundant'. The CL4 farm was dominated by the grass *Digitaria milanjiana*, and the CL5 by *Eragrostis superba*. Overall, the CL3 farm had four species ranked as 'common', three grasses and a shrub. In CL4, apart from the abundant grass specie, no plant was ranked higher than 'present'. In CL5, in addition to the abundant grass specie, three grasses, one non-woody herb and one shrub were rated 'common'. Ground cover on the CL4 farm was more scattered than on the other farms.

Table 1. Abundance of the major plant species in natural pasture on farms in Kaloleni[1]

Plant Category	Plant Species	Farms		
		CL3	CL4	CL5
Grass	*Digitaria milanjiana*	3	4	3
Grass	*Dactyloctenium sp*	3	2	3
Grass	*Cynodon sp*	2	1	2
Grass	*Sprobolus sp*	3	1	1
Grass	*Panicum tricladium*	2	1	1
Grass	*Perotis patens*	1	2	1
Grass	*Eragrostis superba*	0	0	4
Grass	*Bothriochloa insculpta*	0	0	3
Grass	*Chloris sp*	0	0	1
Grass	*Heteropogon contortus*	0	0	3
Woody herbaceous	*Waltheria indica*	3	2	2
Woody herbaceous	*Agathisanthemum bojeri*	2	2	2
Woody herbaceous	*Justicia uncinualate*	2	2	1
Non woody herbaceous	*Vigue pakeri*	2	1	1
Shrub	*Lantana camara*	1	1	3

[1]Key for Abundance; 4 = abundant, 3 = common, 2 = present, 1 = rare, 0 = absent

Animal Behaviour

Preliminary statistical analysis showed that the behaviour of Zebu and grade cattle were the same; both groups spent the same amounts of time feeding and grazing and selected the same plants, with the same bite counts. Zebu and grade animals were therefore combined in a single category for the final analysis.

As shown in Table 2, cattle spent significantly (P < 0.01) more time feeding than goats (77% vs 70%). Cattle spent a higher proportion of the feeding time in grazing than did goats (80% vs 33%). Goats, however, spent more time walking (24% vs 17%).

Table 2. Proportion of time spent by goats and cattle on different activities, averaged over seasons, farms, days and sessions

Animal species	Feeding	Grazing[1]	Walking	Resting
Goats	0.70 a[2]	0.33 a	0.24 a	0.03 a
Cattle	0.77 b	0.80 b	0.17 b	0.02 a

[1] Proportion of feeding time spent grazing.
[2] Values followed by the same letter in a column are not significantly different at the 1% level.

Seasonal effects on behaviour are shown in Table 3. Time spent feeding was lower in the short dry season than in the other two seasons because more time was spent walking (P<0.01). Time of day also had a significant effect on feeding time; across all farms, animals were most inclined to feed in the late afternoon (P<0.01). Farm location also affected feeding time, with the highest level recorded in CL3.

Table 3. Proportion of time spent on different activities in different seasons, averaged over animal species, farms, days and session

Season	Feeding	Grazing[1]	Walking	Resting
Short dry	0.68 a[2]	0.55 a	0.26 a	0.03 a
Short rainy	0.75 b	0.59 a	0.18 b	0.02 a
Long dry	0.77 b	0.55 a	0.18 b	0.02 a

[1] Proportion of feeding time spent grazing
[2] Values followed by the same letter in the same column are not significantly different at the 1% level.

Overall, goats took 24 bites/min and cattle 26 bites/min (P<0.001) (Table 4). Season had no effect on bite count, but season by animal species interaction was significant. Season had little effect on bite counts for cattle, but goats took 0.30 more bites in the long dry season than in the short rains (P<0.05). Farm location was a significant factor (P<0.001). Seasonal differences in bite counts were smallest on the farm in CL5, but on the CL3 farm, bite counts were almost 0.50 higher in the long dry season, while in CL4, 0.40 more bites were taken in the short rainy season (P<0.001).

Table 4. Least square means for bite count (bites/min) for goats and cattle in Kaloleni district, and interactions with season and location

	Goats	Cattle	Significance
Overall	26.0	23.5	***
Season			*
Short rains	23.2	24.9	
Long dry	28.8	22.2	
Location			***
CL3	30.6	19.9	
CL4	23.5	23.2	
CL5	24.0	27.5	

* $P<0.05$; *** $P<0.001$

There were differences in choice between plant types for goats and cattle. Grass accounted for 0.79 of the total bites for catt... compared with only 0.42 for goats ($P<0.001$). A third of the diets comprised woody herbs for goats, with shrubs a further 0.17 (Figure 1).

Figure 1&2

Grasses were the major component of the intake on farms in CL3 and CL5, but were equal in importance with woody herbs in CL4 ($P<0.001$), as shown in Figure 2.

Individual Plant Species Selection

The 27 grasses, five non-woody herbaceous, 22 woody herbaceous and 15 shrub species were observed as eaten during the study period. Differences were observed between the selection by cattle and by goats. Cattle depended on a wide range of plants, but goats concentrated on two main species. Selection ranking has been based on the proportion of total bites directed towards a particular plant species. For cattle, eight individual plant species occupied more than 5% of the total bites, but only two species were as important for goats (Table 5).

