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SMALL RUMINANT WORKSHOP
7-9 September 1993, San Juan, Puerto Rico

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Small Ruminant Workshop

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Edited by

Mary Keane

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Preface

A Small Ruminant Workshop was held 7-9 September 1993, San Juan, Puerto Rico, to present the successes, impacts, and results of the Small Ruminant Collaborative Research Support Program (SR-CRSP). In one sense, this was a celebration of the accomplishments of this unique program by its participants. It was also a way to share research results with an international audience.

These proceedings represent thirteen years of small ruminant research. The nature of the research and the structure of the SR-CRSP are distinctive: the United States and the host country institutions strive to achieve true collaboration. Although many different disciplines are involved, e.g., economics, animal nutrition, range management, production systems, genetics, breeding, sociology, animal health, the organization is multidisciplinary.

An example of the U.S.-host country collaboration can be seen in the Kenya Dual Purpose Goat (KDPG) Production Systems program (Chapter 5). The sociology and economic projects determined through baseline studies and interviews what interventions and constraints were most needed; these research conclusions had implications for the production systems and breeding projects research design. In recognition of the multidisciplinary nature of the KDPG program, each chapter of these proceedings constitutes a separate component: Chapter 1, Humid Tropics: Hair Sheep and Integration of Sheep into Tree Crop Plantation; Chapter 2, Andean Agropastoral Systems; Chapter 3, Mediterranean Sheep Production Systems; Chapter 4, Animal Health: Vaccine Development; and Chapter 5, The Kenya Dual Purpose Goat Production.

As you read each chapter in these proceedings, you will note the spirit of teamwork that infuses the research. The overview papers are an excellent place to start; each country that has collaborated with the SR-CRSP—Bolivia (Chapter 2), Brazil (Chapter 1), Indonesia (Chapter 1), Kenya (Chapter 5), Morocco (Chapter 3), and Peru (Chapter 2)—has contributed a summary of achievements and impacts from the viewpoint of the host country.

To provide a different perspective on the information presented, however, the following are some highlights by discipline.

Breeding projects are carried out in Indonesia, Kenya, and Morocco. Bradford and Boujenane report that native Moroccan sheep breeds are characterized by low productivity (ch. 3). They describe how a D'Man and Sardi crossbred is more productive than either purebred parent, and they then discuss feeding and management implications. In a related study, Benlamlih and Derqaoui summarize the environmental constraints, such as heat, that affect the D'Man and Sardi purebreds and their crosses (ch. 3).

Research on breeding for prolificacy is conducted in Indonesia. It has been argued that the prolificacy gene in small ruminants is desired only when supplemental feed is available. With this important consideration in mind, Bradford and Inounu describe a breeding program to accomplish the following: in flocks without supplemental feed which are solely dependent on forage, production of ewes without the prolificacy gene, and in flocks with supplemental feed, production of ewes with the gene (ch. 1). In other breeding research, Gatenby et al. report the results of the first phase of a crossbreeding trial to develop hairsheep more suited to hot, humid climates (ch. 1).

Concern about the environmental effects of anthelmintics and possible resistance development has led the Kenya breeding project to search for a molecular genetic approach for the detection of genes associated with resistance to *Haemonchus contortus*. Taylor et al. postulate that if resistance to nematode infections could be incorporated into small ruminants, it might eliminate, or at least reduce, the need for anthelmintics (ch. 5). In related research, Ruvuna et al. describe the development of the Kenya Dual Purpose Goat (KDPG): the baseline study which determined the need for such a breed; the genetic improvement strategy employed; and the stabilization and multiplication program (ch. 5). The KDPG was designed to fit within high-density agricultural areas where demand for meat and milk is high but available land is scarce.

The multidisciplinary nature of the KDPG component is seen in the report by Semenye and Getz (ch. 5). They provide an overview of the production systems research in Kenya. This research developed management strategies, including forage and food-crop selections, for KDPG systems. Getz and Onim discuss this project from the systems approach, particularly the feed resource and feeding strategies development (ch. 5).

The animal health research is also conducted in Kenya. DeMartini et al. present an overview of the development and objectives of the multivalent virus-vectored vaccines for small ruminants (ch. 4). Washington State University and Colorado State University are collaborating on the development of such a vaccine. Soi et al report on the search to identify an improved viral vector to deliver appropriate genes from important pathogens to the animal while remaining cost-effective, multivalent, and non-hazardous to humans (ch. 4). Jasmer et al. summarize the progress toward identifying *Haemonchus contortus* gut antigens that can induce protection against challenge infections (ch. 4). Vaccination against this serious disease would provide an alternative to anthelmintics.

Two other papers round out the animal health research. DeMartini et al. give an overview of retrovirus diseases of small ruminants and discuss new techniques for diagnosis control (ch. 2), and Wilson et al. report a study of important parasitic diseases and disease constraints that exist in Indonesia (ch. 1).

A wide variety of research projects are underway in Indonesia, including a nutrition project. This research involves hairsheep and prolific sheep, with a particular focus on grazing sheep under tree crops. Horne et al. discuss two alternative planting systems for tree crop plantations using sheep grazing to control weeds and to provide forage (ch. 1).

In Morocco, the nutrition research of Luginbuhl et al. is directed toward feeding strategies for sheep, particularly to supplementation with cereal stubble, straw, and agro-industrial by-products (ch. 3).

The SR-CRSP has worked in Peru in the past and is currently collaborating in Bolivia in agropastoral systems research. San Martin and Bryant present an overview of the nutritional concerns of South American cameloids in comparison to sheep (ch. 2).

The SR-CRSP multidisciplinary concept would not be effective without inclusion of the sociology and economic research. Mbabu and Nolan present an overview of the socio-economic studies of animal health programs and discuss the constraints to implementation of this technology by small-holder farmers (ch. 4). Lipner and Brown report the successes and constraints to integrating a vaccine, developed by the SR-CRSP and the Kenya Agricultural Research Institute, into the animal health delivery system in Kenya (ch. 4). Sheikh and Valdivia report a study to determine differences between men and women in adopting management techniques for Kenya Dual Purpose Goat technology (ch. 5).

Nyaribo-Roberts and Ospina provide the economic perspective on KDPG technology with an overview of on-farm research methodology used by the SR-CRSP and impact of the KDPG on farmers' incomes (ch. 5).

Economics research also focuses on impacts in Indonesia. Valdivia assesses the costs of the SR-CRSP vs. its benefits and impacts, concluding that the short-term benefits of the breeding and nutrition projects' research, along with the long-term impact of training, far outweigh the costs (ch. 1). More specifically, Kartamulia et al. report an economic analysis of grazing sheep in rubber plantations (ch. 1), concluding that this strategy can provide 40% more income to small-holder farmers while also providing the environmental benefit of reducing overtapping of rubber trees.

It seems particularly appropriate to conclude this overview with the economic impacts of the SR-CRSP. After all, the ultimate goal of the program is to assist small-holder farmers to raise their incomes through the production of small ruminant meat, milk, and fiber. With the SR-CRSP research mandate, this is achieved through researching constraints, designing interventions, and training host country personnel who, in turn, extend the research in their home countries.

With a look to the future, Dr. Patrick Cunningham's keynote address, *Development of Animal Agriculture: The Challenge for Research*, is particularly fitting. He relates the concerns that research programs will face in the future and challenges SR-CRSP participants to re-examine their priorities and strategies in order to fit the international agricultural livestock needs in the years ahead.

This challenge should energize debate about the future of the SR-CRSP. The accomplishments related in these proceedings are stellar, and the Workshop pays tribute to the contributions of the participants. We hope you will find these proceedings illuminating and noteworthy. We trust that the SR-CRSP's future progress will be as impressive as it has been for the past thirteen years.

In this light, it is appropriate for participants to review SR-CRSP accomplishments and impacts. By studying what has worked in the past, planning for the future will be more effective. Following this Workshop, a meeting was held to discuss the future of the SR-CRSP: the current grant from the Agency for International Development ends in 1995; planning for the extension of the program from 1995-2000 is now underway.

Special recognition for assistance with the development of these proceedings and with the organization of the Workshop go to Jennifer Barber, Saundra Kajiyama, and Susan Sainz the long hours, late nights, and grace under pressure. Without them these proceedings would not have been completed. Acknowledgment of Dr. Eric Bradford's role is also required; he organized the scientific content of the Workshop, and we are deeply appreciative of his guidance.

Mary R. Keane

Small Ruminant Workshop Program

Tuesday, September 7

1:00 pm - 5:30 pm	Arrival and Registration
5:30 pm - 7:00 pm	Reception
7:00 pm - 9:00 pm	Keynote Speaker. Dr. E.P. Cunningham, Director, Animal Production and Health, FAO, Rome. Paper entitled, "Development of Animal Agriculture: The Challenge for Research."

Wednesday, September 8 AM Session

Humid Tropics - Hair Sheep and Integration of Sheep into Tree Crop Plantations

8:30 am	Feeding Systems for Sheep Integrated into Tree Crop Plantations. *Kevin Pond and Simon Ginting.*
8:50 am	Stategies to Improve Forage Production in Rubber Plantations. *Peter Horne*
9:10 am	Growth, Mortality, and Wool Cover of Sumatra Sheep and Crosses with Three Breeds of Hair Sheep. *Ruth Gatenby, Eric Bradford, Meruwald Doloksaribu, Endang Romjali, Djoko Pitono and Hakan Sakul.*
9:30 am	Studies on the Epidemiology and Control of Important Diseases of Sheep at Sungei Putih, North Sumatra. *Alan Wilson, Beriajaya, G. Adiwinata, R. Gatenby.*
9:50 am	Economic Analysis of Sheep Grazing in Rubber Plantations: A Case Study of OPMM Membang Muda. *Izuddin Kartamulia, Setel Karokaro, and John DeBoer.*
10:10 am	Break
10:40 am	Genetic Variation in Prolificacy in Indonesian Sheep and its use in Increasing Productivity. *Eric Bradford and Ismeth Inounu.*
11:00 am	Returns to Investments in Small Ruminant Research in Indonesia: The SR-CRSP in West Java. *Corinne Valdivia.*
11:20 am	The Small Ruminant CRSP in Indonesia 1980-1993: Achievements and Impact. *Subandriyo.*
11:40am	EMBRAPA/CNPC-SR-CRSP: A Successful Partnership in Northeast Brazil. *EderlonRibeiro de Oliveira and Aurino Alves Simplicio.*
Noon	Lunch

Wednesday, September 8 PM Session

Andean Agropastoral Systems

1:30 pm Overview of Achievements of the SR-CRSP in Perú and National and Regional Impacts. *Arturo Florez, C. Novoa, F. San Martin, E. Ameghino, and M. Carpio.*

1:50 pm Current Work and Future Plans IBTA/CRSP, Bolivia. *Edmundo Espinoza.*

2:10 pm Comparative Nutrition of Sheep and Camelids. *Felipe San Martin and Fred Bryant.*

2:30 pm Nutrition Research in Boliva: Progress and Future. *Karen Launchbaugh and Fred Bryant.*

2:50 pm Retroviral Diseases of Small Ruminants. *J. DeMartini, E. Ameghino P. Rwambo, and T. McGuire.*

3:10 pm Break

3:40 pm Managing Herds and Managing Households: Labor Allocation in San Jose Llanga. *Lisa Markovitz.*

4:00 pm The Plimsoll Line of the Bolivian Altiplano: Estimating the Carrying Capacity of the Communities. *Sibylle Scholz*

4:20 pm A Diachronic Analysis of Changing Land use Patterns on the Central Bolivian Altiplano. *Christian Jette.*

4:40 pm Intra-household Borrowing: A Look at Gender and the Impact of Dairy and Sheep Production. *Corinne Valdivia, Elizabeth Dunn and Jennifer Sherbourne.*

5:00 pm Adjourn

*Wednesday evening free or available for Country Work Group Meetings.

Thursday, September 9 AM Session

Mediterranean Sheep Production Systems.

8:30 am The SR-CRSP in Morocco 1981-1992: Achievements and Impacts. *Fouad Guessous.*

8:50 am Utilization of Moroccan Sheep Breed Resources to Increase Productivity. *Eric Bradford and Ismail Boujenane.*

9:10 am Physiological Differences Between D'Man and Sardi Breeds Related to Improving Sheep Productivity in Morocco. *Said Benlamlih and Lahsen Derqaoui.*

9:30 am Feeding Systems for Sheep Integrated into Cereal Cropping Regions. Jean-Marie Luginbuhl, Fouad Guessous, Nacif Rihani, and Ahmed Kabbali.

9:50 am Break

Animal Health - Vaccine Development

10:20 am Strategy for Development of Multivalent Virus-vectored Vaccines for Small Ruminants. *J. DeMartini, F. Rurangirwa, P. Rwambo, and T.McGuire*

10:40 am Current Status of Capripoxvirus Multivalent Vaccine for Small Ruminants. *R. Soi, T. McGuire, P. Rwambo, F. Rurangirwa, J. DeMartini, and T. Crawford.*

11:00 am Identification of Genes Useful for Control of Parasitic Diseases of Small Ruminants. *D. Jasmer, F. Rurangirwa, F. Karanu, L. Perryman, T. McGuire.*

11:20 am Constraints to the Integration of the CCPP Vaccine into Kenya's Animal Health Delivery System. *M. Lipner and Ralph Brown.*

11:40 am	Socioeconomic Elements for Effective Herd Health Programs in Developing Countries. *A. Mbabu and M. Nolan*
Noon	Lunch

Thursday, September 9 PM Session

The Kenya Dual Purpose Goat Production System

1:30 pm	Creation of the Kenya Dual Purpose Goat. *F. Ruvuna, J. F. Taylor, S. K. Davis, T. C. Cartwright, B. A. J. Mwandotto, D. O. Ahuya, Joseph Kogi, and F. Mkuu.*
1:50 pm	Quantitative and Molecular Approaches to Genetic Improvement of the Kenya Dual Purpose Goat. *J. F. Taylor, S. K. Davis, F. Ruvuna, F. Rurangirwa, E. Bhebhe, J. Kogi, T. McGuire, D. Jasmer, and R. M. Waruiru.*
2:10 pm	How Farmer-Oriented Research with Dual Purpose Goats Evolved in Western Kenya. *Patterson Semenye and Will R. Getz.*
2:30 pm	The SR-CRSP in Kenya, 1980-1993: Achievements and Impacts. *Cyrus Ndiritu.*
2:50 pm	Changing Farming Systems in Western Kenya: Factoring Out the Influence of SR-CRSP Interventions. *Domingo Martinez-Castilla.*
3:10 pm	Break
3:40 pm	Gender Differences in the Adoption of Dual Purpose Goat Technological Practices. *Dekha Sheik and Corinne Valdivia.*
4:00 pm	An Overview of Dual Purpose Goat Technology Development and Economic Returns on Small Farms in Western Kenya. *Fanny Nyaribo-Roberts and Enrique Ospina.*
4:20 pm	Systems Approach in Developing Feed Resource and Feeding Strategies. *Will R. Getz and Moses Onim.*
4:40 pm	Adjourn

*Thursday evening reserved for Caribbean Roundtable. An informal discussion of small ruminant research activities, needs and plans in the Caribbean region, led by Caribbean country scientists.

Keynote Address

Development of Animal Agriculture: The Challenge for Research

Patrick Cunningham[1]
[1]*Food and Agriculture Organization, Vialle delle Terme di Caracalla, 00100 Rome, Italy*

The context

It is normal to see the universe as centered on ourselves–on our planet, on our species, on our time. So far as we know, our world, in all its marvelous complexity, is unique. Within that world, our species, and all the complex civilizations we have built, are the dominant reality. What is not always so evident is how uniquely important is our particular generation in the forward march of time.

In simple terms, the century in which our generation finds itself, while it constitutes 100 millionth of the lifetime of our world, is likely to prove the most critical point in time for its survival in any recognizable form. The reality which makes our time so central in the history of the world is the explosive growth of human population, and the impact of that explosion on the rest of creation. The doubling time of human population has come down rapidly and is now little more than the generation interval. Based on present trends, the next doubling, to over 10 billion people, will be complete by 2050. It is also to be hoped that this will be the last doubling, with stability being gradually achieved sometime over the succeeding century.

The generation in which we live therefore faces the greatest challenge in the history of the human race, and of the world we inhabit: to manage our affairs through this critical period in such a way that ordered human society will still be possible in the generations which follow.

The development process

The evolution and growth of human society to its present worldwide complexity is very recent. Some 10,000 years ago, people, who were in biological terms the same as ourselves, gradually learned how to produce food rather than to simply harvest it from nature's bounty. Improvements in the efficiency of food production have made possible all else: growth in numbers, urbanization, and the harnessing of all the technologies which make modern society possible.

The whole process of economic and social development is therefore firmly grounded in agricultural technology. The process is too complex to be described only with numbers. However, among the many indicator variables that one can choose to chart the development of society from its purely agricultural origins, there are four which best tell the story. These are the percent of the population actually engaged in food production; the percent of the national wealth accounted for by agricultural output; the percent of the population living in urban centers; and the percent of household consumption which is accounted for by food.

The pattern that emerges is a remarkably consistent one showing very rapid structural change in the early stages of development, though with most consumers also being food producers, rural dwellers, and using a high proportion of their disposal income for food. At the other end of the scale, we have countries with agriculture accounting for 5% or less of the economy, a similar percentage of employment, and with most consumers totally divorced from food production, living in urban centers, and needing to spend only 10-20% of their disposal income for food needs.

A further important consequence of development is a rapid reduction in the rate of population growth. Since the death rate is always 100%, the main determinant is the total fertility rate, a measure of the expected lifetime number of offspring per woman. The pattern of change is parallel to the other development indicators: a rapid decline as average wealth increases, with most developed countries at or below a figure of 2, which corresponds to the replacement rate.

The point of this excursion into the structure of development is first to emphasize that constant improvement in agricultural productivity is a key element in the whole process, and secondly that organized research to promote agricultural productivity has an enormous range of different markets to serve.

Livestock in development

The livestock sector represents 55% of agricultural production in the developed world. A similar calculation gives a figure of 27% in developing countries, though this does not take account of work, manure, hides, and other social and economic benefits from livestock. While consumption patterns in the developed countries have stabilized at about 80 kg of meat and 200 kg of milk, consumption is expanding rapidly in developing countries, where intake is approximately 14 kg of meat and 36 kg of milk per head. In fact, while livestock has been the fastest growing major sector of agriculture (4.3% per annum growth in 1970-1990, compared to 3.0% for crop production) it has not been able to keep up with the combined effects of population growth and the rising individual demand which follows increased incomes.

Projections for the next 20 years indicate a continuing rapid expansion in demand, though at a slightly lower annual rate than before (approximately 4% per annum, as against 5% per annum for the last two decades). There is also expected to be continued structural change in world meat production, with a continued shift to intensive pig and poultry meat. Meat from ruminants has declined from 53% of the total in developing countries in 1970 to 36% at present, and it is expected to be less than 30% of the total 20 years from now. This shift is partly explained by the very rapid growth in demand in Asia, and partly by technical factors which make pig and poultry meat cheaper than meat from ruminants.

In the case of milk, annual growth in demand in 93 least developed countries is expected to be lower in the coming decades than in the past two (2.5% per annum as against 3.7%). This nevertheless calls for increases of from 50 to 100% in production in the different developing regions of the world over a 20-year period.

To achieve these rates of expansion in production over a sustained period presents very large technical challenges. These include:

- Reducing the wastage in livestock production systems caused by disease and parasitism. Since disease patterns tend to be both more severe and more complicated in tropical climates, the challenges to science and application are very great. They include not only the epidemic viral diseases (foot-and-mouth, rinderpest, swine fever) but also a range of insect and tick-borne diseases unknown in the developed world.
- Development of the feed base. In the poorest developing countries, cereals are almost exclusively for human consumption, and livestock production must therefore depend on other feed resources. The challenge of increasing production and at the same time improving quality, including protein content, in tropical forages is a field with very large potential.
- Conserving and developing genetic resources. The livestock breeds and types adapted to survival in the tropics have generally not been subject to systematic improvement for productivity. They are therefore often at risk of replacement by more productive, but less resilient strains. The development of information, breeding programs and practices to best utilize and conserve genetic resources is an important task.
- Development of balanced production systems. Two-thirds of the world's utilized agricultural area is used by grazing animals. Production systems which conserve the rangeland resource still exist in many parts of the world, while in other areas degradation of the resource base has occurred. Similarly, the development of livestock and cropping systems in which a balance is maintained is a major task in developing countries.

- Efficient marketing of livestock products. As the urban populations of developing countries expand, the physical task of safely providing perishable livestock products on a regular basis becomes more demanding. Much investment of research effort will be required in this area.

Non-technical factors

Every farmer is aware that non-technical factors can often be the most important determinants of profitability. The great swings in interest rates in the late seventies, for example, overwhelmed many well-run farms in Europe. In Eastern Europe at the present time, the collapse in consumer purchasing power has not been matched by reductions in the cost of farm inputs, with great consequences for both the technical and financial structure of farming.

Distortions in the economic environment for agriculture have been even greater, and for longer periods, in developing countries. The broad pattern has been one of heavy discrimination against agriculture, both through direct taxation and indirect burdens. This pattern has now been definitively mapped in a major study published by the World Bank last year. This study covered 18 countries, almost all in the developing world, over a 25-year period. It documents the extent of direct taxation and of indirect price interventions (exchange rate and industrial protection policies) which impose further taxes on agriculture.

The results were very clear. Over the period 1960 to 1985, on average, agriculture in these countries carried a total tax rate of about 30%. More than two-thirds of this was accounted for by protection policies for industry and by overvalued exchange rates.

The transfers out of agriculture have been enormous. On average 46% of agricultural Gross Domestic Product was transferred to other sectors. During that period studied, the general tendency to distort prices to the detriment of domestic agriculture increased.

The most important conclusion was that this pattern of high taxation of agriculture was associated with low growth in agriculture and also with low growth in the economy as a whole (Table 1). It is also notable that the poorer countries in this study, which are the ones that can least afford constraints on development, are those whose policies have been least encouraging to growth.

Table 1. Agricultural protection rates and corresponding growth rates for 18 countries over 25 years (Source: Schiff & Valdés, 1992).

Country Group	Nominal Agricultural Protection Rate	Annual Growth Rate GDP	Annual Growth Rate Agriculture
Côte d'Ivoire, Ghana, Zambia	- 52	3.3	2.7
Argentina, Colombia, Dominican Republic, Egypt, Pakistan, Philippines, Sri Lanka, Thailand, Turkey	- 36	5.1	
Brazil, Chile, Malaysia	- 16	5.3	5.2
Korea, Portugal	+ 10	6.5	

The tax and pricing regime also discriminated against agricultural exports. Apart from direct taxation on exportables averaging 16%, indirect effects tended to provide net protection for importables. The average impact on the relative price of importables to exportables was then 40% in favor of importables.

To some extent these policies are easy to rationalize. Countries at the very early stages of development, whose wealth generating capacity is still almost entirely agricultural, inevitably rely on this sector of the bulk of fiscal revenues. The rapid construction of the apparatus of a modern state on such a slender revenue base often leads to excessive impositions. Furthermore, many countries, either implicitly or explic-

itly, favor industrial development over agricultural development in the belief that the former is more responsive to incentives. An important conclusion of the study was that this belief is misplaced, and that overall economic growth was hindered by the way in which agriculture's domestic terms of trade were adversely effected by these policies. In addition, the authors concluded that the policies pursued were, on balance, socially regressive, and that in the longer term the poor have probably lost disproportionately.

Four examples

I have chosen four examples to illustrate some of the successful applications of research results to daily life in the developing world, as well as to highlight the kind of challenges which still lie ahead.

Traditional cheese in Niger

In a pastoral country such as Niger, cattle, sheep and goats are the principal wealth of the people, and live animals and milk are the main saleable products. Traditionally, milk has been converted into a dry cheese called Tchoukou.

In a recent FAO dairy development project, some small improvements have been made to the traditional process. Better filter cloths are used, special perforated earthenware vessels are used for storage, and a microbial rennet, the product of advanced genetic engineering in Denmark, is used as a coagulant. The cost of the microbial rennet is trivial, and it, together with the other improvements in the technique, gives a 50% increase in cheese yield, as well as a product which obtains a higher price. The net effect is to almost double the financial return to the women whose business this is.

By comparison, the large investments made in centralized dairy processing facilities in Niamey are now used only to recombine imported milk powder.

This project illustrates several useful points: how high technology can sometimes be incorporated in very traditional systems; how a small investment in existing products and processes is often more profitable than a large investment in transferring inappropriate technology; and how the application of knowledge to the improvement of traditional agriculture can pay handsome dividends.