Table 5: Rank order of plant species selected by cattle and goats

	Cattle			Goats		
Rank order	Plant species	Plant categ.	Proport. of bites	Plant species	Plant categ.	Proport. of bites
1	*Digitaria milanjiana*	1	0.16	*Agathisan. bojeri*	3	0.24
2	*Dactyloctenium sp*	1	0.10	*Panicum tricladium*	1	0.14
3	*Eragrostis superba*	1	0.08	*Dactyloctenium sp*	1	0.04
4	*Panicum tricladium*	1	0.06	*Eragrostis superba*	1	0.04
5	*Spobolus sp*	1	0.06	*Lantana camara*	4	0.04
6	*Bothrioch. insculpta*	1	0.06	*Vigue parkeri*	2	0.03
7	*Cynodon sp*	1	0.06	Shrub *	4	0.03
8	*Justicia uncinulate*	2	0.05	Shrub *	4	0.02

Category 1 = grass, 2 = non woody herbaceous, 3 = woody herbaceous, 4 = shrubs, * unknown species

The top ranked plant specie for goats was *Agathisanthemem bojeri*, with 0.24 of the total bites. It was rated present on all farms. *Panicum tricladium*, the second specie for goat with 0.14 of the total bites and the fourth specie for cattle (0.06 of cattle bites), was found in limited quantities on all farms. The top two ranking plants for cattle, *Digitaria milanjiana* (0.16) and *Dactyloctenium sp.* (0.10), occurred on all the farms with abundant-present rating. The third-ranked plant for cattle, *Eragrostis superba* (0.08), was only found in CL5. The only non-grass specie K by cattle was the woody herb *Justicia uncinulate*, accounting for 0.05 of the total cattle bites.

When plants with a low abundance rating are frequently consumed by animals, a positive selection for that specie has occurred. *Panicum tricladium* fits this category. On the other hand, the browse specie *Waltheria indica* was rated common-present on all farms but was infrequently eaten, showing that animals selected against that plant.

DISCUSSION

· Since no differences in behaviour were observed between grade and Zebu cattle, observations on one are directly relevant to the other in the study zone. The grade cattle were mainly F_1 Ayrshire-Sahiwal crosses and these findings would need confirmation for crosses with more exotic blood. For both animal species, more time was spent feeding in the late afternoon than at other times of the day. Air temperature will affect the ability of animals to dissipate heat arising from digestive and metabolic processes in the body. Thermal stress, accompanied by depressed appetite, will occur when air temperature rises above a critical level that varies with several factors, including breed (Weston, 1982). In the late afternoon, air temperature is falling and feeding activity is observed to rise.

The two main categories of time use in the study were feeding and walking. Time spent walking may reflect the density of palatable plants on the ground. It is surprising to find that more time was spent walking in the short dry season when considerable plant material still remains from the long rains. Unfortunately, bite counts were not available from the short dry season to indicate whether animals were more selective at this time. There may also be differences in bite size with season which could allow fewer bites to produce the same total dry matter intake. Stobbs (1973) and Hodgson (1981) have shown that increases in biting rate do occur when intake per bite is depressed, as could be expected in the dry season, they are seldom large enough to compensate. Intake, based on bite counts from natural pasture, would be difficult to determine. The top eight plant species account for less than 0.60 of the total intake for both cattle and goats. The wide diversity of species selected across farms and seasons shows that when the quantity of a preferred specie is low, a different specie is consumed to compensate. On cultivated tropical pasture, Stobbs (1974) showed that cattle will take between 70-80 bites per minute at the start of grazing and between 40-50 at the end when appetite has been partially satisfied. Dry matter intake will depend on the time spent grazing, the number of bites per unit of time and the amount of food ingested per bite (Allden and Whittaker, 1970). On cultivated pasture, the variation in intake per bite is usually greater than variations in either biting rate or grazing time (Stobbs 1973; Hodgson 1981).

Assessment of feed resource availability on natural grazing depends on which animal species will be using the plot. A plant that should be counted as fodder for goats may not be consumed to any significant degree by cattle. As reported here, the top eight plant species by bite count rank order account for only 0.60 of the total bites taken. Assumptions on intake per bite are needed to convert bites, and hence plant preference ranking, to dry matter intake. One method to determine bite size would be to use animals with oesophageal fistula, collecting extrusa and separating plant material for individual species identification and quantification. This would also allow assessment of the nutritive value of feed consumed.

Some plant species, for example *Panicum tricladium*, are selectively chosen by animals so that they occupy a high position in bite count ranking, even though abundance on the ground may be relatively low. Low abundance may be due to high grazing pressure or because the ecology is not suited to that plant. If ecological conditions are suitable, it may be possible to use the abundance of that particular plant specie as an indicator of grazing pressure and pasture condition.

CONCLUSION

The behaviour of goats differs from cattle on natural pasture in the coastal zone, but there is no difference between the behaviour of grade and Zebu cattle. Two plant species for goats accounted for 0.38 of total bites taken whereas for cattle, the top two selected species comprised 0.26 of the total bites. The eight top ranking plant species across both animal species would account for less than 0.60 of the total bite counts. Assessment of feed resources, concentrating on plant species that are selected by animals, becomes more difficult when large numbers of plant species are involved. It may be possible to choose indicator plants to assess grazing pressure and pasture condition. In the study area, the grass *Panicum tricladium* had a high selection ranking for both goats and cattle, although limited quantities were available on the farms. In Kaloleni, on farms with both goats and cattle, attention should be given to the possible use of *Panicum tricladium* as an indicator plant for pasture condition and grazing pressure.