Screwworm in North Africa

In 1988, a new pest of animals turned up in North Africa. The New World Screwworm is endemic to tropical areas of the Americas and had never occurred on this side of the Atlantic. It is an obligate parasite of warm-blooded animals. The female lays up to 300 eggs in any break in the skin, and the resulting larvae burrow into the living flesh. Infested animals frequently die, and the annual cost of controlling the pest in domestic animals is estimated at U.S. $5 billion in the Americas.

Within two years of arrival in Libya, the screwworm had spread to an area equal to 60% of the surface of Denmark, and threatened not only the two million animals in that area, but also the whole of the Mediterranean basin, and eventually the livestock populations, both domesticated and wild, of Sub-Saharan Africa.

Fortunately, over the preceding 30 years, a large amount of research had been invested in methods of controlling this pest in the United States and Mexico. A successful method, based on the use of sterile insects, had been developed. Because the problem had been thoroughly researched, a technical solution was available, and a large international program was launched to bring sterile insects from Mexico and to spread them in the infested area. The result was a spectacular success: whereas over 12,000 animals were infested with screwworm in 1990, in the following season, after some months of distribution of sterile insects, the pest had effectively died out, and only six infested animals were found. The area has since been clear.

This case illustrates how effectively research results can be put to work, provided the initial investment has been made. The volume of detailed work required to investigate the biology of the fly and to develop mass rearing methods and a variety of population suppression techniques can be judged from the fact that the literature on screwworm at this stage contains more than 600 scientific papers and reports.

Improving feed resources in China

It has been known for a long time that the digestibility of straw or other low quality forages can be improved by pre-treatment with either urea or ammonia.

This technology has been widely researched, not least in Denmark, and also widely used in Europe in circumstances where the economics were right. In 1985, the technology was introduced to China, where a series of experiments and demonstrations was set up to explore the possibilities of improving beef production from local feed materials, primarily straw and cottonseed meal. The technology took off, and the tonnage of straw treated has doubled in each of the last four years. The expectation is that by 1995, 30 million tons of straw will be treated each year. The net effect of straw treatment, combined with supplementation with up to one kilogram of cottonseed cake, is to treble animal live weight gains from about 200 to about 600 grams per day, with similar effects on profitability.

This illustrates the speed with which an impact can be made on a large-scale when appropriate technology is applied to improving the productivity of traditional systems.

Trypanosomiasis in Africa

Among the many challenges to African agriculture, none is greater than that from trypanosomes, blood parasites transmitted by the tsetse fly. The disease effectively prevents the use of cattle in about one-third of Africa's territory and imposes a great burden of loss and debility on livestock, and indeed humans, in the 37 countries in which it occurs.

Trypanosomiasis constitutes one of the great research challenges of the future. As with malaria in humans, much research has concentrated on eliminating the vector. However, this is costly, and with widespread use of insecticides, unacceptably harmful to the environment. Research is therefore now focused on selective methods of eliminating the vector, by the use of impregnated targets, or pour-on applications on animals. In isolated areas, like Zanzibar, sterile insects may be useful. Drug treatment of animals can be effective, though it has the disadvantages of expense and the development of resistance. Much research is continuing on the search for an effective vaccine and for an understanding of the in-built trypanotolerance which is characteristic of many West African cattle breeds.

This particular challenge is one which requires much more research at the highest levels of sophistication, as well as research at the level of village cultural practices which can reduce the local impact of the disease. Much of the expertise required to make advances against difficult challenges like trypanosomiasis lies in the global pharmaceutical companies and research institutes. The difficulty is that this resource cannot be harnessed to the problem unless there is either the prospect of profit for the companies concerned or a funding source for the institutes. We clearly need to find an innovative way of deploying international funds to bring this problem and its possible solutions together.

The research agenda

The organized pursuit of knowledge to assist development in agriculture, particularly through state-supported institutions, is very recent. Most of the world's agricultural research establishment is less than 50 years old. In general, it has served its purpose extremely well, and those formal studies which have been done have shown rates of return to investment which are higher than those of most other forms of public expenditure.

Research is an expensive business. Research in livestock is somewhat more costly than in other areas of agriculture, because livestock facilities are more expensive, and because the projects are often longer-term. In general, at least in the developed world, it costs over U.S. $200,000 per year to support a scientist with associated staff and facilities. Measuring the costs is easy enough. Measuring the output, and its value, is much more difficult. The first stage of output, that is the published results of research, can be quantified and often is to the annoyance of the scientists involved. Measuring the impact of that information in terms of increased output or improved resource use is much more complex, though a large number of such studies have now been done. They have been tabulated recently by Echeverría (1990). Most of his examples come from the plant sector, but I have extracted from his study the twelve livestock cases reported (Table 2). As

can be seen, in every one of these formal studies, the return to investment has been high and positive, indeed much higher than the normal expectation of return on public investment, for which 12% is regarded by the World Bank as acceptable.

In the developed world, the context in which this work is carried out has changed rapidly in the last decade. The major factors involved have been the following. The accumulation and application of knowledge from previous successful research means that, for many lines of work, future gains are likely to be smaller and more expensive to achieve. The primary clients of agricultural research have been farmers, who are halving in numbers every 25 years and are progressively better informed and better equipped to solve problems directly themselves. More important, the constraints on continued expansion of output, either for environmental or for market reasons, have meant that the output-enhancing benefits of research no longer have the same return, and that the cost/benefit ratio is therefore less.

All of these factors have led to changes both in the objectives and structures of research. Much work is now directed to increasing quality or reducing costs, with the objective of achieving greater market share. In mass markets, such as in the United States, and increasingly in the European Economic Community, this is particularly the case. In the United States, for example, some 12,000 new food products (including 3,000 new brands) are introduced to the market each year. While less than 10% survive, the whole process of innovation, from the primary producer through to the supermarket shelf, is very much driven by the imperative to serve the consumer.

While it has always been true that the benefits of agricultural research flowed through the agricultural industry to the consumers, it is paradoxical that when this is now more clearly the case than ever before, there is a growing reluctance at government level in many countries to maintain what are seen as research services for agriculture.

Table 2. A summary of estimates of returns from investments in livestock research (from Echeverría, 1990).

Study	Year and Country[a]	Commodity	Period	Rate of Return[b]
Peterson	1967 (1)	Poultry	(1915-60)	21 to 25%
Bredahl and Peterson	1976 (1)	Poultry	(1969)	37%
		Dairy		43%
		Livestock		47%
Eddleman	1977 (1)	Beef cattle & forage	(1978-85)	16%
		Swine		52%
		Dairy		38%
Wennergren and Whittaker	1977 (2)	Sheep	(1966-75)	44%
Norton	1981 (1)	Poultry	(1969)	30% to 56%
		Dairy		27% to 62%
		Livestock		56% to 132%
Smith et al.	1983 (1)	Dairy	(1978)	25%
		Poultry		61%
		Beef, swine, sheep		22%
Haque et al.	1987 (3)	Eggs	(1968-84)	106% to 123%
Huot et al.	1988 (3)	Swine	(1968-84)	45%
Power and Russell	1988 (4)	Poultry feeding	(Present)	Benefit-cost ratio of 78:1
Widmer et al.	1988 (3)	Beef	(1968-84)	63%
Zachariah et al.	1988 (3)	Broilers	(1968-84)	48%
Fox et al.	1989 (3)	Dairy	(1968-84)	97%

[a]Country: (1) USA, (2) Bolivia, (3) Canada, (4) United Kingdom

[b]Depending on the study, these are average or marginal rates of return. More than one value means a range of returns depending upon different assumptions or periods of analysis.

The situation throughout the developing world presents even bigger challenges to research. In the first place, technology which increases output is needed urgently for many decades into the future, and output-enhancing research therefore should pay off as handsomely as it has elsewhere. Secondly, in countries where most consumers are also producers, distinctions do not need to be drawn between who are the ultimate beneficiaries of research: investment is clearly in a "public good" context. Thirdly, countries which follow rather than lead in the development path can profit enormously from research which has already been done and can therefore concentrate their resources on moving forward from there. For example, much of the investment in research in the developed countries over the past 50 years has been in methodology for analysis, diagnosis, standardization. This is all in the public domain, and does not need to be repeated–merely adapted to local circumstances. Fourthly, there are undoubtedly a large range of technical opportunities for the application of research to real problems in developing countries. These range from the control of uniquely tropical diseases of plants and animals to the documentation, conservation, and appropriate use of the large reservoirs of genetic resources which are special to the tropics.

For both markets, developed and developing, the advancing front of science is opening up new opportunities for research to continue its leading role in agricultural development. New knowledge on diet and its relationship with human health, particularly in later life, is presenting new challenges to developed country agriculture and food industries. The expanding front of molecular biology has multiple possibilities, initially in disease diagnosis and control, and also in aspects of production efficiency. New levels of both knowledge and research are required also at the global level–to better understand and better manage the planet whose resilience or fragility we have only begun to measure.

Literature Cited

Lee, David R. and Rausser Gordon C. 1992. "The Structure of Research and Transfer Policies in International Agriculture: Evidence and Implications," Issues in Agricultural Development: Sustainability and Cooperation, International Association of Ag. Economists (IAAE) Occasional Paper No. 6, pp. 34-41.

Schiff, Maurice and Valdés, Alberto. 1992. "The Political Economy of Agricultural Pricing Policy," A Synthesis of the Economics in Developing Countries, Vol. 4, A World Bank Comparative Study.

Echeverría, Ruben G., Ed. 1990. "Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research, Volume II: Assessing the Impact of Agricultural Research." Proceedings of the ISNAR/Rutgers Agricultural Technology Management Workshop, 6-8 July 1988, Rutgers University, New Jersey, USA.

Chapter 1. Humid Tropics: Hair Sheep and Integration of Sheep into Tree Crop Plantations

Strategies to Improve Forage Production in Rubber Plantations

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Abstract

Improvement of forage production for conventional rubber plantations on large estates is limited to the first five years when light conditions at ground level are acceptable for plant growth. Forage selection programs in Malaysia and Indonesia have identified a number of shade-tolerant species, including accessions of the grasses *Panicum maximum, Brachiaria humidicola, B. brizantha, Paspalum notatum, and Stenotaphrum secundatum* and the legumes *Arachis pintoi, other Arachis* spp., *Desmodium heterophyllum, Stylosanthes humilis,* and *Stylosanthes guianensis.* These species are being evaluated in mixed swards under young rubber trees when subjected to cutting and grazing. Tree legumes of the genera *Calliandra, Albizia, Leucaena, Sesbania,* and *Gliricidia* are the most promising alternative for improving forage resources of smallholder rubber producers.

Sustainable production of forage (and hence sheep production) in rubber plantations will depend on either flexible management of replanting programs in conventional plantations or altering the conventional planting system to favour forage growth. Two potential alternative planting systems are discussed.

Introduction

In Southeast Asia, small ruminants are common in areas dominated by cropping, where they are kept to provide additional income, cash reserves, and meat. This is typified by the intensive cropping systems of Java, on which 62% of the Indonesian population occupy 7% of the national land area but raise 68% of the total small ruminant population of Southeast Asia. These small ruminants are usually fed whatever feedstuffs are available, especially wasteland forages which are characteristically high in fiber and low in protein, energy, and minerals. It has been estimated (Remenyi and McWilliam, 1986) that if these traditional feeding practices remain in place, the demand for forage resources in the region will double (from 1985 figures) by the year 2000 and meat self-sufficiency will fall from 95% to 62%. Given the substantial areas of ungrazed land in rubber plantations (Table 1), integration with sheep as a way of reducing the region's projected meat supply deficit has attracted much recent research .

Table 1. Natural rubber production statistics for the three major world producers.

	Thailand	Malaysia	Indonesia
1986 Latex production (% world total)	17.5	34.3	23.4
1992 Latex production (% world total)	26.8	21.9	24.9
1992 Total Plantation area ('000 hectares)	1832	1844	3040
Smallholder producers (% of total area)	81	95	84

Source: IRSG (1993)

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The benefits of combining sheep production with rubber plantations have been well documented (for reviews see Dahan et al., 1978; Shelton et al., 1987; Iniguez and Sanchez, 1991; Shelton and Stür, 1991). These include reduced weeding costs (Tajuddin, 1986), utilization of unused forages and plantation byproducts, more efficient cycling of nutrients (Jusoff, 1988), potentially higher plantation yields, reduced soil erosion, reduced accretion of herbicide residues in the soil, and only minor interference with plantation management. An additional potential benefit, especially for smallholders (who produce the great majority of latex in Southeast Asia, Table 1), is a more stable and diversified income. Despite recent attempts to stabilize world prices for natural rubber through stockpiling, producers have suffered a net 32% reduction in latex prices since 1988 (IRSG, 1993). This is particularly hard on smallholders whose livelihood depends largely on income from latex.

Limitations of forages in rubber plantations

A major constraint to the expansion of sheep production in rubber plantations is the provision of sufficient forage of adequate quality throughout the year and throughout the duration of a plantation (20-25 years) (Chen, 1991). On a per-head basis, modest liveweight gains (LWG) are possible from existing plantation forages 40-90g/head/d for unsupplemented lambs have been variously reported (Chen et al., 1991; Sanchez, 1991). This can be explained partly by the reasonable nutritive value of plantation forage species. The dominant plantation forages have metabolisable energy levels of greater than 1.8 Mcal/kg, crude protein levels of greater than 11%, and dry matter digestibilities of greater than 55% (Chen, 1991; Sanchez and Pond, 1991). Sheep also have the capacity to select a diet of higher nutritive value from the plantation forages available. However, sustainable stocking rates in mature plantations (>5 years of age) are very low (2-4 head/ha) with annual LWG per hectare of <100kg (Chong et al., 1991).

The data in Table 2 highlight the two main problems of forages in rubber plantations: a rapid decline in both productivity and legume composition of plantation forages with increasing plantation age. Conventional legume cover crops in young rubber plantations (*Pueraria javanica, Centrosema pubescens,* and *Calopogonium* spp.) are not very shade tolerant and are gradually replaced by native grasses and broadleaved species, especially under grazing. With lower forage yields and poorer quality (especially digestibility and energy content) in mature plantations (Wilson, 1991), voluntary forage intake, and hence energy and protein intake, can be inhibited. Sivaraj et al. (1993) fed *ad libitum* forage cut from a mature oil palm plantation to four-month-old lambs in pens. Intakes of dry matter, energy and crude protein were only 57 g/kg$^{0.75}$/d, 0.9 Mcal/d, and 60 g/d, respectively. There is also evidence that while moderate levels of production are possible from local sheep grazing existing plantation forages, better quality diets are required if improved sheep breeds are to achieve their genetic potential growth rates. Horne (unpublished data) found that while LWG of crossbred ram lambs (Virgin Island x Sumatran thin tail) on a high energy/protein diet (concentrate and *Paspalum*) were significantly greater than for the Sumatran lambs (168 and 128g/head/d, respectively), there was no difference in LWG between the two breeds when fed a diet based on *ad libitum* plantation grass (86 g/head/day). These problems of restricted intake, low forage availability, and low forage quality can only be overcome by either feed supplementation (Pond et al., this proceedings) or by improving the basic forage resource.

Table 2. Typical yields of forages in rubber plantations established with cover crops.

Age of rubber (y)	PAR Transmission (%)	Standing Dry matter (t/ha)	Forage productivity (t/ha/yr)	Botanical composition (%)		
				Legume	Grass	Broadleaf
1-2	70-90	2.0-3.5	5-7	14	79	2
3-5	20-70	1.0-2.0	1-5	31	37	25
6-20	<20	0.5-1.0	<1	37	10	46

Sources: Wan Mohamed (1977), Chee and Faiz (1991), Chong et al. (1991)

Three ways in which the forage resource of rubber plantations can be improved are:
1. Selection of higher yielding, shade-tolerant forage species.
2. Forage management practices to promote productivity and persistence.
3. Alternate plantation management practices to promote sustainable forage growth.

Forage selection

Selection of forages for shaded environments requires a number of equally important stages of research (Figure 1), which accommodate the special circumstances encountered in the physiological and morphological responses of most forage plants to shade. Plants growing in shade tend to divert larger amounts of energy into shoot production than those grown in full sun. This, combined with the generally lower yields of plants under shade, means that there are much lower root reserves of soluble carbohydrate for regrowth after defoliation (Wilson and Ludlow, 1990). Regrowth of shaded forages is therefore likely to be more dependent on the amount of green leaf left on a plant after it has been grazed or cut than on root energy reserves. Persistence of shaded forages will also therefore be largely determined by grazing frequency and intensity.

Ideally, improved forages for young rubber plantations should:

- Be persistent and productive under moderate shading and defoliation.
- Be tolerant of acid soils.
- Be able to establish rapidly to control weeds.
- Not grow too vigorously as to severely compete with the rubber trees for water or nutrients.
- Require only moderate fertilization.
- Be no more expensive to establish than conventional cover crops.
- Produce higher yields of better quality forage than the conventional cover crops.

Since the mid 1980's, several groups in Asia, including the Rubber Research Institute of Malaysia (RRIM), the Australian Centre for International Agricultural Research (ACIAR), and the Small Ruminant CRSP (SR-CRSP), have been evaluating forages that satisfy many of these criteria for use in young rubber plantations (Wong et al., 1985a,b; Sanchez and Ibrahim, 1991; Shelton and Stür, 1991). In particular, ACIAR and RRIM have completed a comprehensive screening of tropical forages (86 grasses and 48 legumes) for shaded environments as part of the Stage 2 and Stage 3 evaluations in Figure 1. The SR-CRSP has also completed a larger scale evaluation of 22 species and 12 mixtures under a regular cutting regime. This selection work has focused on species and mixtures for the first five years of a rubber plantation, when light conditions are conducive to forage growth. After this period, it is unlikely that productivity can be improved much beyond that of the existing native forages.

The first three stages of forage selection for rubber plantations (Figure 1) have now been adequately covered. A number of promising shade-tolerant tropical forages have been identified, including accessions of the grasses *Panicum maximum, Brachiaria humidicola, B. brizantha, Paspalum notatum,* and *Stenotaphrum secundatum,* and the legumes *Arachis pintoi, other Arachis* spp., *Desmodium heterophyllum, Stylosanthes humilis,* and *Stylosanthes guianensis.* These species are being carried through to the fifth and sixth stages of evaluation (Figure 1) in which their yield, persistence, and value as animal feed in grazed or cut swards under young rubber will be assessed.

Forage management

Estates

Rubber estates offer the best opportunity for utilization of herbaceous forages on a large scale. Integrating forages with conventional rubber plantations (those with a triangular planting pattern, usually at a spacing of 6m-4m) involves establishing a mixture of improved forages in alleys between the rows of newly-planted rubber where the less productive and less palatable cover crops would normally be planted. A strip of 0.5m width would normally be left on either side of each row of rubber trees for clean-weeding with herbicide. Once established, the alleys of forage can then be harvested for cut-and-carry feeding during the first two years, when the trees are susceptible to damage from grazing sheep. Thereafter grazing can continue until

the closure of the rubber tree canopy reduces forage yields to negligible levels. Experiments are being conducted by the SR-CRSP in Indonesia to examine liveweight gains of lambs and reproductive performance of ewes on such improved forages, with and without various forms of supplementation.

Establishment problems with improved forages in rubber plantations have been experienced in Malaysia (D.T. Chong, RRIM; pers. comm.). These include poor seed quality, high seed price, and slow establishment requiring top-dressing and foliar sprays as well as several costly rounds of hand-weeding. The costs of establishment have been up to four times higher for improved forages than for the cover crops. While similar problems have been experienced in Indonesia, the soils are more fertile and labor costs, which comprise 60-70% of the cost of establishment, are significantly lower than in Malaysia.

Once established, persistence of forages (especially in shade) depends on management of defoliation. Light but frequent grazing is more likely to promote persistence of improved forages than heavy or continuous grazing. As well as assisting regenerative ability of the plants, this defoliation regime maintains the forage at a younger age which promotes higher digestibility and voluntary intake (Preston and Leng, 1987). Residual green leaf values of 40-50% following grazing under light to moderately shaded conditions should maintain adequate regrowth. Of the commonly used grazing systems, rotational grazing gives the best control over forage quality and residual green leaf but requires investment in fencing and careful monitoring. Shepherded grazing, as is commonly practiced in Indonesia, could be managed to imitate rotational grazing, if tightly controlled, especially if some electric fencing is available. The choice of grazing system will depend largely on the relative costs and benefits of pasture establishment and maintenance, fencing, and sheep parasite control measures.

The soils in most of the rubber producing areas of Sumatra are broadly classified as red-yellow podzolics and are highly leached, acid, and have high aluminum saturation, low inherent nutrient status, and low organic matter content (Pushparajah, 1984; Leiwakabessy, 1989). Replacement of traditional cover crops with mixtures of tropical grasses and legumes may have adverse effects on the growth of young rubber trees, especially through increased competition for nitrogen, phosphorus, potassium, and magnesium, unless fertilizers are used (Waidyanatha et al., 1984, Dissanayake and Waidyanatha, 1987). As a minimum management practice, fertilizers will have to be added to the sown forages prior to sowing and periodically thereafter to replace nutrients removed. This will be especially important during the initial cut-and-carry stage when all harvested forage is being removed. It is not so important during the grazing phase as the percentage of dietary nutrients excreted by grazing sheep can be quite high (33-95% of ingested nitrogen, depending on the feed type). It is expected that if replacement fertilization is carried out, competitive effects will be minimized, especially as rubber is very competitive for nutrients and current management practices include the application of 70-150 kg N/ha/y, 30-40 kg K/ha/y and 20-40 kg P/ha/y in spot applications around each tree.

In existing estates, approximately 25% of plantation area at any time is immature rubber. Given that forage yields under immature rubber decrease and forages ultimately die after the plantation canopy closes, rubber replanting schedules should ideally be adjusted by estate managers to ensure that there are always areas of young rubber for grazing within easy walking distance of the sheep barns. The only other ways to ensure a continued supply of forage for the sheep are to move flocks to new locations within an estate when the existing one becomes unproductive or to transport cut forage to the sheep barns.

Smallholder rubber producers

Of the smallholder rubber producers in Indonesia, 21% are part of Nucleus Estate and Smallholders (NES) schemes. These schemes involve the establishment of smallholder rubber farms by a large estate (Nucleus) which are then managed for the smallholders by the estate until ready for tapping (>5 years of age). In general the farms are small (two hectares of rubber) with 0.5-1.0 hectares for food crops and a homeyard. Fertilizers (N and P) and lime are provided over the first three years (Leiwakabessy, 1989). The remainder of the smallholders are unregulated, many consisting of 5-10 hectares of "jungle" rubber. Rubber management practices used by unregulated smallholders are inefficient and yields are low, as indicated by the relatively low latex production per unit area in Indonesia compared with Malaysia where smallholders are

organized in the FELCRA and FELDA schemes (Table 1).

Opportunities for forage improvement within the plantations of NES smallholders are limited. Farmers normally plant food crops in the inter-rows of immature rubber. Even if NES farmers were to be given financial assistance from the Nucleus estate to establish improved forages under their immature rubber, they face the problem of having to reduce rapidly their sheep numbers as the forage yields decline with canopy closure. The best opportunity for forage improvement for both NES and uncontrolled rubber smallholders lies in the planting of acid-tolerant grasses and tree legumes in the cropping and homeyard areas. In some areas, NES farmers have abandoned their cropping areas after several years because the soils are too acid and infertile to sustain productivity. Many forage species are better adapted to these conditions than the usual dryland crops. Even so, lime will normally be required to neutralize the low pH as well as to supply calcium, with other additions of phosphorus, magnesium, sulfur, and potassium possibly being required. These areas may also be suited to a mixed cropping-forage-tree legume system similar to that of the three-strata system described by Nitis et al. (1991).

Tree legumes are particularly well adapted to the needs of smallholder rubber producers. Unlike herbaceous legumes, the more common tree legume genera in Indonesia (*Calliandra, Albizia, Leucaena, Sesbania,* and *Gliricidia*) are persistent, easy to grow, can be planted in small areas of wasteland, and can be harvested to provide a highly-digestible protein supplement at strategic times. There is also evidence that for some species (including species in the genera *Leucaena, Calliandra,* and *Gliricidia*) the protein in the leaves takes longer to digest than the leaf dry matter and may therefore contribute both fermentable and bypass nitrogen (Preston and Leng, 1987). Most of these species are able to survive on acid soils, but, for acceptable levels of production, some fertilizers will be required (Palmer et al., 1989). SR-CRSP has conducted feeding trials with the more common tree legume species and is commencing on-farm trials with smallholders.

Alternative plantation management

An alternative approach to the problem of the long period of negligible forage production in conventional plantations is to reduce or eliminate the problem altogether by changing the planting pattern of the rubber trees (or the number of trees per hectare) to allow more light to reach the ground. However, as animal production will continue to be a secondary enterprise in rubber plantations, the feasibility of new planting systems will depend on there being negligible reduction in plantation yield. The two potential systems of most interest are hedgerows and block plantings.