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EFFECTS OF GOATS' GRAZING AND CONTROLLED BURNING ON GRASS-BUSHLAND VEGETATION

A.B. Orodho and D. King'aru[1]

INTRODUCTION

For a long time, goats have been accused of destroying vegetation by causing soil erosion. Goats may, however, be effectively used to control bush encroachment particularly if accompanied by other range management tools such as controlled burning. An experiment was conducted at Buchuma Range Research Station, Coast Province, Kenya to find out the effects of goats grazing and controlled burning on bush-grass vegetation. The main grasses based at the study site were: *Panicum maximum*, *Digitaria milanjiana*, *Aristida adoensis*, *Chloris roxburghiana*, *Eragrostis superba*, *Enteropogon macrostachyus*, *Heteropogon contortus* and *Cymbopogon excavatus*. The dorminant woody plants were *Commiphora riparia*, *Commiphora africana*, *Boswelia hildebrantii*, *Loicissus revoillii*, *Grewia villosa*, *Cordia gharaf*, *Combretum* spp. and *Acacia* spp.

The main aim of the study was to investigate if controlled burning combined with grazing by goats will cause significant changes in bush and grass stand and thus attain an effective management of grass-woodland vegetation at low cost and with significant contribution to profitable livestock production.

EXPERIMENTAL PROCEDURE

Design and Treatments

A bush-grassland vegetation site was selected which was fairly uniform. The experiment was composed of three blocks with two burning x two grazing treatments interacting in a randomised block design. In each block, four plots each 100 x 200 metres were marked and the following four treatments assigned to them at random:

No Burning	Grazing	Burning
T1	No grazing	T2
T3	Goats grazing	T4

Two of the four plots were burned after the initial grass and woody plant inventories.

Grazing

Plots were grazed for six days each week and usually three weeks per month. On average when grass and woody vegetation was abundant the plots were grazed four weeks per month. The number of grazing days decreased as the vegetation became drier and scarce. Grazing/browsing continued each year as long as there was enough grass and browse for the animals to get a fill. On average, goats spent eight hours from 0800 - 1200 hours and from 1400 - 1800 hours grazing/browsing in the field. Between 1200 and 1400 hours, the animals were herded to water points. During the rest of the period, goats were either herded between the bomas and experimental fields or were night bomared.

In some cases, close attention was given to observe and record the time spent grazing various plant species. Observations were made both during the dry period when vegetation was dry and also during the wet growing season when vegetation was green and larsh. Twenty five 10 minutes stopwatch records were taken on individual goats selected at random.

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Two trained men were required to observe time and record grazing plants preferences of selected goat for a ten minute period. The recorder was equipped with forms, a datum holder, biro pen and a stop watch with a sweep-second hand that covers 10 seconds in on sweep around the dial. The observer would select the animal to be observed at random and call "ready" when appropriate. He would follow the animal closely and quietly call the species being grazed and when the animal stopped grazing. For example, [Grazing started on Pan. max ____ (Time Lapse time laple) _____, still on Pan. max (if grazing extended on that species) ___ _. Dig. mil _____ T.L. _____ Era. cae ______T.L., stopped _____ T.L., etc. until the 10 minutes period was completed].

The recorder noted and recorded the time spent on each species by entering the species code number (Pan. max is 1 for example) each 10 seconds in a segment of the appropriate time scale.

Sometimes an animal grazed indiscriminately and would change species frequently, with less than 10 seconds consecutively on any one species. In such cases, the recorder had to use his/her best judgement to apportion the time to species.

At the end of each 10 minute period, the recorder called time out, checked his form for completion, counted the total minutes for grazing time recorded and then credited the remainder of the 10 minutes to 'not grazing'. The grazing period observations of goats were spread throughout the day and were done during both dry and wet seasons.

The goats that were used included 50 white Boran/Angora crossbreds, 17 white Boran/Galla crossbreds and 10 East African dwarfs either tan or brown coloured. As another control measure, Saanen goats from Israel were grazed on similar vegetation to compare their browsing/grazing habits with the local goats.

Woody Plant Inventory

The woody plant inventory was conducted in 1969 and again in 1972 by running fifteen 50 metre line transects across the central 50 by 150 metres rectangle in each 100 by 200 metre plots. Thus the central measurement rectangular plot was surrounded by an isolation strip 25 metres wide. The fifteen line transects were located in a stratified/random manner, each 10 metres wide by 50 metres long. One line transect was in each strip at a randomly selected location. These transects were located by using the same locations used in the 1969 initial inventory.

A 50 metre steel tape was stretched along to mark the transect line. Crown cover intercept measurements were taken along the tape at the edge of each opening. All open areas were measured in metres and recorded separately. Where woody vegetation crowns occurred above treatment line, the length of crown for each species was measured and recorded separately. Minor species were grouped and recorded as "others" bushes or trees. In some places, there were two or three layers of crown cover, where the crown of 2 or 3 species overlapped above a line. Each was measured and recorded separately. This resulted in total measurement value (crown cover plus openings) exceeding 50 metres on most lines. The results of the initial 1969 and 1972 woody plant inventories are given in Appendix I.

RESULTS AND DISCUSSION

Table I shows the main plants species grazed and browsed by goats and the percent grazing time spent on each plant. It should however be noted that the time spent grazing various grasses depends on relative abundance of each species as well as animal preferences and phenological condition of the plant vegetation.

Table 1: The Main Plant Species Grazed/Browsed by Goats and Percent Grazing Time Spent on Each Plant

Plant Species	Percent Time (dry season)	Percent Time (wet season)
Panicum maximum	23	10
Digitaria milanjiana	20	9
Chloris roxburghiana	10	5
Cymbopogon excaratus	5	2
Other grasses	6	10
Total grasses	65	36
Woody Plants		
Combretum spp	8	12
Cordia gharaf	5	7
Rhoicissus revoillii	5	8
Grewia villosa & spp	4	9
Commiphora africana	3	5
Other woody plants	6	12
Total woody plants	31	53
Forbs		
Indigophora schimperi	5	5
Other forbs	0	6
Total forbs	5	11

Goats reared in an area dominated by grasses spent 68% of their time on grasses and 32% browsing. However, Galla goats from North Eastern Province spend over 60% of their time browsing. This browsing has helped to keep the bush sprouts from getting thicker and larger.

Grazing/browsing had no apparent effect on trees except on one species of *Commiphora africana*, that was small enough for the tops to be killed by fire. The new sprouts from these top killed trees had been browsed heavily by goats. Most trees are high and not within the reach of goats. Thus, grazing had no effect on them.

In comparing the 1969 and 1972 crown cover woody plants, plots that were grazed by goats had an increase of 9.8% in crown cover when compared to the controlled plots that were not grazed and increased by 24% (Table 2).

Table 2. Changes in Crown Cover of Trees and Bushes Under all Treatments, 1969 and 1972

	Unburned Plots		Burned Plot	
Grazing	None	Goats	None	Goats
Sept 1969	159	227	191	208
March 1972	195	249	142	114
Changes in cc	38	22	-49	-94
Changes in %	24	9.8	-25.7	-45

There was a general decrease in crown cover on all plots that were burned. The greatest decrease in crown cover resulted from plots that were burned and then grazed by goats. Burning alone decreased crown cover by 25.7% while burning plus goats grazing decreased the crown cover by 45%. This gives a clear indication that burning followed by goats browsing would significantly open up the bushy vegetation.

Comparing the results of 1969 and those of 1974, it is evident that there was an increase of bush crown cover by 14% in control plots. There was also a decrease of 16% due to goats grazing (Table 3).

Table 3. Changes in Crown Cover of Bushes Under all Treatments, 1969 to 1974

	Unburned Plots		Burned Plot	
Grazing	None	Goats	None	Goats
Sept 1969	205.9	264.0	238.7	239.8
July 1974	234.8	219.6	161.1	121.8
Changes in cc	+28.9	-44.4	-77.6	118.0
Changes in %	14.0	16.8	32.5	49.2

In the burned plots, the 1974 results indicate that there was a decrease of crown cover of bush vegetation by 32.5% resulting from burning alone and a decrease of 49.2% resulting from burning and goats browsing on bushes.

Similarly there was an increase in tree canopy in all plots that were not burned (81.9%) (Table 4). There was only an increase of 25.6% on plots that were grazed by goats. Fire also decreased crown cover by 15.1% but fire plus goats browsing decreased tree canopy by 26.3%. It must be pointed out in this case that most of the trees were high and beyond the reach of goats. Most reduction resulted from the effects of fire. However, some of the trees, like *Commiphora africana*, were low enough and could be reached by goats. Results of the crown cover inventories conducted in this trial show that the woody plant vegetation (trees and shrubs) increased by 24% within 2 years and by 48% in 4 years in control plots. Burning however, reduced the crown cover of the woody plants by up to 26% four years after burning.

Table 4. Crown Cover of Trees in Metres During 1974 Inventory

	Unburned Plots		Burned Plot	
Grazing	None	Goats	None	Goats
Sept 1969	292.2	403.9	437.3	424.6
July 1974	531.4	507.3	371.3	312.8
Changes in cc	239.2	+103.4	-66.0	-111.8
Changes in % cc	81.9	25.6	-15.1	26.3

Looking at trees and shrubs separately, results show that the crown cover of trees increased by 82% in control plots after four years while the bushes increased by 14%. However, burning significantly decreased the crown cover of woody plant vegetation. Four years after burning, the crown cover of tree vegetation still showed a decrease of 15% while bushes showed a decrease in crown cover vegetation of about 33%. Burning is, therefore, an effective method of controlling bush encroachment in grass bushland vegetation. Fire has always been used to reduce woody plants and to improve herbaceous pastures for livestock grazing. Vogl (1965) also observed that burning had been used on tall grass-hardwood savannahs to control the bush while maintaining or improving the forest.

It has been well demonstrated that different species of grazing animals have different forage preferences. Goats, for example, tend to use large quantities of browse as compared to cattle. The most effective control of undesirable woody range plants by livestock grazing has been from the use of goats.

An FAO report (1970) concluded that because of their general browsing tendencies, goats can be a potential factor in controlling woody plants and in preventing their return in areas of low and erratic precipitation throughout the world. The act of grazing is mostly one of defoliation, although not all defoliation is due to grazing.

The results of this trial show that the crown cover of bush vegetation decreased by 17% while that of trees decreased by 26% in plots that were not burned but grazed by goats after four years. This clearly shows that goats' grazing can effectively control bush encroachment. The results of this trial also indicate that plots that were burned and also grazed by goats showed even greater decrease in crown cover of woody plants. There was a decrease of 49% in bush crown cover and a decrease of 26% on tree crown cover resulting from both burning and goats' grazing after four years. It is clearly evident that a combination of burning and goats' grazing can be used as an effective method of bush control in grass bushland vegetation.

Repeated defoliation of woody plant species by goats has been found to either control the plant growth or spread or to kill some of the most preferred plants if continued long enough. Goats have also been effectively used in rather wide range of shrubs in Texas. Both the Spanish goat and the Mohair-type Angora goats have been used successfully in biological bush control, but differences in physiology and nutritional requirement make the Spanish goat more preferred for this use (Biswell, 1967). The latter was found to be more rangy and can browse to heights of seven feet or more.

When a grazing animal eats, it selects certain plants or plant parts and removes them to a definite degree or intensity. This event occurs at a specific season in the phenological development of the plant and it may be repeated at frequent intervals.