Hedgerow planting

Hedgerows were originally tried in the 1930's in Java to allow integration of rubber with coffee. The two planting patterns tried involved rubber trees closely planted (1-3m apart) in rows 8-9m apart or 16-20m apart. In the narrow alleys, coffee could be grown for about 12 years until the canopy closed, but in the wide alleys the coffee could be grown indefinitely. It was reported that latex yields were higher than from conventional plantations (possibly because of selective thinning of the mature trees) but the length of time to first tapping was increased (Blencowe, 1989). Research on hedgeplanting was abandoned in Malaysia in the 1950's because of lower latex yields per hectare and a higher incidence of damage to hedge-planted trees by root disease and wind.

Hedgerow plantings are being reinvestigated by the Rubber Research Institute of Malaysia to allow integration of sheep production with rubber plantations. In conventional plantations the planting distance is 6m-4m (450 trees/ha), and the canopy closes after four to five years. The hedge-planted rubber consists of double rows of rubber trees (with a spacing of 2m-3m) planted with a 22m wide alley between the double rows (450 trees/ha). Improved forages in the alleys receive only moderate shading from the rubber trees on the edges of the alley. With the possibility of stronger clones that can resist wind damage and new techniques for stimulating latex production, it is hoped that latex yields from hedge-planted rubber may equal yields from conventional plantations (I. Tajuddin, RRIM, pers comm.). Such systems have great potential, especially for organised smallholders, because sheep production may be sustainable on one area of widely-

spaced, hedgerow-planted rubber regardless of the age of the trees. Hedge systems would not be suitable for hilly land as the hedges following contours would require very wide terraces.

Block planting

In block planting, rubber trees are planted in blocks with intervening blocks being sown with forages and tree legumes for sheep production. The relative size of the blocks can vary according to forage requirements, topography, and plantation management objectives. Similar systems are being tried in southern China, where the main aim of block planting is to reduce wind damage by planting a protective barrier of fodder and timber trees around each block. It may be possible to achieve equivalent latex yields per hectare from block plantings as conventional plantations by using higher planting densities within the blocks. Some estates in Indonesia are already trying higher planting densities of 625 trees/ha with the potential of lower yields per tree but higher yields per hectare.

Block planting has some distinct advantages for diversified plantation management on estates. The treeless-blocks could be planted entirely to forages, tree legumes (as a protein bank), or a mixture of both, depending on the availability of other forage resources. If the treeless blocks were planted to improved forages, research experience on acid soils indicates that the high yields in the unshaded conditions would also result in a build-up of soil organic matter and alleviation of the negative effects of low pH and high aluminum saturation (von Uexk-ll and Bosshart, 1989). Adjacent treeless (forage) blocks could be spelled from grazing on a rotational basis to limit rates of reinfection of sheep with gastrointestinal parasites. Treed and treeless (forage) blocks could be rotated every 20 years, allowing rehabilitation of the organic matter levels of all soils by forages, over a long rotation. The treeless (forage) blocks, having been spelled for 20 years, may also have lower potential for reinfecting rubber trees with the major fungal root disease, white root rot.

The Rubber Research Institute of Indonesia is investigating means of plantation diversification that would be compatible with block planting. Experiments are being conducted to look at the potential of planting rubber at very high densities (up to 2500 trees/ha) and thinning the plantation at three or five years of age, then selling the wood for paper production. The cut trees will then be replaced with rattan, a high value crop that requires heavy shade.

The major disadvantage of block planting and hedge-row planting schemes is that they require large areas be left unplanted with rubber. It may be difficult to convince estates that this is a worthwhile change in management, even if experiments were to show significant advantages to plantation income.

Conclusions

The physical conditions that exist in conventional rubber plantations limit the period in which forages can be used to the first five years. Despite this, the potential gains in animal production from immature plantations are great. SR-CRSP has identified a number of supplement strategies for sheep in rubber plantations and is continuing research on forage/supplement combinations that are beneficial for smallholder and estate sheep-rearing operations.

Areas of future research and development for forages in rubber plantations include:

- The development of cheap and efficient methods of establishment of forage species.
- The effect of grazing and cutting intensity and frequency on the persistence and quality of shaded forages.
- The investigation of growth performance of lambs and reproductive performance of ewes fed, grazed, or cut forages under immature rubber, with and without supplementation.
- the investigation of dry matter intake and nutritional imitations of sheep reared by smallholders.
- The investigation of alternative plantation management systems that promote sustainable forage production.
- The development of schemes to organize the majority of smallholder rubber producers in Indonesia.

Literature Cited

Blair, G. 1991. Methodologies for evaluating forage germplasm integration into tree cropping systems. In Iniguez, L.C. and M.D. Sanchez (Ed.) Integrated Tree Cropping and Small Ruminant Production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9-14 September 1990. SR-CRSP, University of California.

Blencowe, J.W. 1989. Organisation and improvement of smallholder production. In: C.C. Webster and W.J. Baulkwill (Ed.) Rubber. John Wiley and Sons, New York.

Chee, Y.K., and Ahmad Faiz. 1991. Sheep grazing reduces chemical weed control in rubber. In: Shelton, H.M. and W.W. Stür (Ed.) Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Chen, C.P. 1991. Management of forages for animal production under tree crops. In: Iniguez, L.C. and M.D. Sanchez (Ed.). Integrated Tree Cropping and Small Ruminant Production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9-14 September 1990. SR-CRSP, University of California.

Chen, C.P., Z. Ahmad Tajuddin, W.E. Wan Mohamed, I. Tajuddin, C.E. Ibrahim and R. Moh Salleh. 1991. Research and development on integrated systems in livestock, forage and tree crops in Malaysia. In: Z. Ahmad Tajuddin (Ed.) Proceedings of the International Livestock-Tree Cropping Workshop, 5-9 December, Serdang, Malaysia. MARDI/FAO, Serdang, Malaysia.

Chong, D.T., I. Tajuddin and M.S. Abd. Samat. 1991. Stocking rate effect on sheep and forage productivity under rubber in Malaysia. In: Shelton, H.M. and W.W. Stür (Ed.) Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Dahan, M.M., R.I. Hutagalung and W.E.Wan Mohamed. 1978. Integration of small ruminants with plantation crops. In: Proceedings of a workshop on Integration of Animals with Plantation Crops. Pulau Pinang, Malaysia, 13-15 April 1978.

Dissanayake, S.N., and U.P. de S. Waidyanatha. 1987. The performance of some tropical forage grasses interplanted with young Hevea trees and their effect on the growth of the rubber. Trop. Agric. (Trinidad) 64(2):119.

Iniguez, L.C., and M.D. Sanchez (Ed.). 1991. Integrated Tree Cropping and Small Ruminant Production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9-14 September 1990. SR-CRSP, University of California.

IRSG. 1993. International Rubber Study Group (IRSG) Rubber Statistical Bulletin. 47(7).

Jusoff, K. 1988. Influence of sheep grazing on soil chemical properties and growth of rubber (*Hevea brasiliensis*) in Malaysia. Agroforestry Systems 7:115.

Leiwakabessy, F.M. 1989. Management of acid humid tropical soils in Indonesia. In: E.T. Craswell and E. Pushparajah (Ed.) Management of Acid Soils in the Humid Tropics of Asia. ACIAR/IBSRAM, Canberra.

Nitis, I.M., K. Lana, M. Suarna, W. Sukanten and S. Putra. 1991. Legume trees as alternative feed resources for small ruminants integrated with tree crops. In: Iniguez, L.C. and M.D. Sanchez (Ed.) Integrated Tree Cropping and Small Ruminant Production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9-14 September 1990. SR-CRSP, University of California.

Palmer, B., R.A. Bray, T. Ibrahim and M.G. Fulloon. 1989. Shrub legumes for acid soils. In: E.T. Craswell and E. Pushparajah (Ed.) Management of Acid Soils in the Humid Tropics of Asia. ACIAR/IBSRAM, Canberra.

Preston, T.R., and Leng, R.A. 1987. Matching Ruminant Production Systems with Available Resources in the Tropics and Sub-Tropics. Penambul Books, Armidale, NSW, Australia.

Pushparajah, E. 1984. Nutrient availability in acid soils of the tropics following clearing and cultivation with plantation crops. In: E.T. Craswell and R.F. Isbell (Ed.) Proceedings of the International Workshop on Soils. Research to Resolve Problems of Soils in the Tropics. 12-16 September 1983. Townsville, Queensland. ACIAR/IBSRAM, Canberra.

Remenyi, J.V., and J.R. McWilliam. 1986. Ruminant production trends in Southeast Asia and the South Pacific and the need for forages. In: G.J. Blair, D.A. Ivory and T.R. Evans (Ed.) Forages in Southeast Asian and South Pacific Agriculture. Proceedings of an international workshop held at Cisarua, Indonesia, 19-23 August 1985. ACIAR, Canberra.

Sanchez, M.D. 1991. Supplementation of sheep under rubber in Indonesia. In: Shelton, H.M. and W.W. Stür (Ed.) Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Sanchez, M.D., and K.R. Pond. 1991. Nutrition of sheep that are integrated with rubber production systems. In Iniguez, L.C. and M.D. Sanchez (Ed.) Integrated Tree Cropping and Small Ruminant Production. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, 9-14 September 1990. SR-CRSP, University of California.

Sanchez, M.D., and T. Ibrahim. 1991. Forage species for rubber plantations in Indonesia. In: Shelton, H.M. and W.W. Stür (Ed.) Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Shelton, H.M., L.R. Humphreys and C. Batello. 1987. Pastures in the plantations of Asia and the Pacific: performance and prospect. Trop. Grassl. 21(4):159.

Shelton, H.M., and W.W. Stür. 1991. Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Sivaraj, S., P., Agamuthu and S. Tukimin. 1993. Botanical composition and nutritive value of native herbage in oil palm plantations. In: Proceedings of the workshop on Development of Sustainable Integrated Small Ruminant-Tree Cropping Production Systems, University of Malaya, Kuala Lumpur, 30 November - 4 December 1992 (In press).

Tajuddin, I. 1986. Integration of animals in rubber plantations. Agroforestry Systems 4:55.

von Uexküll, H.R., and R.P. Bosshart. 1989. Management of acid upland soils in Asia. In: E.T. Craswell and E. Pushparajah (Ed.) Management of Acid Soils in the Humid Tropics of Asia. ACIAR/IBSRAM, Canberra.

Waidyanatha, U.P. de S., D.S. Wijesinghe and R. Stauss. 1984. Zero grazed pasture under immature *Hevea* rubber: productivity of some grasses and grass-legume mixtures and their competition with *Hevea*. Trop. Grassl. 18(1):21.

Wan Mohamed, W.E. 1977. Utilisation of ground vegetation in rubber plantation for animal rearing. In: Proceedings of the Rubber Research Institute of Malaysia Planter's Conference, Kuala Lumpur, Malaysia. RRIM, Kuala Lumpur.

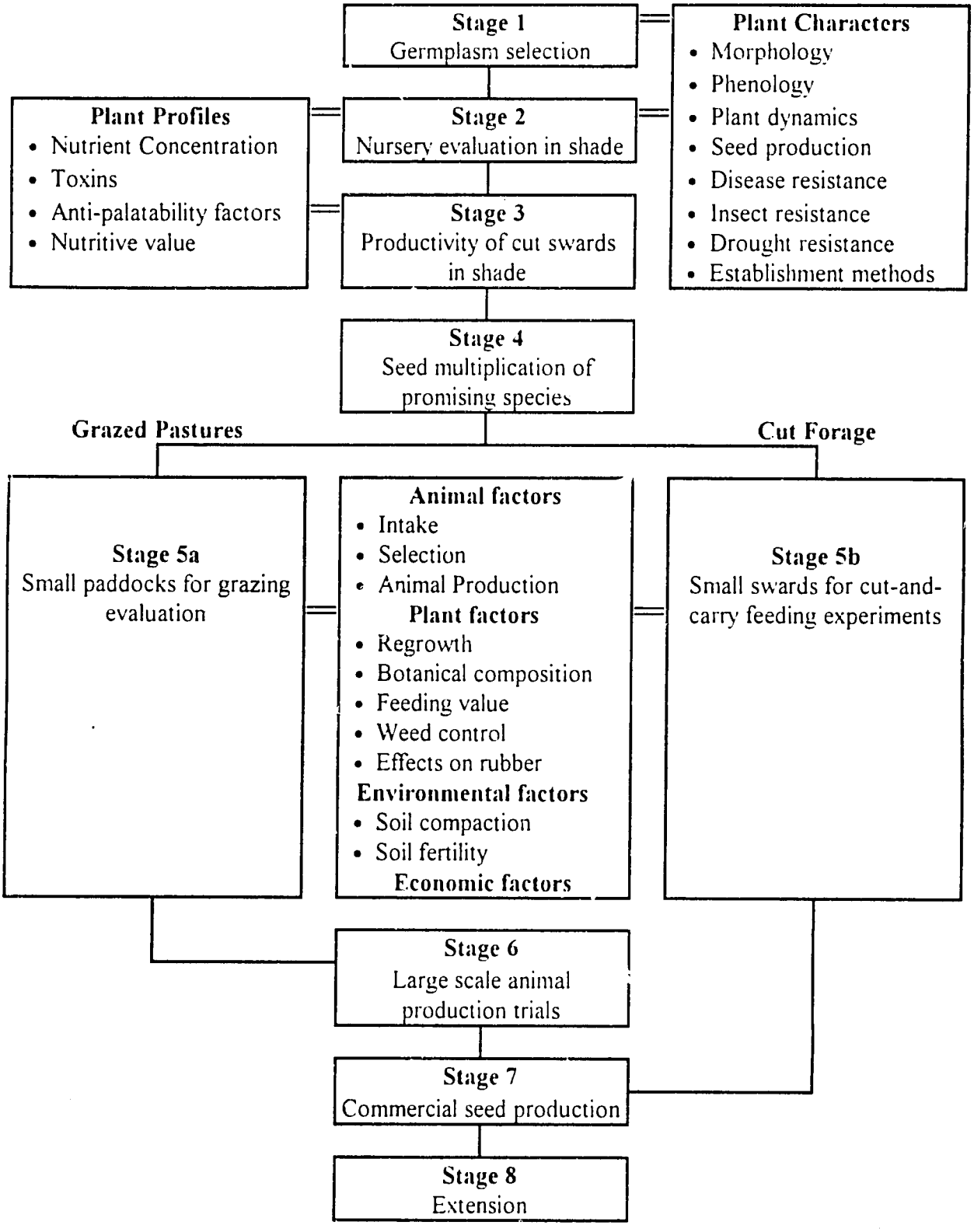
Wilson, J.R., 1991. Ecophysiological constraints to production and nutritive quality of pastures under tree crops. In: Z. Ahmad Tajuddin (Ed.) Proceedings of the International Livestock-Tree Cropping Workshop, 5-9 December, Serdang Malaysia. MARDI/FAO, Serdang, Malaysia.

Wilson, J.R. and M.M. Ludlow. 1990. The environment and potential growth of herbage under plantations. In: Shelton, H.M. and W.W. Stür (Ed.) Forages for Plantation Crops. Proceedings of a workshop held at Sanur Beach, Bali, Indonesia, 27-29 June 1990. ACIAR, Canberra.

Wong, C.C., H. Rahim and M.A. Mohd. Sharudin. 1985a. Shade tolerance of some tropical forages for integration with plantations. 1. Grasses. Mardi Res. Bull. 13(3):225.

Wong, C.C., M.A. Mohd. Sharudin and H. Rahim 1985b. Shade tolerance of some tropical forages for integration with plantations. 2. Legumes. Mardi Res. Bull. 13(3):249.

Figure 1. Scheme for evaluationof forages for rubber plantations (after Blair 1991).



Growth, Mortality, And Wool Cover Of Sumatra Sheep And Crosses With Three Breeds Of Hair Sheep

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Abstract

Sumatra ewes were mated to give Java Fat-tail crossbred (E1), Virgin Island crossbred (H1), and purebred Sumatra (S) lambs, or were inseminated to give Barbados Blackbelly crossbred (B1) lambs. A total of 882 lambs were born to 407 ewes in 568 lambings between March and October 1992. Average litter size was 1.55 and lamb mortality to weaning at three months was 22.5%. Weights of lambs averaged 1.83 kg at birth and 8.7 kg at weaning. For female lambs only, weights averaged 14.4 kg at six months and 17.9 kg at nine months of age. The average increase in weight of the crossbreds above S was E1 7%, H1 15%. and B1 20%. Growth rates of weaned ram lambs on high quality diets were more than 120 g/d for all genotypes, and the ranking of growth rates was S < E1 < H1 < B1 with B1 exceeding S by 27%. On mediocre diets there was little effect of breed on post-weaning growth rate. At three months of age all breed groups had similar wool scores, but in older animals the ranking was B1 (least wool) < H1 < E1 < S (most wool).

Introduction

The local breed of sheep in North Sumatra has a high reproductive potential, but it is small and growth rates are usually low. Most Sumatra sheep have some coarse wool which is not used. In some other parts of the humid tropics, sheep are larger and have no wool. The performance of different breeds of hair sheep is not well documented. It has been postulated that sheep without wool are better adapted to a hot humid climate and are more productive.

The objective of the crossbreeding trial in Sei Putih is to evaluate various genetic stocks of hair sheep and their suitability for the humid tropics. The results presented in this paper are those of the first phase, namely lamb growth, mortality, and wool cover.

Materials and methods

Breeds

In this trial, Sumatra (S), the local breed in North Sumatra, was crossed with:

- Barbados Blackbelly (B), from the Caribbean, which was introduced using frozen semen rather than live animals.
- Java Fat-tail (E), known in Indonesia as Ekor Gemuk. Thirty-five ewes and 15 rams were introduced from East Java to Sei Putih in 1991.
- Virgin Island (H), also known as St Croix, originally from the Caribbean. Seven ewes and seven rams were introduced to Sei Putih in 1986 from the U.S.

In addition, Garut crossbred ewes (Garut x Sumatra) were used as dams to avoid purchasing more Sumatra ewes. The Garut (G) is a strain of Java Thin-tail, similar to but larger than the Sumatra, and is also known as the Priangan. The Garut crossbred ewes in Sei Putih had been produced during a previous experiment.

The symbols used to denote genotypes in this paper are as follows: B1 (B x S, first generation), E1 (E x S, first generation), G1 (G x S, first generation), H1 (H x S, first generation), and S (Sumatra).

Location

This comparison was carried out at the Research Institute for Animal Production, Sei Putih in North Sumatra (3°N, 99°E). Altitude is about 50 m above sea level. Annual rainfall totals about 1800 mm, with rain in every month. Mean minimum temperature is 23°C and mean maximum temperature is 32°C, with little seasonal variation.

Animals and management

The sheep were housed in group pens in four large sheep houses with raised slatted floors. Ewes and suckling lambs were grazed from 0800 h to 1600 h daily in rubber plantations. Ewes with single lambs were given concentrate for only two weeks after lambing, and those with two or more lambs receive concentrate for six weeks postpartum. All ewes were fed a small amount of molasses mixed with urea. Ewes were exposed to rams for 34-day periods four times a year, and lambs were weaned at exactly three months of age.

Mating program

In October 1991, more than 400 S and G1 ewes either were inseminated with frozen semen from Barbados Blackbelly rams or were mated to East Java Fat-tail, Virgin Island, or Sumatra rams. Natural services were individually supervised following twice-daily detection of estrus by vasectomized rams. All ewes returning to estrus were remated in January-February and April-May 1992.

A total of 407 ewes (312 S and 95 G1) in this trial lambed in three seasons, starting mid-March, mid-June and mid-September 1992. The numbers of ewes lambing in the three seasons were 314, 70, and 184, respectively, for a total of 568 lambings. The majority (161) of the 184 ewes which lambed in September had previously lambed in March. A total of 882 lambs were born.

All the genotypes were managed as similarly as possible. However, B1 lambs were born only in the first season and their management was not identical with that of the other genotypes. Therefore the major statistical analyses presented in this paper compare only the E1, H1, and S lambs born in all three seasons. Secondary analyses compare the B1 lambs with the other lambs born in March 1992.

Results

Litter size

The percentages of litters (of all four breed groups in all three seasons) of one, two, three, and four lambs were 54, 38, 7, and 1%, respectively. These figures are almost identical to those reported by Iniguez et al. (1991) for the same flock in 1985-1988. Overall litter size was 1.55.

Litter size was affected by breed of dam ($P<0.001$), but not by age of ewe or season of birth. Average litter size (+SE) was 1.78($\pm$0.07) for G1 and 1.46($\pm$0.04) for S dams. The higher litter sizes of the G1 dams can be attributed to (i) hybrid vigor and (ii) the higher frequency of the prolificacy gene (Bradford et al., 1990) in the Java Thin-tail breed which sired the G1 dams than in the Sumatra.

Weights of lambs

Data from three breed groups (E1, H1, S) in three seasons were analyzed using a model which included breed group, season, sex, type of birth (or birth and rearing), dam breed group, ewe age, and sire within breed. A second analysis involved all four breed groups born in March only (since B1 lambs were produced in only that season). The results are presented in Table 1. Lambs averaged 1.83 kg at birth and 8.7 kg at weaning for lambs of both sexes. For female lambs only, weights averaged 14.4 kg at six months and 17.9 kg

at nine months of age. Six and nine-month weights were corrected for age by linear interpolation between monthly weights to give weights at exactly 183 and 274 days of age.

Lamb weights were affected by breed of sire, sex of lamb, type of birth and rearing, breed of dam, age of dam, and season of birth. Sire within breed had no statistically significant effect.

Effect of breed of sire on weight of lambs

The average weights in Table 1 show that

1. The ranking of average lamb weights was S < E1 < H1 < B1 at all ages, and
2. The average increase in weight of the crossbreds above the S was 7% for E1, 15% for H1, and 20% for B1. These differences are highly significant. Variation within and between breed groups is illustrated in Figure 1.

Table 1. Least squares means and standard errors (kg) for lamb weights. Values for birth and three months are for both sexes; values for six and nine months are for females only.[1]

Three Genotypes, All Seasons	Birth		Three months		Six months		Nine months	
n	799		616		275		159	
Overall mean	1 83		8.7		14.4		17.9	
Breed group	***		***		***		***	
E1	1.73	.05	8.6	.25	14.3	.5	18.2	.5
H1	1.95	.05	8.9	.26	15.4	.4	19.9	.5
S	1.71	.03	7.8	.17	12.8	.4	17.0	.6
Sex	***		**					
Female	1.74	.03	8.2	.18				
Male	1.85	.03	8.6	.17				
Type of birth (or birth and rearing)	***		***		***		***	
1 11	2.31	.04	11.0	.18	16.3	.4	19.8	.5
21			8.2	.29	14.2	.5	18.6	.8
2 22	1.75	.03	7.5	.17	13.3	.3	17.5	.4
3 32	1.33	.05	6.9	.27	12.9	.6	17.5	.9
Breed of dam	***		***		**		ns	
G1	1.92	.04	9.1	.22	14.8	.5	18.5	.6
S	1.68	.03	7.7	.15	13.6	.3	18.2	.4
Age of dam	***		***		ns		ns	
< y	1.53	.04	7.4	.24	13.5	.5	17.7	.6
2-3 y	1.75	.03	8.7	.19	14.5	.3	18.6	.5
3-4 y	1.88	.04	8.8	.21	14.7	.4	18.5	.6
4-6 y	1.95	.05	9.2	.25	14.6	.5	18.2	.7
>6 y	1.88	.06	7.9	.35	15.8	.7	18.8	.9
Season of birth	ns		*		***		**	
March	1.82	.03	8.5	.17	13.1	.4	17.3	.4
June	1.73	.05	8.6	.25	14.0	.5	19.4	.6
September	1.85	.04	8.1	.20	15.5	.4		
All Breed Groups, March Only								
n	488		391		163		156	
Genotype	***		***		*		***	
B1	1.97	.06	10.3	.29	14.7	.5	19.9	.6
E1	1.82	.08	8.8	.37	13.5	.6	17.2	.7
H1	1.95	.06	9.0	.31	13.9	.5	19.0	.5
S	1.71	.05	7.8	.24	12.8	.5	6.6	.6

[1]*P<.05; **P<.01; ***P<.001; ns=nonsignificant.

Lamb mortality

Pre-weaning mortality (from birth to three months) averaged 22.5%, and for females post-weaning mortality (three to nine months) averaged 13.1%. The factors affecting lamb mortality are summarized in Table 2. Analyses were carried out using actual mortality data, and since these are not normally distributed, the results of the tests of significance are only approximate. Three periods were considered:

1. Zero to two weeks of age. "Perinatal mortality." Lambs born dead were included in this variable.
2. Two weeks to three months of age.
3. Three to nine months of age. "Post-weaning mortality." This variable is for females only, and includes the few animals that were culled for physical deformities and those that lost their identification tags or were stolen. Thus the 13% value is a slight overestimate of actual death loss.