Specific records and observations made on goats revealed that goats somewhat change their grazing habits depending on the phenological condition of the vegetation. During the condition when every vegetation is green, Galla goats from NorthEastern Province of Kenya spend about 60% of their time browsing woody plant vegetation and less of their time grazing. However, during dry conditions when most of the trees and shrubs have shed their leaves or when leaves are very dry, these goats tend to spend more time grazing whatever soft grasses that is available. In fact, these goats would even browse some of the forage species that would otherwise be considered of low value. For example, *Sericocomopsis* spp. is one shrub which was never preferred during wet season. This shrub was greener most of the dry season and at that time this plant provided forage for the goats.

It was generally observed that goats like Saanen goats reared in an area dominated by grasses spend more of their time grazing while goats reared in an area dominated by bushland vegetation (like Galla goats) spend more of their time browsing. This browsing habit can be effectively utilised to keep the bush sprouts from getting thicker and larger and thus control bush encroachment.

It was evident from this trial that most trees were high and beyond the reach of goats. In this case most reduction of trees resulted from the effects of fire. However, some of the trees like *Commiphora africana* were low enough and within goats' reach and so the sprouts from these trees were browsed heavily by goats. It was also noted that some of the trees which had been reduced by fire started sprouting the following growing season. Most of the sprouts were kept under control by goats.

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Appendix I

The Crown Cover of Woody Plants in Meters

Species	Year	Unburned Plots No Grazing	Unburned Plots Goat Grazing	Burned Plots No Grazing	Burned Plots Goat Grazing
Commiphora	1969	117.6	132.4	128.5	156.1
riparia	1972	150.9	126.3	92.3	124.0
Commiphora	1969	130.5	114.0	172.1	129.5
africana	1972	145.2	144.6	76.4	83.5
Boswellia	1969	115.5	102.1	92.9	96.4
hildebrantii	1972	99.0	115.4	86.8	90.6
Acacia spp	1969	42.9	25.0	26.2	16.9
	1972	36.4	24.7	6.6	13.0
Combretum spp	1969	7.9	24.0	49.5	44.6
	1972	13.3	25.2	43.3	21.4
Boscia	1969	8.4	12.0	14.2	15.5
coriaceae	1972	8.6	13.9	3.8	5.2
Rhoicissus	1969	61.7	102.3	64.7	88.8
revoillii	1972	79.6	108.8	50.2	58.4
Grewia	1969	41.4	45.5	23.0	27.2
villosa	1972	50.6	47.4	12.3	18.2
Lannea	1969	40.0	26.0	30.5	16.5
alata	1972	27.6	25.0	12.0	5.6
Sericocomopsis	1969	12.3	19.0	20.5	20.4
hilderbrantii	1972	12.1	18.8	16.1	8.8
Other trees	1969	16.2	30.4	17.6	25.7
	1972	33.5	46.5	9.7	13.0
Other bushes	1969	34.2	36.2	33.3	26.8
	1972	39.6	48.9	20.0	7.4
Total crown	1969	628.7	668.8	673.0	664.4
cover	1972	696.3	745.6	429.6	449.0
Total open area	1969	244.8	255.8	251.4	256.4
	1972	230.7	221.6	427.0	430.8

THE UTILISATION OF UREA-TREATED RICE STRAW BY LAMBS

E.M. Kiruiro[1] and F.G. Youssef[2]

ABSTRACT

Two experiments were conducted to determine the effect of treating rice straw with 0 (control diet-RS) or 15 g (RS-15), 30 g (RS-30) and 45 g (RS-45) urea/kg air-dry straw (Experiment 1) or 40 g (RS-40), 60 g (RS-60) and 80 g (RS-80) urea/kg air-dry straw (Experiment 2) on voluntary feed intake (VFI), digestibility and lamb performance. In Experiment 1, urea treatment increased the total nitrogen (N) and metabolisable energy (ME) contents of the straw and resulted in a partial reduction of its neutral detergent fibre and hemicellulose contents. Treatment did not effect VFI ($P>0.05$) but significantly ($P<0.05$) improved the intake of digestible organic matter (DOMI) and calculated ME (MEI). Treatment also improved ($P<0.05$) the average daily gain (ADG); values were 30 g, 37 g, 65 g and 83 g for diets RS, RS-15, RS-30 and RS-45, respectively. Corresponding values for feed conversion efficiency (FCE) ratios were 20, 26, 14 and 12 ($P<0.05$). In Experiment 2, there were no major changes in chemical composition except for an increase in N with urea levels. Neither were there significant differences ($P>0.05$) in VFI, DOMI, MEI, ADG and FCE ratios among diets. Under the conditions of this study, optimum responses in nutrient utilisation and lamb performance appeared to occur at urea rates between 30 and 45/kg air dry straw. The results demonstrate that urea has considerable potential for improving the nutritive value of rice straw.

INTRODUCTION

A major factor limiting ruminant livestock production in the Caribbean community (CARICOM) and indeed many other sub-tropical and tropical countries including Kenya, is the inadequate availability and poor nutritive value of feedstuffs.

Rice (*Oryza sativa*) is a valuable crop in the CARICOM region as well as in Kenya. Supplementation currently provides the most potential for improving the nutritive value of most fibrous forages including rice straw but it may not be economical.

However, the voluntary intake and digestibility of low-quality forages may be increased by chemical treatment using sodium hydroxide and ammonia (Sunstol and Coxworth, 1984). There is lack of information in the CARICOM region and Kenya on the use of urea as a cheaper alternative source of ammonia for improving the nutritive value of available fibrous forages including rice straw.

This paper reports on two experiments conducted in the Republic of Trinidad and Tobago to evaluate the effect of urea treatment of rice straw on its utilisation by sheep.

MATERIALS AND METHODS

Experiment 1

Straw from a rice crop (*Oryza sativa*) harvested by Caroni (1975) Ltd., Central Trindad and Tobago, West Indies, between February and March 1986, formed the main ingredient of the experimental diets.

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The straw was chopped through a 0.10 cm screen prior to treatment. Treatment involved spraying and mixing the appropriate amounts of urea to the straw on concrete floor. Treated straws were stored in polythene-lined 244-l metal drums for 30 days before feeding. In Experiment 1, the untreated straw or straw treated with 15 g, 30 g and 45 g urea dissolved in 400 mls water per kg air-dry material were used to formulate the experimental diets; these were designated as diets RS, RS-15, RS-30 and RS-45, respectively. All diets were sprayed with a mineral premix and urea, the latter to make diets isonitrogenous.

The straw diets were allocated to 16 Barbados Blackbelly male lambs with a mean liveweight of 22 kg in a randomised complete-block design. Straw and water were offered *ad libitum*. In addition, each lamb received 12 g/kg$W^{0.75}$ rice bran per day. Prior to the start of the experiment, animals were adapted during a 5-week period to a urea added and urea treated straw diet. During this period, animals were also treated for internal and external parasites and injected intramuscularly with Vitamin A, D and E solution. Animals were housed in individual metabolism crates with wooden slatted floors during the entire experimental period of 87 days. The amounts of feed offered and refusals were taken daily for determination of voluntary intake. Animals were weighed at weekly intervals. During the last 10 days of the experiment, bulk collections of faeces were made for subsequent evaluation of diets digestibility.

Chemical analyses of the feed, refusals and faeces samples were determined using standard procedures. Statistical analysis of variance on feed intake, liveweight and digestibility data was conducted for a randomised complete-block design with treatment means separated by least significant difference (LSD) according to Steel and Torrie (1960). The use of the initial animal liveweight as a covariate to adjust the feed intake and liveweight gain parameters had no appreciable effects. Thus, no adjustments were made. Estimates of individual animal daily rates of gain were provided by the regression coefficients of liveweight on time.

Experiment 2

The bulk of the rice straw in this experiment came from the batch of straw left over from Experiment 1. However, the straw was treated in three batches to which 40 g, 60 g and 80 g urea per kg air-dry straw were added to constitute the three experimental diets: RS-40, RS-60, and RS-80, respectively. Apart from a mineral premix which was added to the diets at the time of feeding, no urea was added as for Experiment 1 to make diet isononitrogenous.

The diets were fed to 18 Barbados Blackbelly male lambs (initial liveweight 29 kg) in a completely randomised design following a 4-week diet-adaption period. During the adaption period, animals were also treated for internal and external parasites and injected with a vitamin solution. The animals were kept in individual metabolism crates as for Experiment 1 during the entire 77 day growth study and the 10 day digestibility study that followed.

The procedure for feed intake and liveweight measurements and chemical analyses were similar to those employed in Experiment 1. Analysis of variance and regression analysis were also conducted as in Experiment 1.

RESULTS

Chemical Composition

All batches of the urea-treated rice straw in both experiments had no mould formation; the straws remained well preserved and soft in consistency. The chemical composition of the rice straw-based diets offered to sheep is presented in Table 1.

Table 1. Mean Chemical Composition (g/KgDM or as stated) of diets offered to sheep in Experiments 1 and 2

	Constituents							
	Dry-matter	Acid Detergent Nitrogen	Neutral Detergent Fibre[2]	Acid Detergent Fibre	Lignin[2]	Hemicellulose	Cellulose	Gross energy (MJ/kgDM)
Experiment 1								
Urea-added straw, RS	690	25.2(10)[1]	398	714	49	316	34	14.87
Urea-treated straw:								
RS-15	616	20.7	418	686	49	269	368	14.79
RS-30	620	23.2	419	688	53	269	367	14.97
RS-45	627	24.1	427	689	54	265	370	15.15
Experiment 2								
Urea-treated straw:								
RS-40	608	24.9	414	686	58	272	356	15.21
RS-60	607	28.5	408	684	52	276	356	15.09
RS-80	612	35.6	408	685	52	277	356	15.28
Rice bran supplement	909	27.2	129	384	50	254	80	20.33

[1] Value in brackets refers to nitrogen content of field-dry straw prior to urea addition or treatment.
[2] Determined on ash-free basis.

In Experiment 1, treatment of straw with urea caused a slight reduction in neutral detergent fibre content with a resultant decrease in the hemicellulose content, while changes in acid detergent fibre, cellulose and gross energy were small. Treatment, however, resulted in a marked increase in the total nitrogen content of the straw. In Experiment 2, however, no major differences were found in the contents of most cell-wall constituents and gross energy among the three straw diets. However, total nitrogen content increased as expected with increase in urea treatment levels.

Voluntary Feed Intake

The intake of dry matter, organic matter and calculated metabolisable energy in Experiment 1 and 2 are given in Tables 2 and 3, respectively. Although the intake of the above constituents in Experiment 1 tended to be higher for the urea-treated straw diets, no significant differences ($P > 0.05$) were found among the four diets when intakes were scaled to metabolic body weight. Similarly, differences in the intake of the three constituents were not significant ($P > 0.05$) among the three diets tested in Experiment 2 (Table 3).