Pre-weaning mortality, which is the sum of periods 1 and 2, is also shown.

Table 2. Least squares means and standard errors for lamb mortality (%) of three breed groups in all seasons. Values until three months are for both sexes; the final column is for females only.[1]

	0-14 d (1)		0.5-3.0 months (2)		0-3 months (1+2)		3-9 months (3)	
n	799		799		799		183	
Overall mean	10.1		12.4		22.5		13.1	
Breed group	ns		*		ns		ns	
E1	15.9	3.2	3.8	3.5	19.7	4.3	14.6	6.7
H1	8.0	3.3	17.3	3.6	25.3	4.5	3.8	6.6
S	12.9	2.2	11.2	2.4	24.2	3.0	17.6	6.7
Sex	ns		ns		ns			
Female	14.2	2.3	9.1	2.5	23.2	3.1		
Male	10.4	2.2	12.5	2.4	22.9	3.1		
Type of birth (or birth and rearing)	***		***		***		ns	
1 (11)	2.7	2.5	4.0	2.7	6.7	3.4	8.2	6.3
(21)							12.6	9.2
2 (22)	9.0	2.2	14.4	2.3	23.4	2.9	10.3	5.0
3 (32)	25.1	3.3	13.9	3.6	39.0	4.4	16.9	10.5
Breed of dam	*		**		***		ns	
G1	9.3	2.9	6.3	3.1	15.6	3.9	9.7	7.8
S	15.3	1.9	15.2	2.1	30.5	2.6	14.4	5.0
Age of dam	*		***		***		ns	
<2 y	19.6	3.0	11.4	3.3	31.0	4.1	12.3	6.9
2-3 y	11.4	2.3	12.2	2.6	23.6	3.2	17.2	6.4
3-4 y	8.8	2.8	9.7	3.0	18.5	3.8	18.9	7.7
4-6 y	12.2	3.2	0.0	3.5	11.6	4.4	3.5	8.7
>6 y	9.4	4.3	21.1	4.7	30.6	5.9	8.1	10.7
Season of birth	ns		**		***		ns	
March	9.3	2.2	9.1	2.4	18.3	3.0	11.2	4.9
June	13.7	3.3	5.5	3.7	19.2	4.6	12.8	7.4
September	13.9	2.5	17.7	2.7	31.6	3.4		

[1]*P<.05; **P<.01; ***P<.001; ns=nonsignificant.

Table 2 shows that mortality was affected by type of birth and rearing, breed of dam, age of dam, and season of birth. Genotype had a significant effect only on mortality from two weeks to three months of age, when the mortality of E1 lambs was lower than that of other breed groups.

Comparison of the least squares mean mortality rates of all four breed groups in March shows that the mortality rates of B1 lambs were similar to those of the other three genotypes.

Causes of mortality

A substantial number of lambs were born dead. Post-mortem examination of still-born lambs which were superficially normal showed accumulation of fluid in the body cavity of the lamb.

There were four main causes of death in lambs before weaning:

1. Insufficient milk consumption which predisposes lambs to parasites.
2. Worms, particularly *Haemonchus contortus* which cause severe anemia. Worms were most obvious in the final weeks before weaning.
3. Coccidia, which cause diarrhoea in lambs aged about two months.
4. Pneumonia in ewes in December 1992 when there was prolonged rain.

Wool coat

The coats of lambs at birth were assessed as either straight or curly. Approximately half (48%) had curly coats, and half (52%) straight.

Wool score is the product of wool cover (0-9) and wool length (0-9), so this can range from 0 to 81. The effect of genotype on wool score is summarized in Table 3. Wool scores at three months of age were similar for all breed groups, but in older animals the scores were consistently B1 < H1 < E1 < S. B1 had the least wool, and S were the most woolly. Comparison of the results of the two analyses suggests a seasonal effect on wool scores, which may exist; the differences might also be due in part to different persons doing the scoring in different seasons. Comparisons of the different breed groups within analyses should not be affected by the latter.

Table 4. Least squares means and standard errors for wool scores. Values for three months are for both sexes; values for six and nine months are for females only.[1]

	Three months		Six months		Nine months	
Three Genotypes, All Seasons						
n	575		276		166	
	ns		***		*	
E1	54.7	2.0	64.9	3.2	61.1	4.4
H1	55.9	2.1	51.9	2.5	54.0	4.3
S	54.7	1.4	68.0	2.2	68.7	4.6
All Genotypes, March Only						
n	375		164		163	
	ns		***		***	
B1	41.4	1.6	38.8	4.6	17.9	5.5
E1	42.8	2.0	58.1	5.1	38.6	6.0
H1	41.6	1.7	41.6	4.0	34.3	4.7
S	43.4	1.3	64.4	4.5	52.3	5.4

[1]*P<.05; **P<.01; ***P<.001; ns=nonsignificant.

Effect of wool coat on lamb weights

Lambs with straight birthcoats had higher average weaning weights than lambs with curly birthcoats ($P<0.05$). The least squares means (+SE) for the 3-genotype three-season comparison were 8.09(±0.21) kg for curly coats and 8.57(±0.21) kg for straight coats.

At three and six months of age, there was a positive correlation between wool score and lamb weight; bigger lambs were more woolly than smaller lambs. By nine months the correlation had become non-significant; this may have been due to the smaller number of animals scored at nine months.

Growth of ram lambs after weaning

Weaned ram lambs were evaluated in feeding trials. In an experiment by Sianipar (pers. comm.), groups of rams were fed with a diet at 3% body weight, comprising *Paspalum dilatatum* grass (30% intake) plus concentrate (70% intake) containing either (i) 7% molasses, (ii) 30% molasses, or (iii) 48% molasses. The crude protein level in all three diets was 12.7%.

Horne (pers. comm.) fed either (i) a low quality diet of plantation grass *ad libitum* plus 400 g/head/d concentrate (2.77 MCal ME/kg, 11.8% CP) comprising locally-available feedstuffs, or (ii) a high quality diet fed at 3.3% body weight containing concentrate (3.22 MCal ME/kg, 15.3% CP, given at 70% of DM intake) and *Paspalum dilatatum* grass (30% intake).

Figure 2 shows that all genotypes grew at more than 120 g/d if given a good quality diet. On high quality diets when the lambs could express their growth potential the ranking of breed groups was B1 > H1 > E1 > S, and the B1 grew 27% faster than the S.

On mediocre diets, which more closely resemble those in villages, there was little difference between the genotypes. Where a limited amount of concentrate was fed on a per head basis, not according to body weight, the S lambs slightly outperformed the crossbreds. This genotype by environment interaction, noted here for lamb growth, is potentially very important in overall evaluation of the different groups. The subject merits further investigation, particularly with regard to ewe reproduction and production.

Color and ear type

Doloksaribu et al (1993) reported that more than 90% of E1 and H1 sheep are completely white. Most S are white or light brown. A few S are black, and some have the dark brown and black coloring characteristic of purebred Barbados Blackbelly. Only 10% of B1 have the brown and black color pattern typical of purebred Barbados Blackbelly sheep, but a large proportion are brown. Nineteen per cent of B1 are white, and a further 13% are largely white with a black belly.

The short-ear gene, which results in small ears in heterozygotes and earlessness in homozygotes, is present at an estimated frequency of about .25 in S sheep, and is also present in the Fat Tail breed. Crossbreds had short ears in the expected proportions.

Future plans for the crossbreeding program

Susceptibility to internal parasites is being assessed. We have found that the parasite burdens of the crossbred genotypes are slightly lower than those of the purebred Sumatra.

All the ewes born in March and June 1992, and ten randomly chosen rams from each genotype are being mated in 1993. Ewes are mated to sires of the same breed group, and, starting June 1993, lambs of the F_2 generation will be born. The reproductive performance of the four genotypes will be evaluated on the basis of the first two lambings of the B1, E1, H1, and S ewes. Grazing behavior and behavior at lambing are also being assessed.

Discussion

Litter size averaged 1.46 and 1.78, respectively, for the Sumatra and Garut crossbred dams. The higher litter size of the latter is most probably due to the higher frequency of the FecJF gene (Bradford et al., 1991) in the Garut population sampled than in the S breed, although this gene apparently also is found in some S individuals.

Average weights of lambs were 1.83 and 8.7 kg at birth and three months. Weights of females at six and nine months averaged 14.4 and 17.9 kg. There was a consistent effect of genotype on lamb weight. E1, H1 and B1 crossbreds were 7, 15, and 20% heavier than Sumatra lambs.

In Tobago which has a similar climate to North Sumatra, a six-year comparison showed that the growth of Barbados Blackbelly lambs to weaning was markedly superior to that of Virgin Island lambs (Rastogi et al., 1993). In their islands of origin, Barbados Blackbelly ewes are generally larger than Virgin Island ewes. The mean mature weight of Barbados Blackbelly ewes in Barbados has been estimated to be 40-45 kg (Bradford et al., 1983) or 50 kg (Devendra, 1972). Weights of Virgin Island ewes in the US Virgin Islands average about 35 kg (Hupp and Deller, 1983).

Fat-tail sheep in Java are larger than Thin-tail sheep (Mason, 1978; Gatenby et al., 1988). At Suka Damai, the average weights of S and G1 ewes in 1992 were 22.0 kg and 25.6 kg, whereas the average for E was 26.2 kg and the average for H was 31.2 kg. Thus the breed differences in weights of lambs can be partly attributed to differences in mature size of the sire breed. There is probably also an effect of hybrid vigor in the crossbred lambs; we shall have an estimate of hybrid vigor when the F2 lambs are evaluated.

On good quality diets weaned crossbred lambs grew faster than purebred lambs, and the four genotypes ranked S < E1 < H1 < B1. However, on typical village diets there was no benefit of the superior growth potential of the crossbreds. In New Jersey, USA, Horton and Burgher (1992) found that the growth rate of Virgin Island wethers (200 g/d) was slightly but not significantly higher than the growth rate of Barbados Blackbelly wethers (140 g/d) when a commercial diet containing 16% crude protein was offered ad libitum.

Lamb mortality to weaning averaged 22.5%. This high value can be attributed to the high litter size and health problems associated with the hot-humid climate. Mortality rate was not significantly affected by genotype.

Wool scores at three, six, and nine months of age showed an effect of genotype. The breed groups were ranked B1 < H1 < E1 < S. Comparison with the ranking of body weights suggests that genotypes with a low wool score have high body weights. However, there was a low positive correlation within groups between wool score and weight at three and six months.

The E1 and H1 animals are largely white, but the S and B1 are many colors. If in the future it is decided to standardize the color of sheep distributed from Sei Putih, a wide range of color patterns will be available for selection.

Literature Cited

Bradford, G.E., H.A. Fitzhugh, and A. Dowding. 1983. Reproduction and birth weight of Barbados Blackbelly sheep in the Golden Grove flock, Barbados. In Fitzhugh, H.A. and G.E. Bradford (editors) Hair sheep of Western Africa and the Americas, pp 163-170. Westview Press, Boulder, Colorado, U.S.A.

Bradford, G.E., I. Inounu, L.C. Iniguez, B. Tiesnamurti, and D.L. Thomas. 1991. The prolificacy gene of Javanese sheep. In Elsen, J.M., L. Bodin and J. Thimonier (editors) Proceedings 2nd International Workshop on Major Genes for Prolificacy in Sheep, pp 66-73. INRA, France.

Devendra, C. 1972. Barbados Blackbelly Sheep of the Caribbean. Tropical Agriculture, Trinidad 49:23-29.

Doloksaribu, M., A.D. Pitono, and R.M. Gatenby. 1993. Colour and ear type of sheep in North Sumatra. In Annual Report 1992-93. SR-CRSP Sei Putih, North Sumatra, Indonesia.

Gatenby, R.M., R.A.C. Jensen, Subandriyo, and G.E. Bradford. 1988. Actual and potential levels of performance of Indonesian sheep and goats under traditional management systems. Technical report series 97. SR-CRSP, University of California, Davis, U.S.A.

Horton, G.M.J., and C.C. Burgher. 1992. Physiological and carcass characteristics of hair and wool breeds of sheep. Small Ruminant Research 7:51-60.

Hupp, H., and D. Deller. 1983. Virgin Islands White hair sheep. In Fitzhugh, H.A. and G.E. Bradford (editors) Hair sheep of Western Africa and the Americas, pp 171-175. Westview Press, Boulder, Colorado, U.S.A.

Iniguez, L., M. Sanchez, and S.P. Ginting. 1991. Productivity of Sumatran sheep in a system integrated with rubber plantation. Small Ruminant Research 5:303-317.

Mason, I.L. 1978. Sheep in Java. World Animal Review 27:17-22.

Rastogi, R.K., M.J. Keens-Dumas, and F.B. Lauckner. 1993. Comparative performance of several breeds of Caribbean hair sheep in purebreeding and crossbreeding. Small Ruminant Research 9:353-366.

Figure 1. Frequency distribution of body weight in nine-month-old ewe lambs.

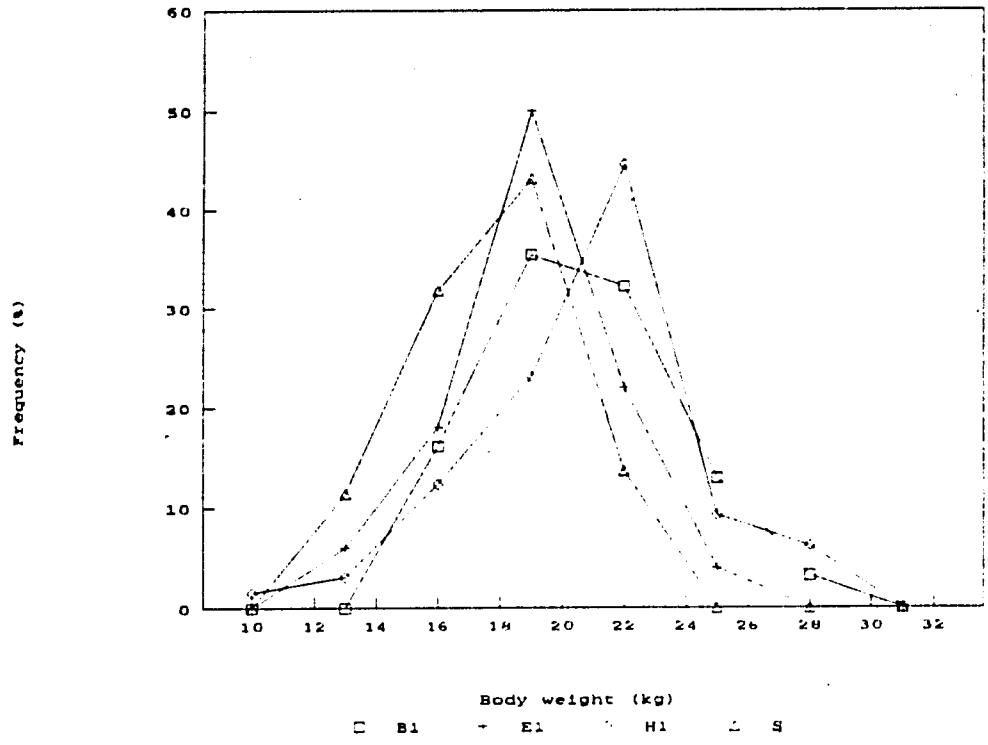
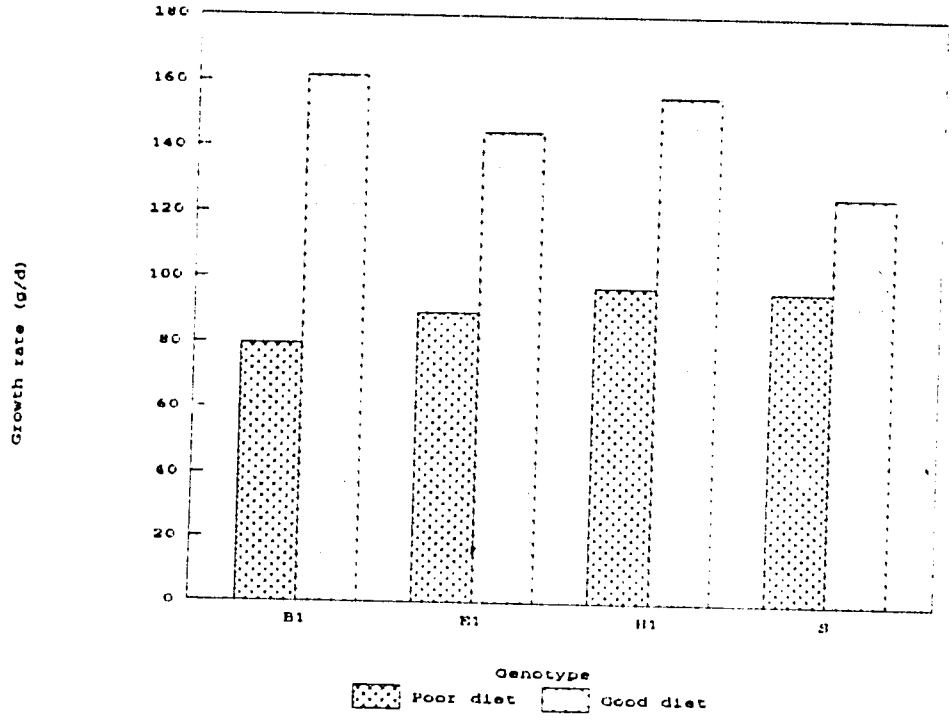


Figure 2. Growth rates of ram lambs. Poor diet is mean of Sianipar 48% molasses and Horne low quality. Good diet is mean of Sianipar 7% molasses and Horne high quality.



Studies On The Epidemiology And Control Of Important Diseases Of Sheep At Sungei Putih, North Sumatra

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Summary

Eight experimental protocols using 309 sheep and over 500 lambs were conducted on aspects of the epidemiology and control of important diseases of sheep maintained under rubber trees at Sungei Putih, North Sumatra, Indonesia. High levels of internal parasitism, caused by *Haemonchus* and *Eurytrema* (pancreatic fluke), and pneumonia are important disease constraints to production.

Parasitism is perennial while pneumonia is seasonal. Pasture spelling combined with anthelmintics was shown to be an effective method of limiting the pathogenic effects of haemonchosis. No resistance to benzimidazoles occurred over three years of use. No drugs tested showed efficacy against *Eurytrema*. Individual sheep of some breeds showed consistently low nematode egg counts over time. More detailed studies on genetic resistance are required to capitalize on these findings.

Introduction

Since 1985 at Sungei Putih in North Sumatra, the traditional system for raising sheep has been modified by the SR-CRSP for improved mutton production using the forage on rubber plantations, which would otherwise remain unused (Reese et al., 1987). By 1990, much progress had been made in studies on nutrition, genetics, and socio-economics. However, data on the effect of disease on production and mortality were not available. The importance of disease was recognized by Sanchez (1989) and studies commenced on the epidemiology of important parasitic diseases (Carmichael et al., 1992), followed by a program that studied other important disease constraints as well (Wilson and Beriajaya, 1992). This paper summarizes these findings.

Materials and methods

Eight experimental protocols were undertaken. The first three have been described by Carmichael et al. (1992).

Protocol 1. Levels of helminth parasitism in sheep grazing on rubber plantations

Fecal samples were regularly collected (usually bi-weekly) from 27 sentinel sheep and monitored for nematode egg counts over the period March 1990 to April 1991. Larval cultures were also conducted regularly from composite samples. The sheep were managed with the main flock under rotational grazing (every four to six days) on limited grassland and treated with benzimidazol anthelmintics according to levels of eggs per gram (epg) counts (five times over the period).

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Protocol 2. Seasonal abundance of nematodes in sheep grazing in rubber plantations
Groups of two to three weaned lambs (total 32) were treated with a benzimidazol anthelmintics and were shepherded with the main flock for consecutive periods of four weeks after which they were slaughtered for parasite recovery.

Protocol 3. Survival period of infective larvae on pastures in rubber
One square hectare ungrazed by sheep for over a year was divided into 15 strips, and on 15 successive days one strip was artificially contaminated by 100 kg of infected feces (mean 780 epg; 48% *Haemonchus*, 40% *Trichostrongylus*, and 12% *Cooperia*). The area was then divided into four 0.25ha areas by electric fencing. Three groups of eight worm-free lambs were grazed on three of the 0.25 ha sites 4-6, 8-10, and 12-14 weeks respectively after contamination, after which they were housed on slatted floors for 28 days and then killed for parasite recovery.

Protocol 4. Effect of pasture spelling on Gastrointestinal (GI) nematodes of sheep under rubber
Two phases were conducted:

4.1. Two groups of 12 and 15 ewes were sampled biweekly for nematode epg over a six-month period with two anthelmintic treatments. The first group was managed as in Protocol 1. The second group was grazed on extensive pasture for three months, treated with an anthelmintic and moved to clean pasture where the process was repeated (pasture spelling) in 1991 to 1992.

4.2. Twenty six yearling animals under anthelmintic treatment and pasture spelling were monitored bi-weekly for nematode epg levels over a one year period from 1992-1993.

Protocol 5. Monitoring for possible traits of helminth resistance in lambs maintained under defined management systems
From mid-1991, all the lambs born in the SR-CRSP flock were monitored for fecal nematode epg at 3, 9, and 12 months of age prior to anthelmintic treatment.

Protocol 6. Health monitoring
Animals over three months of age which die are necropsied on site by lay staff using a simple recording procedure based on tissue size, color, and other abnormalities. Tissues (pancreas, lungs, liver, kidney, and any tissues with lesions) from animals selected at random were stored in formalin for histopathologic examination.

Protocol 7. Studies on the epidemiology and treatment of the pancreatic fluke in sheep under rubber
Two studies were conducted:

7.1. Data were obtained from other protocols on (a) the numbers of flukes and (b) histopathology lesions in pancreases with respect to age and breed.

7.2. The drugs *Praziquantel* (administered orally at 20mg/kg on days 0 and 2), *Nitroxynil* (administered subcutaneously at 10mg/kg on day 0 and at 30mg.kg on days 0 and 2) and *Albendazol* (administered orally at 15mg/kg on days 0 and 2) were investigated for efficacy against the pancreatic fluke (*Eurytrema*). Thirty-two, six-month-old, Sumatran lambs were grazed for five weeks to allow infection with pancreatic fluke. The animals were then confined to housing with slatted floors for four months during which time feces were monitored for fluke eggs. When all were positive, the animals were divided into four groups of eight. Three were treated with the test drugs (as above) and the fourth was an untreated control. One month after treatment all animals were slaughtered and their pancreases were examined for fluke numbers and viability and for histopathologic.

Protocol 8. Effect of breed on gastrointestinal nematodes and pancreatic trematodes in sheep raised under rubber
Three similar experiments were conducted in October 1992, and January and April 1993. Sixteen, three-month-old, lambs were divided into groups of four to six according to breed (Sumatran, St Croix, Barbados Blackbelly, and Javanese Fat Tail and crosses). All were treated with an anthelmintic, stalled for one month, fed on contaminated pasture for one month, and then stalled again for a further month before being euthanized and examined for parasites.

Results

Protocol 1. The attack rates and levels of nematode parasitism over a year at Sungei Putih have been reported by Carmichael et al. (1992). Their results showed that:

- Substantial pathogenic burdens of nematodes were acquired by sheep throughout the year showing that nematodosis is a perennial, not a seasonal, problem.
- Benzimidazol anthelmintics were very effective against the parasite species present.
- Egg counts analyzed over time from individual sheep indicated that there were a few individuals with innate resistance, as their epgs rarely exceeded 120, as compared to a mean of over 6,000 epg.

The results from larval culture showed that the predominant parasite genus was *Haemonchus;* however, a switch to *Trichostrongylus* occurred during June-July.

Protocol 2. Mean monthly nematode burdens acquired by weaned lambs showed pathogenic levels of Haemonchus (505-1740 adults) throughout the year, confirming the importance and perennial nature of this parasite. Other genera detected were *Trichostrongylus, Cooperia, Oesophagostomum,* and *Trichuris.*

Protocol 3. The epgs and worm burdens decreased over time after pasture contamination. The mean epgs and worm burdens in the 4-6, 8-10, and 12-14 week groups after contamination were moderate (2,360 epg and 415 worms), low (630 epg and 130 worms), and very low (55 epg and 20 worms), respectively. This indicates a decline of availability of infective larvae on pasture with time.

Protocol 4.1. The group which was under pasture spelling showed both a lower mean epg count (409), measured fortnightly 28 days after treatment over a period of six months, and a longer mean time to first appearance of eggs after treatment (28 days) compared to the group under rotational grazing (3,458 epg and 14 days).

Protocol 4.2. A summary of mean epgs over 12 months in three breeds of sheep and one cross is shown in Table 1. This shows significant breed differences with a gradation of innate resistance. The St Croix had very low counts and the Sumatran very high. The Javanese Fat Tail showed lower counts than the Sumatran and counts similar to the St Croix-Sumatran crosses.

Table 1. Summary of means of nematode epg of yearling sheep according to breed over 12 months.

Breed	No animals studied	No samples (n)	Mean	SD	SE
Sumatran Javanese	9	43	2472	4355	664
Fat Tail	6	34	837	1978	341
St Croix	9	50	382	775	110
St Croix x Sumatran	10	65	976	1565	195

Protocol 5. Preliminary results indicate that some lambs had low epg's. Detailed results are unavailable as they are currently being studied as a part of a postgraduate degree program.

Protocol 6. Lamb mortality decreased during the three years of study from around 22% to around 14%. Histopathologic results from the examination of 93 animals showed that the most important causes of death were infections of Eurythema, the pancreatic fluke (30.1%) and pneumonia caused by *Pasteurella* bacteria (16.1%). An analysis of the gross pathology sheets in animals showed a different picture, namely, that by far the most important disease was that caused by *Haemonchus* which was very severe in three-month-old lambs causing heavy mortality.

Protocol 7.1. Data obtained from other Protocols have shown that *Eurytrema* is very common in all breeds from six months of age; however, disease mainly occurs in animals over three years of age.
Protocol7.2. None of the three drugs tested showed practical efficacy against the pancreatic fluke, *Eurytrema.* Albendazol and Praziquantel had some effect on limiting fluke numbers and the pathogenic effects of the fluke on both the pancreas and the liver.

Protocol 8. Results of total monthly nematode and trematode counts from 48 animals of four breeds over a six-month period did not show a clear pattern. Individual animals had low counts of both *Haemonchus* and *Eurytrema.* Most animals had pathogenic levels of both parasites.

Discussion and recommendations

The most important animal health constraints to production of sheep under rubber are diseases caused by *Haemonchus contortus* and *Eurytrema pancreaticum* which have a very high incidence. The *H. contortus* is perennial and can cause heavy mortality especially in lambs. The *E. pancreaticum* is also perennial and causes chronic infections which become manifest as a clinical entity in animals over two years of age. Pneumonia is also important and should be monitored especially during the wet season and in young animals.

Pasture spelling is an effective way to limit some of the effects of *Haemonchus* and should be practiced wherever possible. The main limiting factor is the availability of grazing land.

Further detailed studies are required to prove the possible resistance of some individual sheep to nematodosis. Limited results indicate that the St Croix and Javanese Fat Tail may have more individuals resistant to both nematodes and trematodes than other breeds. This must be confirmed.

Suitable drugs to control the pathogenic effects of the pancreatic fluke are urgently required. Further drug trials should thus be conducted.

Literature Cited

Carmichael, I.H., S. Widjajanti, M.D. Sanchez, M. Hutauruk, and A. Wilson 1992. Helminth parasitism in sheep grazing in rubber plantations in North Sumatra. Consultants Report 14/92. INI ANSREDEF, Bogor, Indonesia.

Reese, A.A., S. Ginting, P. Ketaren, W. Handayani, M. Boer. 1987. Integrated small ruminant and tree-cropping systems in Indonesia. In: C. Devendra (Ed), Proceedings of the Small Ruminant Production Systems in South and Southeast Asia, Bogor, Indonesia. October 6-10, 1986, IDRC, Canada. pp 257 - 268.

Sanchez, M.D. 1989. Annual Report 1988-89, SR-CRSP, Sungei Putih, Indonesia p 67.

Wilson, A. and Beriajaya. 1992. Studies on the epidemiology and control of important disease constraints of sheep at Sungei Putih, North Sumatra. Consultants Report 20/92. INI ANSREDEF, Bogor, Indonesia.

Economic Analysis of Sheep Grazing in Rubber Plantations: A Case Study of OPMM Membang Muda

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Abstract

Gross margin analysis indicates that a net farm income of U.S. $196/year/farm could be generated by rearing sheep in rubber plantations, accounting for 21.77% of rubber net income. From the economic point of view, grazing sheep in rubber plantations can be a good source of additional income for farmers and can reduce pressure for overtapping rubber which reduces the lifetime of a plantation. Larger contribution of sheep rearing can be achieved by increasing initial flock size. The on-going collaborative work between SR-CRSP/RIAP and PTPs (governmental-owned estates) provides 11 sheep to farmers and increases rubber farmers' income more than 30%.

Introduction

North Sumatra, Indonesia, has a large area of rubber plantations which occupy nearly 423,000 ha and includes 310,000 ha of smallholdings, 94,000 ha of government owned estates, and 104,000 ha of private estates (Dereindra et al., 1991). These plantations have an abundance of high quality forage grown in the interrows that can be utilized for feeding livestock.

Grazing ruminants in rubber plantations results in: 1) reduced competition for the tree crop from weeds and grasses; 2) an important source of income before the trees enter production; 3) supplemental income during tree crop production; 4) enhanced soil fertility from feces and urine; and 5) diversification of the agricultural enterprise as a hedge against fluctuating commodity prices (Thomas and Bradford, 1991). Sheep are preferred for plantation grazing, as they are less likely to browse trees than cattle, do not disturb collection tins in rubber plantations, are easier to be herded than goats (because of sheep schooling behavior), and are relatively more resistant to scabies than goats.

Small Ruminant Collaborative Research Support Program (SR-CRSP) and the Research Institute for Animal Production (RIAP), Sei Putih, North Sumatra, Indonesia, are developing relevant production technologies for an Integrated Production System (IPS) of sheep in rubber plantations. To study sheep production at the village level, SR-CRSP and RIAP establish on-farm research projects, such as Outreach Research Project (ORP) in Galang and Outreach Project of Membang Muda (OPMM) in Gunung Lonceng, Membang Muda (200 km east of Sei Putih).

This paper highlights additional net farm income incurred from grazing sheep in rubber plantations in ORP and specifically presents new data from more recent findings of OPMM Membang Muda.

Background information

ORP in Sei Putih has existed since 1988. However, as the farmers do not own rubber plantations, they graze sheep under rubber trees "informally," and it has not been possible to examine carefully the economics of grazing sheep under smallholder rubber estates in Sei Putih.

Therefore, the SR-CRSP selected another site where an active smallholder rubber program was being developed.

OPMM in Membang Muda, in conjunction with PTP III (Government-owned Estate Company III), started in September 1991. Each farmer received two ha of rubber in 1986 when the plantation was six years old and the trees ready to tap. The Livestock Research Institute delivered 60 sheep to the farmers in November 1991. Twelve farmers received four ewes and one ram each and must pay back four animals within two years (Sembiring and Scholz, 1991). It is hypothesized that diversification of income by rearing sheep will provide the necessary incentive for farmers to reduce overtapping of rubber. Overtapping is commonly practiced by farmers in order to maximize short-term needs for cash.

Before proceeding to the economics of sheep rearing under rubber in OPMM, a brief review of some key findings of the economics research program of the SR-CRSP in Indonesia are briefly noted.

Karokaro et al. (1990) found out that by rearing sheep, the average additional profit per ORP farmer was Rp 272,300/year (U.S. $149.62/year) and average returns to labor of Rp 119/hr (U.S. $.07/hr)

The most important factors influencing economic returns at farm level were prices, litter size, survival rate, growth rate of lambs, and lambing interval. Litter size could be divided into litter size at birth and litter size at weaning (Verwilghen et al., 1992). Litter size at birth on the ORP (Sei Putih) farms is 1.33 lambs per litter, while litter size at weaning is 1.27 lambs per litter. Survival rate is defined as the percentage of lambs born that are still alive at weaning. The overall survival rate for lambs born at ORP farms is 92.5%. Survival rate of lambs strongly depends on litter size. The survival rate of singles, twins, and triplets was 96%, 91%, and 77%, respectively. The average daily weight gain of lambs on the ORP farms is 79 grams per day with a standard deviation of 20 grams per day. With an average litter size at birth of 1.33, a survival rate of 92.5%, a lambing interval of approximately seven months, and an average flock size of nine ewes, the average number of lambs weaned per ORP farm is 19 lambs per year. Assuming that the weight of lambs at sale is 15 kg and the price per kg live weight is Rp 2500 (U.S. $1.20), the average gross returns per farm per year are Rp 712,500 (U.S. $350). From the eleven ORP farmers who started in 1988, the average annual net income per farmer in 1989 was approximately Rp 1.8 million (U.S. $900), excluding net income from sheep farming. Thus, the net income from sheep has raised farm income by about 40% (Verwilghen et al., 1992).

A major disease problem among sheep in North Sumatra is helminth infection, namely gastro-intestinal worms and pancreatic fluke. Therefore, anthelmintic treatment of the sheep is very important. Scholz (1992) suggests that anthelmintic treatment increases ewe productivity by as much as Rp 42,000 or 29 percent, assuming that survival rate increases from 0.85 to 0.95 with treatment. Having seen the benefit, farmers now regularly apply anthelmintic treatment. An Animal Health Delivery Network has been established to ensure proper distribution of anthelmintic to farmers (Kartamulia, et al., 1992).

Sheep are sold locally or in Medan, the capital of North Sumatra, mostly through middlemen. Live weight selling prices are Rp 2250 per kg (locally) and Rp 2500 per kg (in Medan). There is also the possibility of exporting live sheep to Singapore, Malaysia, and the Middle East (Kartamulia, et al., 1993).

Case study of OPMM farmers and households

Most farmers that joined OPMM are over thirty years of age (range 35-57 years) and have large families (average of 6.4 children). When the project started, most farmers had some experience rearing livestock (range 0-33 years, average of 9.5 years). They are all Muslims; two are ethnically Batak whereas the rest are Javanese. Except for one, they all have sufficient education to be considered literate. Their children are also literate and most go on to junior and senior high school (Sembiring and Scholz, 1992).

Rubber production system, yearly income, and resources available

Rubber trees were planted in 1980 by PTP III and were transferred to farmers in 1986 when the trees were ready to tap (Sembiring and Scholz, 1992). Farmers, their wives, and sons over 14 years of age tap the trees in the morning, collect the latex, and sell the latex, to the Village Cooperative Unit (KUD). Brown and Handayani (1993) reported that husbands work on their farm and off-farm job for 6 hours and 49 minutes, while the wives for 4 hours and 25 minutes and the sons for 5 hours and 34 minutes per day.

The average income earned by farmers from rubber in 1991 was Rp 2.7 million or approximately U.S. $1350, which comes close to the Indonesian Government target in the last five-year plan (U.S. $1500). However, these farmers should repay an average of Rp 680,000 or U.S. $340 per year for the two hectares of rubber plantation and have to pay for housing which yields a net income of about U.S. $ 900 per year is realized. Household expenditure patterns reveal that the largest single item in the budget is still rice, followed by other food, school fees, and uniforms for school children.

Sheep rearing

Sheep are housed in 2 m x 4 m barns. More recently, the barns were enlarged to facilitate more young rams which should be confined separately from other sheep to prevent inbreeding. The barns are placed close to the house to guard sheep more easily.

Sheep are fed with rice bran (200 g/day/sheep) in the morning and in the evening. During the day, after school (1:00 to 5:00 p.m.), sheep are herded (usually by boys) for grazing under rubber trees or grassfields surrounding the rubber trees. Meanwhile, farmers or boys cut grass to feed the sheep in the barns at night. Some farmers provide fire and smoke under the barn as it is believed that smoke helps prevent sheep from disease and from biting insects.

Sheep are regularly treated with anthelminthic every three months. Mineral blocks are hung in the barn to provide essential minerals.

Average birth weight and weaning weight are 2.5 kg and 8.5 kg respectively. The overall survival rate for lambs born at OPMM farms is 95.23%. The number of sheep held by all farmers at OPMM at the end of July 1993 is 221 head consisting of 82 ewes, 28 rams, and 111 lambs. In addition, eight head were stolen by thieves, and nine head were sold for a total of Rp 603,500 or U.S. $289. Three head were slaughtered for farmers' own consumption, which is valued as Rp 165,000 or U.S. $79.

Production parameters

This section represents gross figures for the 20-month period during which ORP has operated in Membang Muda. The figures are aggregated for all 12 farms. At this stage, we only have data on gross animal numbers and disposal; later work will summarize productivity parameters for the individual farmers' flocks as has been reported earlier for ORP Sei Putih.

The original numbers of animal distributed and numbers held as of July 1993 are presented in Table 1 for all 12 farms. Mortality losses are not shown above and averaged 4.76% of lambs from birth to weaning. The net increase in inventory was thus 34 ewes, 16 rams, and 111 lambs, or a total of 161. The value represented by this change of inventory is calculated at the end of the next section.

Table 1. Numbers of animal distributed and held by farmers.

	November 1991	July 1993	Change
Ewes	48	82	34
Rams	12	28	16
Lambs	0	111	111
Sales	n.a.	9	9
Consumption	n.a.	3	3
Theft losses	n.a.	8	8
Increase			181

Economic analysis

Gross margin analysis as illustrated by Lai (1987) is used to evaluate economic return of sheep enterprise in rubber plantations. Based on the above information, the gross margin analysis is depicted in Table 2 which is an aggregate for all 12 farms over the post 20 months.

Table 2 indicates that a net-income of Rp 5,880,300 or U.S. $2,820 during the 20-month period could be generated from rearing sheep in rubber plantations for 12 farmers, or approximately $196/year/farmer.

Table 2. Gross margin for sheep grazing in rubber plantations.

Gross Production Income	Rp	
Sales of animals	603,500	
Animals slaughtered	165,000	
Net inventory change of sheep	6,430,000	
Total value added		Rp 7,198,500
Variable Costs		
Brooms and basins	43,200	
Ropes	15,000	
Medications	207,000	
Mineral blocks	264,000	
Rice bran	165,000	
Miscellaneous	48,000	
Total		Rp 742,200
GROSS MARGIN		Rp 6,456,300
Fixed Cost		
Depreciation costs* (barn)	576,000	
Total fixed cost	576,000	
NET FARM INCOME FROM SHEEP		Rp 5,880,300

* See calculation which follows.

Depreciation rate = 20% of total capital expenditure

a) Fixed Cost - barns = 12 barns x Rp 240,000/barn = Rp 2,880,000

b) Sales of Animals: 9 animals at Rp 67,055 = Rp 603,500

c) Slaughtered Animals: 3 animals at Rp 55,000 = Rp 165,000

d) Estimated Valuation of Net Inventory Change

Weight (kg)	Value/animal (RP)	No. of animals	Value (RP)
> 20	50,000	50	2,500,000
15 - 20	40,000	60	2,400,000
< 15	30,000	51	1,530,000
Total		161	6,430,000

e) All values in Indonesian Rupiah.
One U.S. dollar is equivalent to 2,085 Indonesian rupiah.

Conclusion

Compared to U.S. $900/year/farmer, the net income from rubber farming, the additional net income incurred from rearing sheep accounted for 21.77%. This income is higher than ORP farmers' income in Galang, which was Rp 272,300/year/farmer or U.S. $149.62/year/farmer (Karokaro et al., 1990), but lesser than the findings of Verwilghen et al. (1992) which indicates that the average gross returns per farm per year to ORP farmers were Rp 712,500 (U.S. $350), accounting for 40% above income from rubber. Verwilghen et al. (1992), however, did not count costs for rearing sheep so net income could not be enumerated.

From the economic point of view, grazing sheep in rubber plantations can be a good source of additional income for the farmers. In addition to the cash income, grazing sheep under rubber trees have other advantages. It can reduce overtapping rubber, thus preventing a reduction in the lifetime of a plantation. It also reduces the need for weeding between rubber trees.

The contribution of sheep rearing to farmers' income can further be increased by increasing flock size. The ongoing collaborative work between SR-CRSP and PTPs provide 10 ewes to 1 ram to each smallholders. These relatively small flocks will increase farmers' income by more than 30%.

Literature Cited

Brown, R.P. and Handayani. 1993. Bio-social roles in peasant small-ruminant production: the importance of children versus women in secondary activities. Working Paper. Mississippi State University.

Dereindra, R., L. Batubara, S. Karo-Karo, Z. Zen and A. Arsjad. 1991. Prospects for sheep husbandry and socioeconomic constraints in the nucleus estate and smallholder project in Indonesia. In Iniguez, L.C. and M.D. Sanchez (eds.). Integrated tree cropping and small ruminant production systems. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, September 9-14, 1990. Small Ruminant Collaborative Research Support Program (SR-CRSP), University of California, Davis.

Karokaro, S., E. Sembiring, M.D. Sanchez and H.C. Knipscheer. 1990. Cost benefit analysis of sheep production at the village level in the outreach research project, North Sumatra. Working Paper No. 116. Balai Penelitian Ternak Pusat Penelitian dan Pengembangan Ternak, Bogor.

Kartamulia, I., S. Karokaro, A. Misniwaty, J. DeBoer, and H. Knipscheer. 1993. Characteristics of the international market for live sheep and potential for live sheep exports from North Sumatra. Annual Report 1993. Small Ruminant Collaborative Research Support Program, Sungai Putih, Indonesia.

Kartamulia, I., A. Misniwaty, and M. Doloksaribu. 1992. The development of an animal health delivery network in North Sumatra. Annual Report 1992. Small Ruminant Collaborative Research Support Program, Sungai Putih, Indonesia.

Lai, T.K. 1987. On-farm research in Malaysia: illustration of economic analysis. In Amir, P. and H.C. Knipscheer (eds.). 1987. On-farm animal research/extension and its economic analysis. Winrock International Institute for Agric. Dev., Morrilton, Arkansas, U.S.A.

Scholz, S. 1992. The economics of treating parasites in small ruminants. Working Paper No. 130. Winrock International, Morrilton, AR, U.S.A. and SR-CRSP/SBPT, North Sumatra, Indonesia. Sembiring, E. and S. Scholz. 1991. Socioeconomic survey of farmers in Membang Muda Outreach Project. Working Paper No. 128. Winrock International, Morrilton, Arkansas, U.S.A., and SR-CRSP/SBPT, North Sumatra, Indonesia.

Thomas, D.L. and G.E. Bradford. 1991. Evaluation of potential for hair sheep in integrated tree cropping and small ruminant production systems in the humid tropics. In Iniguez, L.C. and M.D. Sanchez (eds.). Integrated tree cropping and small ruminant production systems. Proceedings of a workshop on research methodologies. Medan, North Sumatra, Indonesia, September 9-14, 1990. Small Ruminant Collaborative Research Support Program (SR-CRSP), University of California, Davis.

Verwilghen, J., T. van Schie, A.D. Pitono, and E. Sembiring. 1992. Production of sheep in villages adjoining rubber plantations. Annual Report 1992. Small Ruminant Collaborative Research Support Program, Sungai Putih, Indonesia.

Genetic Variation In Prolificacy Of Indonesian Sheep And Its Use In Increasing Productivity

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Abstract

Exceptional prolificacy of Indonesian sheep has been reported frequently, but mean prolificacy levels are not exceptionally high. Research conducted by the Small Ruminant CRSP breeding project in Indonesia has shown that this apparent anomaly is due to segregation at a locus (designated FecJ) with a large effect on ovulation rate and litter size. Ewes possessing the FecJF allele frequently have triplets and, if homozygous, higher multiples; ewes lacking the gene have singles and a modest frequency of twins. Mean litter sizes for $FecJ^+$ $FecJ^+$ ewes is 1.2 to 1.3, for $FecJ^F$ $FecJ^+$ ewes is 1.9 to 2.1, and for $FecJ^F$ $FecJ^F$ ewes is 2.6 to 2.8. Effect of the $FecJ^F$ on total weight of lamb weaned per ewe depends on level of feeding and management. Under unfavorable conditions, the gene is detrimental; under favorable conditions, it can increase productivity by up to 60%. Based on presently available information on inputs feasible in farmer flocks in Indonesia, it is recommended that the allele be eliminated in flocks dependent entirely on forage, i.e., that the breeding program be designed to produce $FecJ^+$ $FecJ^+$ ewes only. Where an economical supply of supplementary concentrate feed is available, use of $FecJ^F$ $FecJ^+$ ewes can lead to substantial increases in flock productivity. A breeding program to produce such ewes is outlined. Availability of a means of genotyping animals of both sexes for the FecJ locus would greatly facilitate control of genetic variation in prolificacy. Research toward that goal is in progress.

Introduction

Indonesian sheep have been reported to be highly prolific (Mason, 1978, 1980). However, mean litter sizes quoted by Mason and other authors have usually been in the range of 1.5 to 1.9, i.e., not exceptionally high. The explanation for this apparent inconsistency lies in the fact that there is an unusual degree of variability in prolificacy between ewes within groups, which was documented by data in the Balai Peneliton Ternak flock at Cicadas in the first year of SR-CRSP research in Indonesia. The SR-CRSP breeding project therefore took as a primary objective the characterization of the variation in prolificacy between, and within, strains and individual ewes and determination of the extent to which this variation is inherited as well as the mode of inheritance.

Inheritance of litter size in Indonesian sheep

This research has documented the existence of a gene with large effect on ovulation rate and litter size which is segregating in different breeds and strains of Indonesian sheep (Bradford et al., 1986, 1991). The first of the above reports presented evidence that the gene, which resembles the Booroola gene ($FecB^F$) (Piper et al., 1985) in its effect, is segregating in Javanese Thin Tail (JTT), Javanese Fat Tail (JFT), and Semarang sheep in Java. The data of Reese (1988) and Iniguez et al. (1991) suggest that the gene is also present, at least at

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low frequency, in Sumatran sheep. The evidence consists of unusually high repeatability and heritability of ovulation rate and litter size, and the pattern of transmission of these traits. The effect of the gene is an increase of approximately .8 in ovulation rate and about .7 in litter size at birth, per FecJF (Bradford et al., 1991), which is slightly less than the effect of the Booroola gene reported by Piper et al. (1985).

The gene has been designated as the $FecJ^F$ (Javanese fecundity) gene. The criteria for classification of ewes at the FecJ locus suggested by Bradford et al. (1991) are as follows:

$FecJ^+$ $FecJ^+$ -	Ewes with three or more ovulation rate or litter size records ≤ 2, with a mean < 1.7.
$FecJ^F$ $FecJ^+$ -	Ewes with one or more records of 3, or a high frequency of 2's (all 2's if n = 3),or with a mean ≥ 1.7, if n≥4.
FecJF FecJF -	Ewes with 1 or more records of ≥ 4.

*such ewes usually have many 3's as well. Range 1-8.

These criteria are not completely accurate, in that an occasional heterozygous ewe with one record of 4 has been identified, but such ewes tend to have a mean ovulation rate of 2.0 to 2.5, whereas $FecJ^F$ $FecJ^F$ ewes tend to have a mean of at least 3. Also, the above criteria do not permit accurate classification of ewes with only one or two records of 1 or 2. Some ewes with three records may also not be classified accurately; e.g., a ewe with successive litter sizes of 1, 2, and 2 may prove to be either $FecJ^+$ $FecJ^+$ or $FecJ^F$ $FecJ^+$ with further records. However, it appears that over 90% of ewes with three or more records will be correctly classified using the above criteria. As for the Booroola gene, ovulation rate is a more accurate basis of classification than litter size. However, prenatal survival in Javanese sheep appears to be unusually high (Bradford et al., 1986), which means the discrepancy between ovulation rate and litter size is less than in some breeds.

Impact of the $FecJ^F$ gene

Number of lambs born sets an upper limit to output per ewe in terms of weight of lamb produced per reproductive cycle. Thus a gene that results in a large increase in litter size provides, potentially, an effective means of creating an immediate increase in productivity of the sheep flock. However, lamb mortality rate increases and individual weaning weight decreases as litter size increases, and, depending on the mortality rates of singles, twins, and lambs in larger litters, an increase in litter size of the magnitude created by the FecJ gene, in either heterozygous or homozygous state, may or may not increase output.

Inounu et al. (1993) have evaluated the effects of the FecJF allele on total weight of lamb weaned per ewe for two locations: Cicadas (nine years) where feeding and management levels were limiting and Bogor (one year) where both feeding during pregnancy and lactation, and management at lambing, were markedly improved. The results are presented in Table 1.

Table 1. Litter size, lamb survival, and litter weaning weight for different environmental conditions, for $FecJ^+$ $FecJ^+$, $FecJ^F$ $FecJ^+$, and $FecJ^F$ $FecJ^F$ ewes (from Inounu et al., 1993).