(experimental)

Component	Diet				Standard error of means and significance
	RS	RS-15	RS-30	RS-45	
Daily Feed Intake					
Straw dry-matter, g/day	658	842	734	840	46.3^{ns}
Total dry-mater, g/day	782^{a}	944^{b}	884^{a}	944^{b}	36.7^{**}
$g/kgW^{0.75}$		73.5	81.1	83.0	86.2
3.42^{ns}					
Kg/100kgBW	3.29	3.29	3.57	3.88	0.175^{ns}
Total organic matter, g/day	662	783	741	793	30.5^{ns}
Calculated metabolizable ME[1], MJ/day					
$g/kgW^{0.75}$	5.12^{a}	6.19^{a}	6.08^{ab}	6.92^{b}	0.307^{*}
	0.48	0.53	0.58	0.63	0.028^{ns}
Apparent Digestibility					
Dry matter, g/kgDM	476^{a}	484^{a}	503^{a}	538^{b}	10.1^{*}
Organic matter, g/kgDM	541^{a}	550^{a}	579^{ab}	607^{b}	9.2^{**}
Hemicellulose, g/kgDM	600^{a}	611^{a}	695^{a}	737^{c}	10.7^{***}
Energy, kJ/MJ	514^{a}	518^{a}	539^{ab}	570^{b}	11.1^{*}
Lamb Performance					
Number of animals	4	4	4	4	
Initial liveweight, kg	22.3	24.8	[illegible]	21.4	0.65
Final liveweight, kg	24.3	28.3	25.3	27.2	0.60
ADG, g	30^{a}	37^{a}	65^{c}	83^{b}	7.9^{**}
Energy, kJ/MJ	20^{a}	26^{a}	14^{b}	12^{b}	2.0^{**}

[a,b] Means within a row followed by different superscripts are significantly different ($P < 0.05$).
*, $P<0.05$; **, $P<0.01$; ***, $P<0.001$; ns, Not significant.
[1]ME = Digestible energy x 0.81 (MAFF, 1975)

Table 3. Voluntary feed intake, apparent digestibility and performance by sheep offered urea-treated rice straw diets (Experiment 2).

Component	Diet			Standard error of means and significance
	RS-40	RS-60	RS-80	
Daily Feed Intake				
Straw dry matter, g/day	798	836	896	63.7^{ns}
Total dry mater, g/day	1091	1053	1053	37.2^{ns}
$g/kgW^{0.75}$	83.5	80.9	80.3	2.50^{ns}
Kg/100 kg BW	3.56	3.41	3.49	0.105^{ns}
Total organic matter, g/day	906	883	903	28.4^{ns}
Calculated metabolizable energy (ME)[1], MJ/day	7.5	7.4	8.3	0.56^{ns}
Apparent Digestibility				
Dry-matter, g/kgDM	527	522	526	10.1^{ns}
Organic matter, g/kgDM	593	588	595	9.9^{ns}
Hemicellulose, g/kgDM	725	784	765	13.9^{ns}
Energy, kJ/MJ	566	559	565	10.13^{ns}
Lamb Performance				
Number of Animals	6	6	6	-
Initial liveweight, kg	28.5	28.5	28.6	1.18
Final liveweight, kg	32.7	32.9	33.3	1.37
ADG, g	61	65	71	11.4^{ns}
Energy, kJ/MJ	22	23	18	5.35^{ns}

ns Not significant.
[1]ME = Digestible energy x 0.81 (MAFF, 1975)

Digestibility of Nutrients

In Experiment 1, dry-matter and organic-matter digestibilities were higher for the urea-treated straw diets than diet RS but the differences were significant ($P<0.05$) only with diet RS-45 over diet RS. Similar results were generally observed for the cell-wall constituents; the digestibility of hemicellulose was particularly enhanced (Table 2). Regression analysis of the digestibility data in Experiment 1 showed that digestibility of organic matter (Y) increased linearly with the level of urea (X) applied to straw as described by the following equations:

$$Y = 535.8 + 1.50x;\ r=0.85;\ P<0.001$$

Similar linear trends were also found for the digestibilities of dry matter, hemicellulose and energy.

In Experiment 2, however, no significant differences ($p>0.05$) were found among the three straw diets in the digestibilities of dry matter, organic matter, cell-wall constituents and energy (Table 3). Thus, there were no discernible trends in digestibility by increasing the level of urea from 40 to 80 g per kg straw.

Liveweight Performance

The mean values of liveweight gain (g/day) as determined by regression of liveweight on time and the corresponding feed conversion efficiency ratios for sheep during the 77 day growth studies in Experiment 1 and 2 are given in Tables 2 and 3, respectively.

It was found that diets RS-30 and RS-45 gave significantly ($P<0.05$) higher average daily gains and correspondingly better feed conversion efficiency ratios than diets RS and RS-15. However, differences in average daily gain and feed conversion efficiency ratios between diets RS-30 and RS-45 were not significant ($P>0.05$). Differences between diets RS and RS-15 were also not significant ($P>0.05$). There were also no significant differences ($P>0.05$) observed in either ADG or FCE ratios among the three diets in Experiment 2 (Table 3).

DISCUSSION

In Experiment 1, urea treatment of straw only caused small changes in the composition of the cell-wall structural carbohydrates (Table 1). It is suggested that the ammonia or ammonium compounds released from urea cleaves alkali-labile ester linkages between structural carbohydrates further leading to the solubilisation of hemicellulose - this accounting for the decreased hemicellulose content in treated materials (Dias-da-Silva and Sundstol, 1986). Such changes could, however, have some significant effect on straw utilisation in terms of significance since the N is considered to be in a slowly released form capable of being incorporated to microbial protein (Abidin and Kempton, 1981). Tissue protein supply to the animals could therefore have been enhanced (ARC, 1980).