	Ewe genotype		
	$FecJ^+$ $FecJ^+$	FecJF $FecJ^+$	$FecJ^F$ $FecJ^F$
Litter size (all years)	1.24	1.95	2.59
Ewe postpartum wt (kg)			
Cicadas: poorest 4 yrs	25.5	25.0	24.9
best 5 yrs	27.1	27.1	28.3
Bogor: 1991	30.6	30.2	31.7
Lamb survival (%)			
Cicadas: poorest 4 yrs	74.3	58.2	40.9
best 5 yrs	89.3	75.3	59.3
Bogor: 1991	89.7	79.9	87.9
Litter wt. weaned/ewe (kg)			
Cicadas: poorest 4 yrs	7.7	7.4	6.7
best 5 yrs	10.9	11.9	12.2
Bogor: 1991	17.0	20.0	27.1

The results in Table 1 show a striking interaction between level of feeding and management and ewe genotype for total weight of lamb weaned per ewe. Under the least favorable conditions, the $FecJ^F$ allele reduced total output; under the best conditions it contributed to a statistically significant and economically important increase. The value of the gene therefore depends on the conditions in which the animals are to be kept.

Data from village flocks (Gatenby et al., 1988) in Indonesia suggest that feeding and management level will usually be better than that which pertained in even the better years in the Cicadas flock, though it probably will not be as good as in the Bogor 1991 situation. The $FecJ^F$ allele therefore may contribute to an increase in gross output from Indonesian farmer flocks, though an economic assessment of the returns per unit of extra input needed for the more prolific ewes has not yet been completed.

Based on knowledge of other sheep production systems, we believe that unless an economical source of supplementary concentrate feed is available, $FecJ^+$ $FecJ^+$ ewes may be the most efficient for Indonesian village conditions. This conclusion is based on the assumption that the year-round breeding ability of Javanese sheep will be utilized. Bell et al. (1982, 1983) and Iniguez et al. (1991) have shown that lambing intervals as short as 200 days are feasible. However, as shown by Bell et al. (1982), average intervals in village flocks are much longer, apparently due to inadequate estrus detection and mating management. If ewes are managed to lamb at, say, 230-day intervals, which should be readily achievable, this will give approximately 1.6 lambings per year. A litter size weaned of 1.10 (89% of 1.24 lambs born) and 1.6 lambings per year results in 1.75 lambs per ewe per year, a very good level of productivity, with predominantly single and no triplet births. This will require less feed during pregnancy and lactation and less skilled management at lambing than a mean litter size of 2 (with probably 25-30% triplets) and 87% lamb survival, once a year. If the $FecJ^+$ $FecJ^+$ ewes' lambing frequency could be increased to 1.8 per year, as is possible, a weaning rate of close to 2 lambs weaned/year, with non-prolific ewes, is feasible.

Where an economical supply of concentrate feed is reliably available, introduction of the $FecJ^F$ allele should result in a substantial increase in output/input ratio from the sheep flock. Although the 1991 Bogor data in Table 1 suggest that $FecJ^F$ $FecJ^F$ ewes have an advantage over $FecJ^F$ $FecJ^+$ ewes, these results are associated with a reversal of the expected relative survival rates from the two genotypes, probably due to sampling effects. On average, one would expect $FecJ^F$ $FecJ^+$ ewes to have a higher total weight weaned and $FecJ^F$ $FecJ^F$ ewes possibly lower output, than in these results. Further data are needed, but data from other studies of prolific sheep typically indicate an advantage for a mean litter size of 2.0 compared to 2.6. If one accepts this conclusion, then the $FecJ^F$ allele will be most useful in heterozygotes. Effective utilization in this form will necessitate a stratified breeding program, for example, as follows:

"A" flocks: FecJ+ $FecJ^+$ ewes mated to $FecJ^+$ $FecJ^+$ rams. Replacement ewes and rams produced within this flock or group of flocks.

"B" flocks: specialized flocks obtaining $FecJ^+$ $FecJ^+$ replacement ewes from "A" flocks and mating them to $FecJ^F$ $FecJ^F$ rams (from a homozygous flock maintained specifically to produce rams for crossing). All ram lambs to market, all ewe lambs to "C" flocks.

"C" flocks: specialized flocks, mating $FecJ^F$ $FecJ^+$ ewes to terminal sire breed rams (or growth-selected rams from "A" flocks); all lambs of both sexes slaughtered.

Further details on such a breeding program are given by Bradford (1993). In this system, a high level of feeding and management would be needed only in "C" flocks (and in the numerically small segment producing $FecJ^F$ $FecJ^F$ rams). "A" and "B" flocks would be made up of ewes, most of which would produce singles and none would be expected to produce triplets. The extra inputs needed for successful production from highly prolific ewes would not be needed in the latter flocks, which could be maintained satisfactorily under the traditional management system.

As an alternative to the above three-tiered system, the establishment of commercial $FecJ^F$ $FecJ^F$ flocks might be considered. In general, we believe that flocks with litters of three might be the modal class and that flocks with occasional litters of four and five will require too high a level of inputs, e.g., artificial

rearing on milk replacer, to be consistently profitable. Thus our recommendation at this time is that commercial use of the FecJ allele should focus on $FecJ^F$ $FecJ^+$ ewes.

Whatever the system chosen, knowledge of the mode of inheritance of prolificacy in Indonesian sheep provides a means of controlling the exceptional variation in prolificacy in these populations. Currently, flocks are a mix of genotypes, and a farmer does not know until a ewe lambs (often two or three times) what litter size to expect. Ewes produce 1, 2, or 3 or more lambs at any parturition. Therefore a feeding and management program for the average ewe, with 1.6 to 1.7 lambs, is not relevant. In any case, it would be too costly for a $FecJ^+$ $FecJ^+$ ewe and inadequate for a ewe carrying the $FecJ^F$ allele. It is now possible to ensure a relatively low genetic potential for prolificacy, i.e., ewes which will perform satisfactorily where supplementary feed is unavailable or too costly in some flocks, and a quite reliably high genetic potential for other flocks where the appropriate inputs are available. As shown in Table 1, a large increase in inputs slightly more than doubled the gross output from $FecJ^+$ $FecJ^+$ ewes; this would probably result in an increased net return, but may not be feasible in some situations. For ewes carrying at least one $FecJ^F$ allele, however, gross output, averaged over the two genotypes, increased 3.3 fold. Where the inputs are available, this would almost certainly increase net income. Under such circumstances, the allele should be used. The allele also offers a means of very rapidly increasing the productive potential of Indonesian sheep flocks without any introduction of exotic breeds, which may be poorly adapted to tropical conditions.

At present, classification of ewes as to their FecJ genotype requires at least one and usually three or more ovulation rate or litter size records, and classification of males depends on a progeny test, i.e., evaluation of the ovulation rate or litter size of large numbers of daughters from dams of known genotype. It is possible by these means, over time, to establish flocks which have only $FecJ^+$ $FecJ^+$ animals and, in principle, those with only $FecJ^F$ $FecJ^F$ animals, although the latter has not yet been achieved. Sorting of animals from mixed flocks into carrier and non-carrier groups is therefore a slow and, in the case of males, costly process.

A method of accurate classification of $FecJ^F$ genotype of animals of both sexes, applicable early in life, is therefore needed if the information on mode of inheritance of prolificacy in Indonesian sheep is to be used in the near future and on an extensive scale to improve sheep productivity. To this end, we are seeking to identify polymorphic microsatellite and/or Random Amplified Polymorphic DNA (RAPD) markers that are linked to the $FecJ^F$ locus. The recent detection of a microsatellite marker linked to the Booroola (FecB) locus (Montgomery et al., 1993) may facilitate this search, depending on whether the two genes are allelic. If not, the search may take some time. A rapid means of identifying the FecJ gene or a closely linked marker should eventually be found and will greatly accelerate control of prolificacy in Indonesian sheep.

Literature Cited

Bell, Monte, and Ismeth Inounu. 1982. Sheep reproduction parameters from sixteen farms in Sukawargi villige, District of Garut, West Java. Working Paper No. 8, SR-CRSP/BPT, Bogor, Indonesia.

Bell, Monte, Ismeth Inounu, Bess Tiesnamurti, and Subandriyo. 1983. Variability in reproductive performance of sheep among 22 farms in Tenjonegava and Suldangratu villages, District of Garut, West Java. Working Paper, No. 18, SR-CRSP/BPT, Bogor, Indonesia.

Bradford, G.E. 1993. Small ruminant breeding strategies for Indonesia. Proc. SR-CRSP Workshop, Bogor, August 3-5.

Bradford, G.E., J.F. Quirke, P. Sitorus, I. Inounu, B. Tiesnamurti, F.L. Bell, I.C. Fletcher, and D.T. Torell. 1986. Reproduction in Javanese sheep: evidence for a gene with large effect on ovulation rate and litter size. Journal of Animal Science 63:418-431.

Bradford, G.E., I. Inounu, L.C. Iniguez, B. Tiesnamurti, and D.L. Thomas. 1991. The prolificacy gene of Javanese sheep. pp. 67-73. In: Proceedings, 2nd International Workshop on Major Genes for Prolificacy in Sheep. Ed. J.M. Elsen, L. Bodin and J. Thimonier. INRA, France.

Gatenby, R.M., R.A.C. Jensen, Subandriyo, and G.E. Bradford. 1988. Actual and potential levels of performance of Indonesian sheep and goats under traditional management systems. Technical Report #97, SR-CRSP, UC Davis. 36 pp.

Iniguez, L., M. Sanchez, and S.P. Ginting. 1991. Productivity of Sumatran sheep in a system integrated with rubber plantation. Small Ruminant Res. 5:303-317.

Inounu, I., L. Iniguez, G.E. Bradford, Subandriyo, and B. Tiesnamurti. 1993. Production performance of prolific Javanese ewes. Small Ruminant Res (in press).

Mason, I.L. 1978. Sheep in Java. World Animal Review 27:19.

Mason, I.L. 1980. Prolific tropical sheep. FAO Animal Prod. Health Paper No. 17, Rome.

Montgomery, G.W., Crawford, A.M., Penty, J.M., Dodds, K.G., Ede, A.J. Henry, H.M. Pierson, C.A., Lord, E.A., Galloway, S.M., Schmack, A.E. Sise, J.A., Swarbrick, P.A., Hanrahan, V., Buchanan, F.C. and Hill, D.F. 1993 The ovine Booroola fecundity gene (Fec^B) is linked to markers from a region of human chromosome 4 q. Nature Genetics (in press).

Piper, L.R., B.M. Bindon, and G.H. Davis. 1985. The single gene inheritance of the high litter size of the Booroola Merino. pp. 115-125 in Genetics of Reproduction in Sheep. Ed. R.B. Land and D.W. Robinson. Butterworths, London.

Reese, A.A. 1988. Effects of energy supplementation on Indonesian sheep. Ph.D. Thesis, North Carolina State University. 139 pp.

Returns To Investments In Small Ruminant Research In Indonesia: The SR-CRSP In West Java

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Abstract

Small ruminant research carried out by the Small Ruminant CRSP on management, nutrition, and reproduction was tested through the Outreach Pilot Program in West Java, Indonesia. On-farm testing indicated that the levels of production through different management practices could increase the birth rate and survival rate of the Javanese Thin Tail Sheep. The following paper presents some results of the assessment of research investments in terms of the potential returns from this technological package, weights of these benefits against the costs of research and training of the SRCRSP, and looks at the distribution of these benefits among consumers and producers of sheep in Indonesia. The potential short-term benefits outweight the costs incurred by the breeding and nutrition research programs, as well as the funding of 23 graduate degrees. An important link in measuring potential returns are the means or mechanisms in place that facilitate adoption, i.e., the link with extension.

Introduction

Evaluations of the returns to livestock research in developing countries are not easy to find. Most are concerned with commercial production (dairy, forages, beef, and poultry); few deal with subsistence producers. The Small Ruminant Collaborative Research Support Program (SR-CRSP), and others like it created with AID funding during the seventies and eighties, was targeted at the problems of poor agricultural producers. The Small Ruminant CRSP recognized that poor families in the world usually raise small ruminants as a complementary activity (Durning and Brough, 1991) or as their sole activity. Large numbers of these families in developing countries, especially their women and children, are involved in raising small ruminants. Traditionally they do not have access to government services and/or policy decision making.

The SR-CRSP focused its efforts on research and institutional development with a view to strengthening institutions that will sustain research once the program has been completed. The University of California, Davis (Breeding), North Carolina State University (Nutrition), Universtity of Missouri-Columbia (Sociology), and Winrock International (Economics) collaborated in a comprehensive reseawrch program with the Reseach Insitute for Animal Production (RIAP) of Indonesia.

Several points must be considered when assessing the impact of the SR-CRSP in the development of technology for small ruminants: the process of research and technology production; the marginal areas in which small ruminants are produced; the potential high risks that producers face; and the institutional impacts expected through training to develop human capital.

Evaluation of a program like the SR-CRSP presents a challenge. The program encompasses basic research, development research, and human capital development. There is considerable lag between generating recommendations from research and their adoption in management; nutrition and reproduction studies have impacts that may be seen only after five or ten years of research, with longer lags in the case of breeding

trials and. Lags also exist between training and the impact of human capital development, which are difficult to measure in developing countries due to labor market distortions.

The present paper only considers the benefits of a management, nutrition, and reproduction technological package tested through the Outreach Pilot Program in West Java. The objective is to determine if the short and medium-term benefits of this technological package allow funding of long-term breeding research and training programs with longer adoption lags.

Indonesia and the SR-CRSP

Small ruminants are an important complementary activity in densely populated areas of Indonesia such as West Java, providing between 15 and 25 percent of the family income. They may be found on one out of five farms in Indonesia (DeBoer, 1985). There were 1,317,929 households raising sheep in Indonesia in 1983; 841,025 of them were in West Java.

Potential demand for meat

The population of Indonesia has grown from 147,490,298 in 1980 to 179,136,110 in 1989. The population growth rate is estimated at 1.8%.[1] Income and population growth are internal stimuli for increase in the demand for red meat, which is projected to remain strong for sheepa and goats (Knipscheer et al., 1987). Dramatic increases in demand are typical during Idul Adha, an Islamic holiday, when prices can double and even triple. There is also a potential demand from the Middle East.[2]

Meat accounts for 25% of the protein from non-plant sources that consumers in rural areas receive. The consumption in 1983 was 4.32 kg per capita, which is low, indicating a potential for substantial increase (Knipscheer et al., 1987) At that time only ten percent of the meat consumed was supplied by red meats. Increased income[3] allows greater consumption of red meat and simultaneously helps transfer income to producers that usually are poor.

Price trends, according to Knipscheer et al. (1987) also show a strong demand for red meats. Red meat prices tripled between 1977 and 1982, and the differential between this and poultry prices is increasing. Of the average of 1986-1988 meat production, which includes beef, mutton, goat, and poultry, 10.17 percent is from goat and mutton according to data from the Central Bureau of Statistics.

Small ruminant production in West Java

The population of sheep in Indonesia, based on the household survey by SUSENAS, was estimated at 5,364,000 head in 1987. Of these sheep, 2,423,318 were in West Java and 1,248,834 were in Central Java. Estimates developed by the AARD-ISNAR[4] study show meat supply in West Java growing from 8,096 MT in 1983 to 10,264 MT in 1988, a 27 percent growth in five years. Currently all production is consumed domestically.

"Most sheep and goats are raised by smallholders in highly intensive, crop/livestock production systems with a herd size rarely exceeding five head. Increased herd sizes are found in areas where dry farming is practiced" (Blond 1985, p. 56). The Javanese Thin-Tail (JTT) sheep is found in West Java, generally raised in a zero-grazing or cut-and-carry system. Most sheep in this area are kept in barns with a raised floor. The average small ruminant producer has five to six animals. Supply of animal feed is constrained by the ability of the farmer to collect it and by the size of the farm. About 30 percent of the feed comes from off-farm sources. Feed is composed of grasses (80% in Garut), tree leaves (8.5%), agricultural by-products (9%; rice and bean straw, cassava and corn leaves), and shrubs (2%) (Suparyanto et al., 1992). The average litter size per parturition is high, 1.7 lambs, but mortality rate is also high when triplets and quadruplets are born. On average, there are 14 rams per 100 ewes in West Java, or one ram per seven ewes. In many cases rams are borrowed for the mating season. Actual and potential productivity coefficients (Table 1) have been developed by Gatenby et al. (1988). 'Actual' is the productivity at the village level and 'potential' is that obtained at the research station. The lambing interval and pre-weaning mortality, which varies from 5 to 39%, can both be reduced by improved management practices.

Table 1. Actual and Potential Productivity Coefficients for Javanese Thin Tail Sheep.

	Actual	Potential	Ratio
Litter size	1.4	1.8	0.78
Lambing Interval d.	520	240	0.46
Age first Lambing d.	500	420	0.84
Survival to 90 days %	74	85	0.77
Pre-weaning growth (g/d)	67	85	0.67
Weaning weight (kg)	8.30	12	0.69
Weaning rate (per year)	0.73	2.32	0.31
Productivity per year %	27	110	0.29
Average growth (g/d)	87		
Body weight puberty	17-20		

Source: Gatenby, R. M., Jensen, R. A. C., Subandriyo and Bradford, G.E. 1988. "Actual and Potential performance of Indonesian Sheep and Goats Under Traditional Management Systems," SR-CRSP Tech. Report No. 97.

Raising sheep is a family activity, with grass being cut and fed to animals twice a day. Selling and buying animals, on the other hand, is a male activity. Women have a higher participation in livestock activities when the household is poorer, and can spend up to 2.5 hours per day collecting forage, taking care of both crops and livestock as well as instructing their children on these activities (Wayhuni et al., 1992).

SR-CRSP research results: The outreach pilot project (OPP)

"The small ruminant production potential of the OPP animals was constrained by genetic, environmental, and management factors. Generally, under village conditions, animal productivity is low which is reflected by low body weights, high pre-weaning mortalities, long lambing/kidding intervals, and the unavailability of rams/bucks for breeding" (Ludgate and Priyanti, 1990). The outreach pilot project is a demonstration project (MU, 1987) in Bogor, West Java, that integrates the expertise and insights of all four biological and social science projects.[5] It showcases the results of research into small ruminant nutrition and breeding in the humid tropics.

Three functions were expected of the OPP: 1) a testing ground for new technologies; 2) a demonstration farm to spread knowledge; and 3) a breeding multiplication center. Studies were multidisciplinary in focus, including social science research, sociology, and economics, and occuured at the village level. Ludgate et al. (1990) conducted an evaluation of the OPP's five years of on-farm testing using three discipline parameters: breeding/reproduction, economic/marketing information, and management. Some criteria which were not included in the evaluation may be important to benefit measurement (Mawi et al., 1989).

Results of the OPP evaluation showed that lamb mortality rates decreased from 20.5% to 9.3% in the first year of communication, and rose to 11% afterwards. The minimum lambing interval is approximately 240 days but can be of 360-450 days with traditional animal management. Lambing interval at the OPP was reduced to 246 days, which implies the possibility of three lambings in two years, instead of the traditional one lambing a year, a fifty percent increase in yield per ewe Setiadi and Iniguez (1990).

In many cases absence of rams is a problem, which could be addressed by a sharing system devised to reduce the lambing cycle. Sharing of rams was part of the technical package developed through the OPP. The first socio-economic evaluation (Priyanti et al., 1988) points out that 88% of the farmers agreed with the proposed sharing system, although traditional methods of sharing rams also exist (Sabrani and Knipscheer, 1982).

Ludgate et al.(1990) estimated a population of 2 million adult ewes in West Java (versus are 2,423,320 sheep according to Indonesian statistics for 1987). Assuming only one lamb per lambing and a survival rate of 85%, the adoption of the OPP technical package could represent an increase in production

of 1.7 million more lambs. This potential impact assumes one hundred percent adoption by the farmers,6 which is unlikely due to the present limitations of the extension service.

In an overall evaluation of the OPP, by Ludgate et al. state "An analysis of the OPP research data indicates the farmers' success in improving productivity and suggests areas where further research is needed. The success of the OPP on-farm research model has provided further support to the contention that farmers should actively participate throughout the technology development process" (Working Paper 122, p.26).

Technology

Monitoring of the farmers, management, feeding and marketing practices were carried out during the existence of the OPP and after it terminated. Measures of adoption of techniques were presented in several working papers of the SR-CRSP in Indonesia. Barn separations by physiological status and improved barn management recommendations were adopted by 88% of the farmers. Recommended feeding and management practices (Martawidjaja et al., 1990) were developed and tested in the OPP. Yulistiani et al. (1989) present and evaluate the four technological packages: barn separation by physiological status and feeding regime; roughage feeding throughout the year; salt and water; and legume tree planting. The evaluation done of the nutrition techpack in 1990 by Haryanto et al. (1990), shows seasonal variation in the adoption of the feeding practices, especially in the provision of water and salt. Bilinsky and Gaylord (1992) carried out an adoption study of *Gliricidia maculata* with OPP farmers. Adoption rose from 7 to 67% in two years. Most farmers used it as a supplement in the animal diet. Limited supply and land scarcity were some of the limiting factors in adoption.

Various practices were adopted in varying degrees when the monitoring was in place. These ranged from 5 to 88 percent depending on the season and the nature of the technique. The average yields obtained through OPP have been reported and show this wide range of adoption. Soedjana, Priyanti, and Mujchi (unpublished) collected and processed surveys for the six-month evaluation after the OPP expired, which was kindly shared with this study. Their data show that 84% of the farmers give enough feed (40% feed grasses and tree legumes or grasses and feed supplement), while 48% of the farmers feed grasses and agricultural by-products, with similar percentages of feed availability for young animals, dry ewes, pregnant and lactating ewes, and rams. The feed given was fresh for 84% of the farmers, salt availability was 48% and water availability (clean in the bucket) was 28%. Barn separation and soundness was 44% for the four separation types. Another survey done recently showed that purchased inputs are still a constraining factor.

Returns to research

Two traditional methods to measure economic returns to research exist; one is the econometric approach that treats expenditures in research as a variable to the production function estimated and allows one to estimate the marginal returns on investment. The other approach, the economic surplus model, estimates the average returns to investment by determining the movement or shift of the supply function due to research and looking at the changes in consumer and producer surplus. The return to investment in research can be expressed as an average rate (internal rate of return) for an entire project, given specified expenditures. Echeverría (1990), Daniels et al. (1990), and Norton and Davis (1981) discuss the economic surplus approach.[7] Echeverría's review finds that most of these show high rates of returns for agriculture and underinvestment in this sector.

Assessment studies of crops in developing countries easily outnumber those on livestock and forages. The reviews by Echeverría (1990) and Daniels et al. (1990) on returns to research, yield similar results. Most of the livestock (dairy, beef, and pastures) returns to research were calculated for the United States, Canada, and Australia. For sheep in less developed countries, both cite the same study by Wennergren and Whitaker (1977) done originally for sheep in Bolivia, which later incorporated wheat with marginal returns that fluctuate between 44 and 48 percent. Wennergren and Whitaker analyzed returns to investment of the USAID Technical Assistance Program to Bolivia between 1965 and 1974, using a conventional benefit-cost analysis that emphasized: a) introducing improved management practices, b) upgrading the genetic base of livestock, c) increasing forage production, and d) improving and developing product markets. They assumed

that increases in net returns to farmers were a result of the marginal U.S. investment.[8]

The evaluation of pastures in Latin America by Seré and Jarvis' (1990), obtained 15 to 20 percent returns with an eleven-year lag. Their analysis looks at the returns to research (ex-ante) and measures the impact of improved pasture research in different scenarios, assuming increased free international trade and accomodating the role of poultry in the demand for beef in the tropics of Latin America.

Schwartz and Oehmke (1990) argue in favor of benefit/cost approach to analysis. Economic policies affecting relative prices at the producer and consumer level will affect the rate of return of research in agriculture and can be captured by this method. The rate of return calculation requires defining the acceptable return, which is based on the cost of funding. In developed countries this is around 10 percent not accounting for inflation. The World Bank's range is 8-15 percent and USAID's of 11 percent are considered acceptable. "The rate of return is the maximum interest that a project could pay for resources used if the project is to recover its investment and still break even" (Gittinger, 1982). In their evaluation of the bean/cowpea project, Schwartz and Oehmke (1990) indicate that it is important to list those intangible benefits that are not considered in a classical rates-of-return analysis. Alston and Scobie (1983) point out that it is important to determine at what level in the production chain the surplus is being calculated to determine whose benefits are included in producer and consumer surplus. Lags exist between the research and development of technology, and the adoption, and tend to be larger in the case of livestock research. The shorter the lags, the greater the impact in the early years resulting in larger economic returns. The pattern of adoption will also impact returns.