Voluntary intake results for Experiment 1 (Table 2) indicate that treatment of straw with urea did not improve voluntary intakes of dry matter or organic matter contrary to the findings reported by Dias-da-Silva and Sundstol (1986) who found increased intakes of straw following urea treatment. The increased intake following urea or ammonia treatment is generally attributed in part to the high nitrogen concentration in the diet and the resultant increase in digestibility and rate of passage of digesta (Oji et al, 1979; Dias-Da-silva and Sundstol, 1986). However, reduction in particle size may be more important than digestibility in stimulating intake of low quality roughages (Coombe and Tribe, 1963). The non-significant differences in dry matter-intake between the urea-added straw diet (RS) compared to the urea-treated straw diets could possibly be explained by the effect of a reduced particle size due to chopping of the straw. Digestibility *per se* may not have been a precondition to improved intake. The size reduction could also explain the non-significant differences in dry-matter intakes among the three diets in Experiment 2 (Table 3). Since data comparing the combined effect of urea treatment and physical form of the straw is limited, it would appear that the degree of improvement in intake due to urea treatment may be small in sheep when straw is chopped to particle sizes achieved in the present study (approximately 1.0 to 1.5 cm lengths). It may also not be necessary under practical farm conditions to chop the straw due to the additional cost of processing.

The main effect of the urea treatment procedure in Experiment 1 was the enhancement of digestibility. The organic-matter digestibility coefficient of 579±9.2 g/kg DM for diet RS-45 represented an increase of 3.8 percentage units over diet RS (Table 2). This improvement was lower than that reported by Wanapat et al (1985) for rice straw treated under *in vivo* conditions at comparable treatment conditions. The increase in the apparent digestibility of energy for diet RS-45 over diet RS of 5.6 percentage units was, however, higher than that reported by Hadjipanayiotou (1982) for urea-treated (40 g urea/kg) barley straw. Corresponding ME intake (MJ/kg$W^{0.75}$/day) for diets RS-45 and RS were 0.63 and 0.48, respectively (Table 2) representing an increase of 31.3% a value higher than that estimated by Horton and Steacy (1979) for ammonia-treated and Fernandez-Carmona and Greenhalgh (1972) for Naoh-treated straws offered to sheep. The present results suggest that urea treatment was responsible for the increased availability of nutrients.

The higher ADG and FCE ratios obtained from the urea-treated straw diets over diet RS (Experiment 1) could be explained by the high ME intakes coupled with an enhanced rumen degradable nitrogen supply from these diets for microbial protein synthesis. These factors are also implicated in explaining the superior performance by ruminants offered ammoniated roughages (Holton and Steacy, 1979; Wylie and Steen, 1988).

Based on the linear responses in the digestibilities of most nutrients in Experiment 1 (which also generally corresponded with an increase in ADG), digestibility and possibly animal performance could be improved by higher urea application rates beyond the range studied in Experiment 1. This proposition was the subject of investigation in Experiment 2. However, no significant increase in digestibility, intake of digestible nutrients and animal performance were demonstrated, as hypothesised, by increasing the urea level from 40 g to 80 g/kg straw. Nevertheless, the digestibility coefficients and ADG for diets RS-40, RS-60 and RS-80 were appreciably higher than values found for the urea-added straw diet (RS) in Experiment 1.

The lack of improvement in digestibility with incremental levels of urea beyond 40 g/kg straw was contrary to the findings by Ambar and Djajanegara (1982) who found consistent increases in dry-matter and organic-matter digestibilities of rice straw under *in sacco* conditions. Yodav and Yadav (1988) under *in vitro* conditions found a level of urea of 40 g/kg to be optimal in terms of improving dry-matter and cellulose digestibilities. The linear response patterns observed in most digestibility fractions in Experiment 1 but no significant responses in Experiment 2, suggest that the optimal urea level may have been reached in Experiment 1. The results to suggest that under the conditions of the two experiments, optimal levels of urea treatment for maximum nutrient utilisation and lamb performance are probably between 30 and 45 g urea.

Wylie and Steen (1988) found that the digestibilities of dry matter and energy of hay treated with ammonia at levels beyond 30 g/kg (equivalent to approximately 50 g urea) (Williams et al, 1984) were not improved unless the hay was further supplemented with an energy source. These workers also argued that poor animal performance from hay treated with high ammonia rates could be due to a subclinical ammonia toxicity. Whether the level of energy derived from the rice bran supplement together with that from the fermented straw or some other inhibitory factors affected further improvement in digestibility and lamb performance in Experiment 2 of the present study is not known. Further studies to elucidate this are therefore recommended.

CONCLUSION AND RECOMMENDATIONS

The use of urea as a chemical treatment effectively increased digestibility of nutrients but did not affect voluntary intake. The alteration of the chemical structure together with more intensified utilisation was responsible for the increase in digestibility and corresponding intake of digestible nutrients, in particular, digestible energy. This, together with an enhanced rumen degradable nitrogen content of the straw, increased the supply of microbial protein. The net effect was an improvement in liveweight gain and feed utilization efficiency.

Although the digestibility of nutrients was significantly improved by increasing urea treatment rates up to 40 g/kg straw, urea levels beyond this were inefficient in further improving the utilisation of nutrients and, consequently, lamb performance. Optimum response in these parameters may be obtained at urea levels of between 30 - 45 g/kg straw. However, the results suggest that if straw of higher urea levels is to be efficiently utilised in animal production systems, then favourable conditions for nutrient digestion in the rumen must be satisfied. The practical implication of this study is that nutritive value of rice straw will be upgraded to one that supplies both energy and protein. Additionally, a more efficient use can be made of urea as source of nitrogen, thus reducing dependence on expensive preformed sources with potential for cutting down on the cost of feeding.

In view of the additional advantages of the urea treatment process which include the relatively low cost of urea, safety, urea availability and low technological demands compared to other chemical treatments, the method confers better utilisation of rice straw. Thus it has potential for practical application, particularly at the smallscale farm level. However, it is recommended that simpler and cost effective treatment procedures be advised.

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