The SR-CRSP's OPP economic surplus model and results

The Outreach Pilot Program (OPP) on sheep management, reproduction, and nutrition was assessed in an economic model. The costs of a breeding program on high prolific sheep in Java that has been successful as a research project, but whose results have not yet been translated into technologies presented for farmer adoption, were included in the economic analysis. The training costs of human capital development are also included although the benefits of this and program are also not included. The objective of the analysis is to determine if the short-term impact of improved sheep management, reproduction, and nutrition practices can finance the other programs which have long lag periods.

Method of surplus calculation and distribution

The economic surplus model-intermediate variant (Norton, et al., forthcoming), used for ex-post studies or research priority setting, requires estimates of commodity-specific price elasticities of supply and demand, quantities traded internationally (if there is an open economy), and agricultural policies. Economic surplus models are a step up because assumptions of constant prices are dropped, and market conditions as well as policy distortions can be introduced (Norton et al., forthcomming). Norton et al. derive equations used to calculate the distribution of the gains or returns to research. Total surplus, as well as consumer and producer surplus, are calculated as a function of base prices and quantities, demand and supply elasticities, and the vertical shift in the supply shift measured as a unit cost reduction. Parallel shifts are assumed. The equations are:

Change in consumer surplus:

$$CS' = PQZ(1 + 0.5Zn)$$

Change in producer surplus:

$$PS' = PQ\,(K-Z)(1 + 0.5Zn)$$

where:

$Z = (Ke)/(e+n)$

e:supply price elasticity

n: demand price elasticity

K: vertical shift of supply function expressed as percentage of initial price

P: original price

Q: original quantity

' : change

An estimate of the cost change (K, where K is the vertical shift of the supply curve), J (yield change due to the technology), and the probability of success of the research (if this has not been concluded), as well as estimates of adoption rate need to be included. K is calculated by determining the unit change in the cost of production due to the introduction of the technology at the original level of production.
The natural increase in demand every year is equal to:

$$D = p + mg$$

where:
p is growth rate of the population, m is income elasticity, and g is GDP per capita growth rate. This is used to shift the demand function each year. Adoption of technology will shift the supply function, and population and income growth rates will shift the demand function. These shifts take place until the adoption ceiling has been reached. Market and policies that influence the output are identified. The market for mutton is closed at present, meaning that currently no exports or imports are taking place. However, there are policies in place affecting the possibilities of export.

Data for this evaluation
Quantities and prices for a base year, the elasticities of the identified markets, and interviews with scientists to determine yield changes, cost changes, research success, adoption rate, and ceilings in adoption, are necessary. An important number of statistics were provided by Dr. Philip Pardey at the International Service for National Agricultural Research (Bahri et al., 1991), who was at the time working with the government of Indonesia[9] on the ex-ante evaluation of research in agriculture.

Income and demand elasticities were obtained from various studies and from a review done by Dr. Pardey's project.[10] The supply elasticity was estimated by Nu Nu San[11] (Valdivia, 1992). To determine shifts in demand, projections of population and income growth are required. Population data and Gross Domestic Product per capita were obtained from International Financial Statistics (International Monetary Fund) and the Handbook of Economic Statistics (CIA).

Research costs were collected from the research program Management Entity, University of California, Davis. Budgets from each participating institution in the U.S. from 1980 through 1990 were used to obtain information on the level of the grant allocated to each country (Indonesia in this case), the level of the grant budgeted in the U.S. and the level of money spent in training graduate students from Indonesia and the U.S. from 1981 to 1990. The costs consider a weighted average of funds budgeted for the U.S., and include the research costs, borne by the Government of Indonesia, of four full time researchers (De Boer, 1991). In the case where the component was phased out, and when projects started working in the hair sheep component in North Sumatra, percentages were calculated based on estimates from the principal investigators.

Markets, adoption, supply shifts, and returns
Geographical spread and the rate of adoption are necessary to determine the level and distribution of benefits. It is important to know site specificity and the recommendation domain. A detailed ex-ante evaluation of research in Indonesia provides information on geographical regions where small ruminants can be introduced (Pardey and Wood, 1991).

A first calculation of the returns only considers impact in West Java with a peak adoption of 20%. Researchers at RIAP were confident that the technologies developed in RIAP and tested at the OPP could be adopted in other regions, such as Sumatra. Research lags were estimated by Pardey, Eveleens Abdurachma, and Hermanto.[12] The research lag for sheep management and nutrition is three years, for breeding and genetic improvement it is ten years from the time the research is successfully completed, and for health research it is four years.

A second adoption pattern that includes other provinces of Indonesia is also presented. Pardey and Wood (1991) developed a model for ex-ante evaluation that identifies spillovers of research across Indonesia. The final results of this study were not available. A first approximation considers use of the OPP results in Java and Sumatra.

Cost reductions of a yield increase are calculated by computing yield changes, and additional inputs required to obtain this yield, to net out the additional costs. In Indonesia's Outreach Pilot Project, cost calculations were made with the collaboration of Atien Priyanti.[13]

Additional costs per sheep on a yearly basis[14] considered drenching, barn separations, salt and water buckets. Additional costs per sheep were 270 Rp. per sheep per year. Initial barn construction with a year depreciation for ten sheep was 125,000 Rp. Ten sheep per year were valued at 25,000 Rp. The assumption was that no other purchased inputs were used. With the management and nutrition tech pack the costs were 27,700 Rp per year for ten animals. At the original level of production, costs per sheep were 8,300 Rp. With the new technology, at previous level of production, the cost is 6,155 per sheep. This calculation assumed a yield change of 50% and a mortality rate of 11%. The per unit cost change (K) calculated is 25 percent.

The adoption rate peak was predicted to be 20 percent for farmers in West Java, assuming that ewes available were 39.14% of the animals. Ewe availability was based on the records kept by the OPP. Inventoried animals estimated for 1989 were used as the base.

The price used was a weighted average price of rams and ewes reported by Soedjana and Priyanti for 1989. Their report stated that 66% of the animals sold were male and 34% were female. The price for a male ram was 78,400 Rp. and 72,250 for a ewe. These represented 66 percent of the sales. Younger animals were sold at an average price of 46,150 Rp. (34% of the animals sold). These data were used to determine a weighted average price of 65,500 Rp. An exchange rate of 2,265 Rp./dollar generated a price of 28.91 dollars per sheep, which was used as the base price.

The sheep supply elasticity used was 0.3 (Valdivia, 1992) and the demand elasticity was -1.03 (uncompensated demand elasticity for meats, by Johnson et al., 1987). The income elasticity was 1.6 (Sarma, 1986). Population growth rate was 1.8% (1990) and per capita GDP was 0.1 percent (1990). The SR-CRSP budgets and production and consumption statistics are also included. Costs budgeted for the SR-CRSP in Indonesia and those attributed to West Java are presented in Table 2. These costs include training, research travel, and U.S. research expenses for the four U.S. institutions, University of California, Davis (Breeding), North Carolina State University (Nutrition), University of Missouri (Sociology) and Winrock International (Economics). Estimates of U.S. budget allocations to each country and phase out from Java to Sumatra were obtained from the principal investigators. These costs also include four Indonesian full time researchers[15] paid by RIAP.

Table 2. Budgeted costs of SR-CRSP in Indonesia between 1981 and 1990.

Year	Total Indonesia	Total West Java
1981-1982	147,758	147,758
1982-1983	171,138	171,138
1983-1984	344,448	344,448
1984-1985	358,142	358,142
1985-1986	360,356	360,356
1986-1987	362,749	362,749
1987-1988	470,496	333,011
1988-1989	505,513	234,243
1989-1990	660,633	74,878
1990-1991	575,268	83,040

Source: Prepared with Annual Workplans and Budgets, and information from Principal Investigators Indonesia.

The adoption pattern assumes 10 percent adoption reached in 1996 and 20 percent adoption in 1999, ten years after the technology was developed. This is a conservative pattern given that researchers in Indonesia mentioned in discussions that the technology can be applied to fifty percent of the farmers in

West Java, and that lags of three years are expected, according to Pardey and Wood.

Lotus software[16] for a close economy model with demand shift was used. Costs and benefits between 1981 and 2005 were considered. Results using the animals of 1988 for West Java and the costs and adoption patterns mentioned above yielded an internal rate of return of 17 percent. If spillovers to other provinces are considered, to other provinces, in a first case to East Java, the rate of return is 19 percent. If sheep from West Java, East Java, Aceh, and North Sumatra are considered as the base for calculation, a return of 19.34 percent is obtained. The net present value in this case is $3,335,929 at an interest rate of 10 percent.

Consumer, producer and total surplus are presented in Table 3. Given the market conditions and supply and demand coefficients, shifts due to technological change benefit producers more than consumers.

Table 3. Consumer producer and total surplus of the Indonesian technological package in dollars.

Year	Consumer Surplus	Producer Surplus	Total Surplus
1988	15,844	54,396	70,239
1989	16,148	55,442	71,591
1990	16,459	56,509	72,969
1991	84,171	288,987	373,158
1992	85,795	294,565	380,361
1993	175,664	603,113	778,777
1994	179,065	614,791	793,856
1995	368,235	1,264,276	1,632,512
1996	375,392	1,288,847	1,664,239
1997	382,687	1,313,895	1,696,583
1998	390,125	1,339,429	1,729,555
1999	397,707	1,365,460	1,763,167
2000	405,436	1,391,997	1,797,433
2001	413,316	1,446,628	1,867,976

Calculated with software prepared by George Norton.

Other Benefits: Training in the SR-CRSP

Graduate degree training was supported by the SR-CRSP.[17] Indonesian scientists involved with the SR-CRSP received 23 graduate degrees (Table 4). Of these, 19 were directly funded and others are currently being funded. Eleven are at the masters level and an equal number at the Ph. D. level. Most of this training was done in universities in the United States between 1981 and 1990. During that period ten people were trained for their masters degree and six people were trained for a Ph.D. Three of these degrees were in rural sociology, six were in animal nutrition, four in animal science and breeding, and three degrees were in economics. As of September 1992 there were two Ph.D. students still being trained in the U.S., one in rural sociology and one in nutrition. A masters student in agricultural economics is being supported by the SR-CRSP in Arkansas. The SR-CRSP also funded six bachelor degrees.

Table 4. Degree training of Indonesian scientists in the SR-CRSP by discipline.

Discipline	M.S.	Ph. D.	Total
Rural Sociology	3	2	5
Agricultural Economics	2	2	4
Nutrition	4	4	8
Breeding	3	3	6
TOTAL	12	11	23

Source: Original data collected by Dolores Fernández, additional information and corrections by Valdivia in Indonesia.

Conclusion: future impacts

Sheep is an important commodity of West Java and of potential importance nationally according to the Master Plan for Animal Research and Development 1990/1991-1994/1995. The Central Research Institute for Animal Sciences (CRIAS) is the coordinating agency of animal research and development under which RIAP is the executing agency. There are three sources of funding for research, the routine budget, development budget and the collaborative grants. Between 1985 and 1990 the collaborative grants were 60 percent of the RIAP research funds.

Development and dissemination of research results will be areas emphasized from 1990 to 1995. The objective is to increase the number of technical publications and brochures in more popular media. Twenty percent of the funds of RIAP are being allocated to research in technology adoption. This is crucial to the effectiveness of the research developed through RIAP and with the SR-CRSP. Research funds allocated to small ruminant research is 11.9% of the RIAP research fund for 1991-1992 (Argono and Sabrani, pers. comm.).

The present project evaluation, which considered only the benefits of management, reproduction, nutrition, and socio-economics research tested on farm, and showed positive returns to investment, that can be trigered by an effective extension system. An important aspect of this evaluation was the inclusion of costs of training, breeding, and basic research done in West Java with the SR-CRSP, proving that the technological package alone can pay for the long-term breeding research and human capital development required to sustain productivity in to the future. Currently, emphasis is being placed on the linkages between research and extension in Indonesia (De Boer, 1991). Increasing the rate of adoption will increase the returns to investment. This report presents preliminary results, the lower bound of research returns. A complete evaluation of the benefits of the SR-CRSP Indonesia program in West Java needs to include the benefits of the breeding program in prolific sheep, and the returns to human capital development.

Notes

[1]International Financial Statistics Year Book, 1991, and Winrock International Project Profile "Indonesia Economic Analysis of Small Ruminant Production and Marketing System" April 1991.

[2]Estimate of demand for 500,000 head of small ruminants in Middle Eastern countries (Saudi Arabia for the Idul Ada) is mentioned by Soedjana, T. "Economics of Raising Small Ruminant," Ch. 8 in Goat and Sheep Production in Indonesia, Book manuscript. ed. by Wodzicka-Tomaszewska, et al. Limitations with respect to export of live animals and meat processing for exports exist to date.

[3]Income elasticity in Indonesia for meats was estimated by several authors. Sabrani's estimate from time series data in 1979 was 2.08; the estimate for mutton by Chernichovsky and Meesook in 1984 from cross section data was 1.2. Other elasticities are also quoted in Knipscheer et al., 1987. J.S. Sarma "Cereal feed use in the third world: Past Trends and Projections to 2000," 1990, estimated the income elasticity of mutton to be 1.6.

[4]Indonesian Agricultural Research Priority Project, Dr. Philip Pardey. International Service for National Agricultural Research.

[5]Paula Bilinsky and Mark Gaylord summarize the history of the OPP and the role of farming systems research in West Java in Chapter 8, "Outreach Pilot Project: Small Ruminant Research and Extension in Java", in *Plants, Animals, and People* ed. by C. M. McCorkle. Westview Press, Colorado. 1992.

[6]In how many years can one hundred percent adoption be reached? Usually peak adoption is less than one hundred percent of the farmers as stated by Pardey, Norton, and Alston (forthcoming).

[7]The advantage of this approach is that economic policies that affect the returns to agricultural research can be introduced. Sensitivity analysis can be done to handle uncertainty, it can quantify public and private sector interactions, give average rate of return but cannot be used to evaluate basic research (Norton and Davis, 1981).

[8]This assumption was made on the basis that real government budgets for sheep research were declining during this period, and that previous research was ineffective.

[9]Central Bureau of Statistics, and SUSENAS.

[10]Philip Pardey, Senior Officer, ISNAR: Regional Research Project Asia. "Priority Setting Mechanisms for National Agricultural Research: Indonesia Study", AARD-ISNAR.
[11]Graduate Research Assistant, Department of Agricultural Economics, University of Missouri-Columbia, 1992.
[12]Draft of Public Investment in Indonesian Agricultural Research and Extension, provided by Philip Pardey. The lags between research and development coincided with information obtained from researchers at RIAP.
[13]Atien Priyanti, Agricultural Economist, RIAP, at that time working on her M.S. in Agricultural Economics at the University of Arkansas, returned to Indonesia in December 1992.
[14]Atien Priyanti, OPP.
[15]Thanks to John DeBoer for his suggestion of including these costs instead of using overestimated costs of research in the U.S.
[16]Provided by George Norton, VPI.
[17]Delores Fernández collected training information, which was later revised in Indonesia.

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Literature Cited

Alston, J. M., and G. M. Scobie. "Distribution of Research Gains in Multistage Production Systems: Comment." AJAE 65(1983): 353-356.

Bahri, Sjaiful, Wilhelmina Eveleens and Rita Nur Suhaeti. "An Economic and Technical Data Base for Priority Setting within AARD Indonesia." ACIAR Workshop on "Designing Information Systems to Support Research Priority Assessments in Agricultural Research: Concepts and Practices for International and National Level Institutions." Ming Court Hotel, Kuala Lumpur, Malaysia, 28-31 May, 1991.

Bilinsky, Paula, and Mark Gaylord. "Outreach Pilot Project: Small Ruminant Research and Extension in Java." Chapter 8 in McCorkle, Constance M. (ed.) Plants, Animals, and People. Westview Press, Colorado. 1992.

Blond, R. D. (ed.) Partners in Research: A five year report of the Small Ruminant Collaborative Research Support Program. University of California Printing Department, Berkeley, California. Circa 1985.

Daniels, Lisa, Julie Howard, Mywish Maredia, James Oehmke and Richard Bernsten. "The Impact of Agricultural Research: A Review of the Ex-Post Assessment Literature with Implications for Africa." Department of Agricultural Economics. Michigan State University, July 1990.

De Boer, A. John. "Economic Analysis of Improved Small Ruminant Production Systems." In R.D. Blond ed. Partners in Research: A five year report of the Small Ruminant Collaborative Research Support Program. University of California Printing Department, Berkeley, California. Circa 1985.

De Boer, John. "Research Programming in the Central Research Institute for Animal Science, Agency for Agricultural Research and Development, Indonesia." Winrock International Institute for Agricultural Development. Morrilton, Arkansas. July- August, 1992.

Durning, Alan B. and Holly B. Brough. "Taking Stock: Animal Farming and the Environment." Worldwatch Paper 103. July, 1991.

Echeverría, Rubén. "Assessing the Impact of Agricultural Research." In Echeverría, R. G. (ed.) Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research, Vol. II, Assessing the Impact of Agricultural Research. The Hague: ISNAR. 1990.

Gatenby, Ruth M., R. A. C. Jensen, Subandriyo and G. Eric Bradford. "Actual and Potential Performance of Indonesian Sheep and Goats Under Traditional Management Systems." SR-CRSP Tech. Report No. 97.1988.

Haryanto, Budi, Dwi Yulistiani, I. Wayan Mathius and Mujchi Martawidjaja. SR-CRSP Working Paper 111. NCS and BPT. 1990.

Johnson, S., W. Meyers, H. Jenson, T. Tekle and M. Wardhani. Evaluating Food Policy in Indonesia Using Full Demand Systems. Final Report. Ames, Iowa: Center for Agricultural and Rural Development, Iowa State University, September 1987.

Knipscheer, Hendrik C., M. Sabrani, Tjeppy D. Soedjana and A. John De Boer. "The Small Ruminant Market System in Indonesia: A Review." In Agricultural Systems 25(1987): 87-103.

Ludgate, Patrick J., and Atien Priyanti (eds). "Outreach Pilot Project On-farm Research Activities Annual Report for 1988-1989." WI, MU and RIAP. SR-CRSP Working Paper 109, Feb. 1990.

Ludgate, Patrick J., Tjeppy D. Soedjana, Atien Priyanti and Hendrik C. Knipscheer. "Technology Development in Integrated On-Farm Animal Research: Farmer Groups in West Java, Indonesia." Working Paper No. 122, November 1990.

Martawidjaja, Mujchi, Atien Priyanti, B. Setiadi and Patrick J. Ludgate. "Barn Management Systems of the Sheep and Goats by OPP Farmers." SR-CRSP Working Paper 112. NCS and BPT. 1990.

Mawi, S., M. E. Yusnandar, Tjeppy D. Soedjana and Patrick J. Ludgate. "Marketing and Utilization of Goat and Sheep Manure in the Bogor District." Working Paper 106, August 1989.

MU. 1986-1987 Annual Report,"Sociological Analysis of Small Ruminant Production Systems," in Indonesia Program Year Eight, 1986-1987. University of Missouri Columbia. 1987.

Norton, George W., and Jeffrey S. Davis. "Evaluating Returns to Agricultural Research: A Review." AJAE 63(1981): 685-699.

Norton, George W., Philip G. Pardey and Julian M. Alston. Science Under Scarcity: Theory and Practice for Agricultural Research Evaluation and Priority Setting. Cornell University Press. Ithaca. Forthcoming.

Pardey, Philip and Stanley Wood. "Targeting Research by Agricultural Environments." For World Bank Conference on "Agricultural Technology: Current Policy Issues for the International Community and the World Bank," Airlie House, Virginia, 21-23 October 1991.

Priyanti, Atien, S. Mawi and Kedi Suradisastra. "Farmers Responses to the Outreach Pilot Project (OPP): First Socio-economic Evaluation." SR- CRSP Working Paper No. 94. Bogor, 1988.

Sabrani, M., and Hendrik C. Knipscheer. "Small Ruminants for Small Farmers." Indonesian Agricultural Research and Development Journal 4(1982): 86-90.

Sarma, J. S. "Cereal Feed Use in the Third World: Past Trends and Projections to 2000." IFPRI Research Report 57. December 1986.

Schwartz, Lisa, and James Oehmke. "Applying a benefit/cost approach of rate of return analysis to specific CRSP Projects." Proceedings of the International Research Meeting of the Collaborative Research Support Program, Michigan State University, East Lansing. April 30 to May 3, 1990.

Seré, Carlos, and Lovell Jarvis. "The Betting Line on Beef: Ex-ante Estimates of the Benefits of Research on Improved Pasture for the Latin American Tropics." In Echeverría (ed.) Methods for Diagnosing Research System Constraints and Assessing the Impact of Agricultural Research, Vol. II, Assessing the Impact of Agricultural Research. The Hague: ISNAR. 1990.

Setiadi, B., and Luis Iniguez. "Reproduction performance of small ruminants in on-farm research evaluation of village farms in West Java." SR-CRSP/RIAP. Bogor. 1990.

Suparyanto, Agus, I.Wayan Mathius and Dwi Priyanto. "Sheep Raising Practices in Indonesia," in New Technologies for Small Ruminant Production in Indonesia by Patrick Ludgate and Sibylle Scholz (eds.) Winrock International Institute for Agricultural Development. Sept. 1992.

Valdivia, Corinne. "Assessment of the Small Ruminant Collaborative Research Support Program and the Economic Impacts of Small Ruminant Technologies in West Java, Indonesia." Report to Bean/Cowpea CRSP and the SR-CRSP. University of Missouri, Columbia. September 1992.

Wayhuni, Sri, Agus Suparyanto, I. Wayan Mathius, and Dwi Priyanto. "Social Structure of Small Ruminant Farm Facilities," in New Technologies for Small Ruminant Production in Indonesia. Winrock International Institute for Agricultural Development. September 1992.

Wennergren, E. Boyd, and Morris D. Whitaker. "Social Returns to U.S. Technical Assistance in Bolivian Agriculture: The Case of Sheep and Wheat," in American Journal of Agricultural Economics 1977 (59):565-69.

Yulistiani, Dwi, Wayan Mathius and Mujchi Martawidjaja. "Effect of Technology Packets with the Outreach Pilot Project (OPP) Farmers." SR-CRSP Working Paper No. 101. 1989. NCS and BPT.

The Small Ruminant CRSP In Indonesia 1980 - 1993: Achievements and Impact

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Abstract

The Small Ruminant Collaborative Research Support Program has carried out research in Indonesia from 1980-1993 in West Java and North Sumatra to increase the productivity of intensive production systems and to integrate sheep with plantations. The Agency for Agricultural Research and Development is the Indonesian agency that officially collaborates with SR-CRSP. The components of research include breeding, feeding and nutrition, economics, and sociology. The activities have been conducted on-station and on-farms. The Small Ruminant CRSP supports professional training and networking. Significant achievements include determination of the mode of inheritance of prolificacy in Javanese sheep; developing a new strain of productive hair sheep for the hot humid tropics; economic supplementation using locally available agricultural by-products; developing nutrient requirements of Indonesian sheep and goats; identifying forages appropriate for rubber plantations; and developing the technologies to enhance small ruminant production in villages. Several impacts of the Program have been identified by the Indonesian government and farmers. For example, scientists trained by the Program have improved their research capabilities, and the integration of sheep with rubber plantations gives benefits to the environment and farmers by reducing the use of herbicide and increasing smallholder incomes, especially relieving pressure on overtapping and tree destruction.

Introduction

The Small Ruminant Collaborative Research Support Program (SR-CRSP) activities in Indonesia from 1980-1993 include collection of baseline data for description and diagnosis and technology development through on-station research trials and on-farm testing.

The research activities conducted by SR-CRSP in Indonesia support the long-term goals of the Government of Indonesia to sustain and enhance agricultural production. Research on small ruminants in Indonesia has focused on the improvement of productivity through improved management practices. Research programs are aimed at establishing new technologies that are sound, economically feasible, socially acceptable, environmentally sustainable, and multidisciplinary in approach.

The first five years' activities of SR-CRSP in Indonesia were carried out in Java. Starting 1985, SR-CRSP activities have been extended to North Sumatra. Research activities in Java, where the rural human population is high, are focused on the intensive production system. Research has highlighted the dramatic reduction in forage availability and feed resources due to a net reduction in area of agricultural land for forage production. This is due to use of even marginal land for crops, urban expansion, housing in rural areas, and industrialization. Research strategies have emphasized intensive cut-and-carry small ruminant production and technological options to maximize or intensify production levels.

The activities in North Sumatra are in areas of low human population pressure and are currently characterized by low numbers of small ruminants. In North Sumatra the potential availability of fresh forage is very high under tree cropping systems, especially in rubber and oil palm plantations. Therefore research strategies emphasize integrated tree cropping with small ruminant production.

The Agency for Agricultural Research and Development (AARD) is the Indonesian agency that officially collaborates with the SR-CRSP. The institutions under the umbrella of the Central Research Institute for Animal Sciences (CRIAS) are the executing institutions that conduct research. In Java, research is mostly conducted in collaboration with scientists from the Research Institute for Animal Production (RIAP), while in North Sumatra research is conducted in collaboration with the Sub Research Institute for Animal Production, Sungai Putih, North Sumatra (SRIAP). In North Sumatra, CRIAS and SR-CRSP are also collaborating with the National Center for Rubber Research.

The role of small ruminants in Indonesia

The numbers of sheep and goats in Indonesia in 1989 were approximately 5.9 and 11 million, respectively. About 90% of sheep and 60% of goats are in Java. Sheep and goats contribute approximately 3 and 7%, respectively, to the national meat supply (Directorate General for Livestock Services, 1991). Sheep and goats are kept by smallholder farmers mostly to provide meat and manure. Sheep and goats are not kept as a primary source of income, but the number of farmers raising sheep and goats is large.

Indonesia has two types of native sheep: thin-tail and fat-tail sheep, both of which carry some wool. Thin-tail sheep are found in Central and West Java and Sumatra, while fat-tail sheep are found in East Java and several parts of Eastern Indonesia. A strain of thin-tail called the Priangan or Garut sheep is found in the district of Garut, West Java. Garut rams are kept for fighting.

There are two breeds of goats in Indonesia. The indigenous goat which is small and prolific is called the Kacang goat. The other breed, Etawah, is larger and tall with very long pendulous ears and is descended from the Jamnapari breed in India. This breed is less prolific than the Kacang. Etawah goats have been used extensively for crossing in the country. Phenotypes intermediate between Kacang and Etawah are found in most villages. In some areas of Indonesia, Etawah goats are milked.

Significant achievements of SR-CRSP in Indonesia

Breeding

The SR-CRSP breeding project was initiated in 1980 through on-station research and field surveys. Research emphasis in Java has been on breed characterization and estimation of production potential of Javanese sheep and determination of the mode of inheritance of prolificacy. The breeding project in North Sumatra was initiated in 1985 with the emphasis on improving unconfined Sumatra (S) sheep grazing forages in rubber plantations. The latter program has implemented two simultaneous breeding plans: 1) establishment of a nucleus of S for selection and 2) development of a productive strain of hair sheep with superior genetic potential for resistance or tolerance to internal parasites, which is well-adapted to the climate and feed resources of the humid and sub-humid tropics and lends itself to a variety of management systems.

On-station research on Javanese sheep [Javanese Thin-tail (JTT) from Garut, JTT from Semarang, and Javanese Fat-tail (JFT)] has been conducted since 1981. The genetic potential of Javanese sheep has been determined, and this breed shows exceptional reproductive characteristics; they can reproduce year-round with high levels of prolificacy and much variability. Ovulation rate and litter size do not differ significantly among the three breed types. All have litter sizes of up to four or five with a mean for mature ewes of approximately two with heritability greater than 0.5. Ovulation rates range from one to seven with repeatability exceeding 0.6 (Bradford et al., 1986). Analysis of the segregation of ovulation rate from the dams and their daughters showed that the prolificacy of Javanese sheep is affected by a major gene of the Booroola type (F). Homozygote (++) ewes for the normal allele (the low line) produce mainly singles and occasionally twins, while FF ewes (the high line) usually produce twins and triplets and occasionally quadruplets or more. Heterozygote (F+) ewes on the average produce mostly twins with considerable incidence of

triplets (Bradford et al., 1991). Each copy of the F gene increases litter size by about 0.75 lambs.

Levels of prolificacy which are higher than two lambs per lambing are associated with higher mortality rates. Unless environmental resources and the standard of management are not limiting, higher levels of prolificacy are disadvantageous (Iniguez et al., 1991a).

Using knowledge of the mode of inheritance of prolificacy in Javanese sheep, sheep lines with known prolificacy have been developed. Since evaluation of males requires progeny testing and for the females requires at least three lambing records, studies of DNA markers and level of various hormones (FSH, LH and GnRH) are underway in addition to classification based on ovulation rate or litter size. Studies on DNA markers are being conducted through collaboration between the RIAP, SR-CRSP, and the Australian Commonwealth Scientific and Industrial Research Organization (CSIRO), while hormonal studies are being conducted through collaboration between the RIAP, SR-CRSP, and National University of Singapore.

Establishment of a nucleus of selected Sumatra sheep was started by characterization of S sheep raised under rubber plantations. Lambing and weaning data from 1985-1988 showed that S sheep have exceptional potential for accelerated lambing in rubber plantation systems in humid tropical conditions. Sumatra sheep achieved 1.82 lambings per production year, and weaned 2.2 lambs per year weighing 21 kg per 22 kg ewe (Iniguez et al., 1991b).

The development of a productive strain of hair sheep in North Sumatra was initiated in 1986 when St. Croix (SC) sheep were imported from the Virgin Islands, USA. Woolless JTT were introduced from East Java in April 1991, and Barbados Blackbelly (BB) imported as frozen semen from Barbados, Central America, in October 1991.

Evaluation of contemporary S, SC x S, BB x S, and JFT x S crossbred groups is underway. In addition, a 50% hair sheep composite population (HC) is being produced. The S group will serve as control, with which all of the other groups will be compared.

Evaluation of the long-term productivity of SC x S crossbreds shows promising results. The crossbred ewes produced about 47% greater weight of lambs weaned (22.4 kg/yr) than S ewes (15.2 kg/yr). Productivity per unit weight of ewe and productivity per unit metabolic weight of ewe were 13 and 20% higher than for S ewes, respectively. There seem to be no disadvantages associated with crossbred sheep, and the crossbred of SC sheep with S can be distributed in wider scale (Gatenby et al., 1993).

Feeding and nutrition

The major nutritional constraint for small ruminants in the intensive production systems of Java is a shortage of high quality feed and land devoted to feed production. The feed resources/nutrition program in Java has focused on the development of feeding technologies to overcome feed shortages in villages. The research emphasis in North Sumatra, previously on economic forms of supplementation for sheep, is moving towards improving the basal forage resource for sheep, both in villages and on large plantations.

An evaluation of the feed used by farmers in three locations in West Java (Garut, Bogor and Cirebon) showed that the feed mainly consists of native grasses, with some proportion of herbs, shrubs, tree legumes or other agricultural by-products (van Eys et al., 1984). The amount of feed offered to the animals was dependent on the season and the location, but was generally adequate. The crude protein levels of West Javanese village diets for small ruminants appear adequate, but digestible energy intake appears to be limiting (Johnson, 1984). Supplementation with cassava leaves, tree legumes such as gliricidia, sesbania, leucaena, and with concentrate supplements including rice bran, coconut meal, tofu waste, cottonseed, palm kernel cake, broken rice, molasses, rubber seed, and mixed concentrates improved feed intakes and increased growth by 50-100 g/head/d.

The composition of the feedstuffs utilized in all of the nutrition feeding studies is now part of the computerized data base which is maintained at the RIAP.

Protein and energy requirements of growing sheep and goats less than 20 kg weight have been estimated using data generated from experiments supported by the SR-CRSP and with other data generated in Indonesia (Haryanto and Djajanegara, 1992). The published tables are now used in Indonesia.

A recent emphasis of SR-CRSP nutrition studies has been on the nutrient requirements and pro-

ductivity responses of pregnant and lactating ewes/does to dietary treatment and on strategic supplementation of prolific sheep.

For sheep in plantation systems, SR-CRSP nutrition research has begun to evaluate ways of improving the forage resource. Forage yields under rubber decrease with increasing rubber tree age due to increasing levels of shade. Furthermore, forage quality declines due to a change in botanical composition (grasses dominate under shade) and a tendency for shaded forages to produce less leaf and more stem. Current research is evaluating shade tolerant forages that have the potential to triple productivity during the first five to seven years of a plantation. From nursery evaluations, species showing promise include various accessions of the grasses *Brachiaria mutica*, *Brachiaria humidicola*, and *Panicum maximum* and the legumes *Centrosema pubescens*, *Clitoria ternatea*, and *Stylosanthes guianensis*. These and other species are being carried forward into larger scale trials to assess their persistence and yield characteristics when grazed or cut. These forages are unlikely to be of use for smallholder sheep producers, because of constraints imposed by management and land availability. Tree legumes (such as *Albizia falcataria*, *Gliricidia sepium*, and *Calliandra calothyrsus*) and locally available by-products of agriculture and plantations (such as palm kernel cake, cassava meal, and oil palm solid waste) are being evaluated as potential feed supplements.

Economics

The economics program of the SR-CRSP in Indonesia has focused on constraints to productivity of smallholder sheep and goats in West Java and North Sumatra.

In West Java about every fifth farm household has small ruminants which typically provide 15-25% of gross farm income for those households (Knipscheer et al., 1983b). An important economic component in the villages is the practice of sharing of animals. The extent of sharing is difficult to estimate, but without doubt shared animals constitute an important part of the flock of landless and subsistence farmers. Possibilities of expanding small ruminant numbers through animal distribution ("dropping") schemes was examined (Knipscheer et al., 1983b). The impact was uneven and seemed directly related to the elasticity of forage supply. Economic studies of commercial systems (Knipscheer et al., 1983a) found considerable variation in economic returns per animal unit but this system was, in general, highly profitable because of high rates of compensatory gain made by small ruminants purchased from villages and because of a regular and low cost protein feed supply. Small amounts of cheap feed supplements fed over the short critical period at lambing have more positive economic benefit than more general supplementation. Using cheap available supplementary feeds for a few weeks after lambing will give a 40% increase in productivity and more than 200% gain in net benefit (Karo-Karo and Scholz, 1991).

Studies on marketing have focused on building profiles which describe how the system operates, who the participants are, the general marketing channel, and how prices are formed. The middleman is present in most small ruminant market transactions as a broker or village collector (Sabrani et al., 1982; Sabrani and Knipscheer, 1982; Karo-Karo et al., 1990; Ludgate and Priyanti, 1990). Farmers sell mostly to brokers and village collectors (67-90%). Only a small portion (10-33%) of livestock are sold directly in livestock markets by farmers. About 10-15% of animals sold in local markets are bought by local farmers as stock replacements or for fattening, and the rest supply the provincial and regional needs for slaughter (Karo-karo et al., 1990; Ludgate and Priyanti, 1990; Soedjana et al., 1992). There are some economic reasons why animals are not sold to buyers other than the broker and village collector, for example, high transportation costs and the risk of not selling the animal at all or accepting an even lower price (Ludgate and Priyanti, 1990; Soedjana, 1992).

The village collector is an important link in the small ruminant marketing system. In Java, a stable relationship seems to exist between trader and farmer, which is characterized by a traditional market system with cash/credit payment. A similar system was found in Aceh, but in North Sumatra no credit system seems to exist between producer and trader (Carlson and Scholz, 1991). The selling price generally is set by the middlemen at the time of selling and is considered fair by the farmers. This indicates that the farmer is in a poor bargaining position and has little knowledge in pricing. The factors determining selling price are exterior looks, liveweight, and age (Soedjana, 1992).

The future emphasis of economics studies will be research in North Sumatra on the privatization of animal health services, rural income generation to increase labor use and reduce pressure for overtapping by smallholders, assessment of export market in Singapore, promotion of large-scale finishing enterprises in plantations, and feasibility studies for private investment in sheep production.

Sociology

The sociology program of the SR-CRSP emphasizes the determination of sociological and economic constraints on labor. Small ruminants appear to be an important component of farming systems and are raised by wide variety of farmers, large and small. In the Javanese farming system they do not compete with crops for land, labor, or capital resources and are complementary to intensive crop production. However, small ruminants play an important role in the farmers' social and economic life. They provide a highly liquid source of capital in villages where banks are non-existent (Nolan, 1984).

The importance of small ruminants among farmers is clearly exemplified by the fact that nearly all the major management decisions are made by the male head of household while the role of the wife, although significant, is not as prominent as that of the husband (Suradisastra and Wahyuni, 1989). Usually men engage in small ruminant activities more frequently than do women. The contribution of females in small ruminants raising is more complementary. Women assume males' work if the latter cannot perform such activities, and they can contribute up to 40% of total labor input (Wahyuni et al., 1983).

The involvement of the wife in the small ruminant production process has also been studied. Husbands and wives often have very different perceptions of the wife's participation in the decision-making process concerning the management of sheep and goats (Wahyuni et al., 1985). The time allocation of women's involvement in small ruminant activities is about 1.8 h/d. Women realize the economic value of small ruminants, and they agree to be involved in small ruminant activities (Wahyuni and Gaylord, 1985).

Evaluation of the potential of livestock in peasant household in North Sumatra showed that there was nearly no relationship between farm size and family income due to the large number of small farmers who worked off-farm (e.g., on rubber plantations). Farmers have a lower social perception of sheep than cattle, although they would like to keep sheep if they were given credit or loaned animals. Overall, mean numbers of animals raised were in direct relation to farm size (Handayani et al., 1990).

Health and management

Since 1990, information on disease has been collected for sheep in rubber plantations in an attempt to identify the most serious constraints to production and to develop practicable solutions. The two most serious health problems are gastro-intestinal worms and pancreatic fluke.

Gastro-intestinal worms are severe constraints to the grazing of sheep under rubber plantations. It is reassuring that no resistance to anthelmentics has been detected. However, we do not want to rely solely on the use of the drugs for control, although it has been demonstrated that parasite control has large economical benefits (Scholz, 1991). Studies in North Sumatra have shown that three months after grazing ceases almost all larvae have died and the pasture is effectively clean. Therefore, a system of grazing management has been introduced in which the sheep are given anthelmintic every three months then moved to pasture which has been spelled for three months. Some animals appear to have genetic resistance to worms (Gatenby et al., 1992a).

Pancreatic fluke (*Eurytrema pancreaticum*) were first recorded in Indonesia in 1985. Little is known about the biology of this fluke, in contrast to gastro-intestinal worms. The fluke has two intermediate hosts, land snails and grasshoppers. Almost all sheep are infected with *E. pancreaticum*. In severe cases, the animals are emaciated, and there are several hundred fluke in the pancreas (Gatenby et al., 1992a). Three potential drugs, nitroxynil, praziquantel, and albendazole have been tested. None reduced infections to negligible levels. More frequent doses of the drugs or higher dose rates may be more effective but would almost certainly not give an economic response (Gatenby et al., 1992b).

On-farm research and development of technology packages

Technology packages are tested on farms. In Bogor the Outreach Pilot Project (OPP) was started in 1984 with the primary objective of establishing dialogue with groups of farmers and developing appropriate small ruminant management and technologies. It was anticipated that these new technologies would increase farmer incomes from small ruminant production. In Sungai Putih a similar program was started in 1988, called the Outreach Research Project (ORP). The ORP aimed to evaluate crossbred sheep in integrated tree cropping and sheep production systems.

In the OPP, emphasis has been on shortening lambing interval, reducing lamb mortality, increasing weaning weights, improving marketing information for farmers, improving feeding management, and improving barn design. By introducing ram/buck rotation, a substantial reduction in lambing interval from typical village averages of 12 to 15 months to approximately 8 months has been achieved. This reduction has a marked impact on flock productivity. Instead of lambing once-a-year, now farmers can achieve three lambings in two years, a net annual increase of 50%. Additionally, preweaning mortality has been reduced from 27% to less than 12%. This means that more lambs are weaned per ewe and farmers' income is improved. These achievements indicate the successful adoption of technology introduced to farmers.

Since the completion of the OPP in October 1990, new research to strengthen the already intensive production system has been conducted in four villages of Bogor district. This on-farm research effort tests the feasibility of changing the traditional small-scale system of raising small ruminants to a system that will provide substantial income to farmers evenly distributed throughout the year. This effort is known as the Village Intensive Production Scheme (VIPS). The concept of VIPS is an integrative one. It integrates available information about biological and economic variables into a management package for intensive production. The long-term aim of VIP is to boost the capability of local production to supply domestic and external demand while improving farm income. Economic analysis of this study is expected by the end of July 1993.

In the ORP in North Sumatra similar achievements were quantified. Growth rates of preweaning sheep raised by ORP farmers averaged 79 g/d; preweaning mortality was relatively low (8%), and lambing interval was only 217 days on average. The ORP farmers started with only four ewes, and flock size has increased over the years. The productivity level is very good and sheep production substantially increases the income of farmers (Verwilghen et al., 1992).

The ORP has been extended to Membang Muda about 200 km south of Sungai Putih, where it is called OPMM. The OPMM started in June 1991 with the objective of testing sheep production technologies with farmers in a nucleus rubber estate.

Communication, promotion, and networking

SR-CRSP findings are published in Indonesian and international journals, and the SR-CRSP has published more than 140 working papers.

A sheep and goat production handbook has been published by SR-CRSP in Indonesia. This handbook was written for farmers and extension personnel using pictures and limited text. It is entitled "A Collection of Training Materials Within the Framework of Goat and Sheep Research in the Village," and it was produced in Indonesian, Sundanese, Javanese, and English editions.

A booklet entitled "New Technologies for Small Ruminant Production in Indonesia" has been published. This publication presents a summary of many findings of research on small ruminants in the tropics, and it provides a valuable source of information for other researchers as well as agribusiness enterprises.

Two international workshops have been supported by the SR-CRSP in collaboration with international donor agencies and the host country. The first workshop entitled "Small Ruminant Production Systems in South and Southeast Asia" was co-sponsored by International Development Research Centre (IDRC), SR-CRSP, and AARD. This workshop was held in Bogor, 6-10 October, 1986. A proceedings of 426 pages has been published as Proceeding Series of IDRC-256e. The second international workshop entitled "Integrated Tree Cropping and Small Ruminant Production System" was co-sponsored by SR-

CRSP, AARD, and IDRC. This workshop was held in Medan, North Sumatra, on September 9-14, 1990. A proceedings of 329 pages has been published.

In 1991 ten small grants were given to recipients throughout Indonesia and a further nine in 1993. The purpose of the small grants was to enable Indonesian scientists in locations other than West Java and North Sumatra to undertake research into sheep and goat production.

The Indonesian Small Ruminant Network (ISRN) was launched in 1989 and now is part of CRIAS and SR-CRSP. This communication effort receives direct financial support from SR-CRSP Management Entity. Important accomplishments of the Network are: publication in 1990 of an inventory of human resources and centers involved in production, education, research, and development of small ruminants; establishment of a literature database; support for events of national interest such as a Workshop on Production Aspects of Javanese Fat-Tail Sheep in East Java, a Workshop on Traditional Veterinary Medicine for Small Ruminants in Java, a Workshop on the Role and Potential of Small Ruminants in Eastern Indonesia, and a Workshop on Research and Development of Goats in Eastern Indonesia; and biannual publication of a newsletter, with the first issue in September 1990. The sixth issue will be published in July 1993.

The SR-CRSP Management Entity partially supports the Small Ruminant Production System Network for Asia (SRUPNA). This network also receives financial support from the IDRC. The coordinating unit of SRUPNA is located in Bogor.

Training

Training continues to be an integral component of the SR-CRSP. Training provided by the SR-CRSP is either short-term or long-term. Long-term training or degree-oriented study has been provided in Indonesia, U.S., and other countries. The training is either fully supported by SR-CRSP or funded in collaboration with the National Agricultural Research II project which is funded by the World Bank and managed by Winrock International. For over ten years, SR-CRSP has fully supported six people to pursue B.S. degrees, five people to pursue M.S. degrees, and three people to pursue Ph.D. degrees in Indonesia. SR-CRSP has fully supported six people for M.S. degrees and three people for Ph.D. degrees in U.S. universities. Additionally, one person is supported for a Ph.D. degree in the Philippines. Approximately eight people have been supported partially by SR-CRSP in Indonesia or in the U.S. toward advanced degrees. Partial support includes placement, use of data collected by SR-CRSP, and funding of research.

The SR-CRSP also supports short-term training for scientists and technicians. Several scientists and technicians have been funded for non-degree technical training either in Indonesia, U.S., or a third country. Additionally, the SR-CRSP has also funded scientists to attend national or international conferences.

The Impact of SR-CRSP

Determination of the mode of inheritance of prolificacy in Javanese sheep is an important achievement for the SR-CRSP from two viewpoints: 1) it defines the basis for the development of breeding stock with optimal levels of prolificacy for a range of environments and 2) it contributes directly towards meeting the challenges imposed by the research goal to intensify the already intensive production system. There are some areas in Java that are presently shifting toward more specialized farms to produce lambs. This strategy complements new production schemes which are beginning to raise weaned lambs or feedlot animals for market. This work has helped to identify and characterize valuable genetic material with direct implications for sheep production throughout the humid tropics.

Integration of sheep with rubber plantations can help to reduce environmental contamination by herbicide, saving nationally approximately U.S. $51 million per year. Approximately ten sheep can control weeds in one hectare of rubber plantation, reducing the labor needed for weeding by 18-31%. Small farmers raising sheep have an average 33% higher profit and return for labor–almost three times higher than those without sheep. Increasing smallholder incomes can reduce pressure for overtapping of rubber trees and subsequent tree destruction.

The collaborative work between SR-CRSP and Indonesian scientists to identify the economic potential for improvement of small ruminant production systems and develop technology packages to

improve the income-generating capacity of rural families has been recognized by the Indonesian government. Small ruminants are now used as a major component of technological packages for the Upland Agriculture and Conservation Project in Central and East Java, and the "Banpres" (Presidential Aid) program provides sheep for farmers.

The spillover of small ruminant technologies and networking generated by the SR-CRSP is obvious. Increased willingness by producers to pursue information related to agribusiness in small ruminants is common, particularly with the current challenge of small ruminant export opportunities to the middle-eastern countries. Commercial sheep and goat breeding is starting and an Open Nucleus Breeding Scheme in East Java is now getting support from the Food and Agricultural Organization (FAO).

One major offshoot of the SR-CRSP training program is the development of research capabilities of government institutional staff. Many Indonesian scientists trained through the SR-CRSP now hold important positions in government institutions.

Advantages and disadvantages of the SR-CRSP compared with other foreign aid projects

In general the format of the SR-CRSP in Indonesia is good. The project is relatively small and has been operating for more than ten years. At any time there have been between one to three resident scientists in Indonesia plus varying numbers of students. In comparison with other foreign-aid projects which may be large but stop abruptly after only a few years, the SR-CRSP has the advantage of continuity which allows the achievement of longer-term goals which are needed in animal research.

Although the SR-CRSP has a longer-term perspective we feel that there is adequate project review and reorientation. Resident scientists participate in research program protocol discussions both the RIAP Ciawi-Bogor and the SRIAP Sungai Putih. At least annually, principal investigators from the United States review progress with resident scientists and co-principal investigators. Every two years the whole program is reviewed by the External Evaluation Panel. Approximately every five years there are discussions with AARD as a new Memorandum of Understanding is prepared.

The SR-CRSP focuses only on small ruminant research and development. While this may limit the target for development, the well-defined focus allows specific objectives to be achieved given the limited funds of the SR-CRSP.

Of the total funding received from USAID for support of the SR-CRSP in Indonesia, only a small fraction is spent in Indonesia. A similar situation also occurs in most other projects. Higher financial incentives for collaborators in Indonesia would be appreciated, particularly as government salaries are low. We consider that the use of SR-CRSP funds to support training and visits overseas for Indonesian personnel is very worthwhile.

Relationships between individuals in Indonesia and SR-CRSP personnel in the U.S. are, in general, close, and a substantial degree of trust and goodwill has developed on both sides. However, frustrations occasionally arise because of the bureaucracy imposed by USAID regulations and the involvement of three (originally four) U.S. institutions in addition to USAID Washington and USAID Jakarta. For example, obtaining travel clearance is arduous and seems unnecessarily wasteful of scientists' time. There have been instances of inadequate communication by individuals, reminding us that an administrative system which involves several institutions relies on good communication skills of all personnel involved. The threat of termination of the SR-CRSP by USAID Jakarta in 1991 was unsettling and took time and effort to resolve, and we hope similar problems will not arise in the future.

Foreign-aid projects often suffer from inadequate leadership from the donor country. We appreciate the enthusiasm of principal investigators (Eric Bradford, Henk Knipscheer, and Kevin Pond), former principal investigators (John DeBoer, W.L. Johnson, and M.F. Nolan), Joyce Turk (USAID Washington), and resident scientists and their dedication to make the SR-CRSP a success.

Literature Cited

Bradford, G.E., J.F. Quirke, P. Sitorus, Ismeth Inounu, Bess Tiesnamurti, F.L. Bell, I.C. Fletcher and D.T. Torell. 1986. Reproduction in Javanese sheep: Evidence for a gene with large effect on ovulation rate and litter size. J. Anim. Sci. 63:418.

Bradford, G.E., Ismeth Inounu, L.C. Iniguez, Bess Tiesnamurti and D.L. Thomas. 1991. The Prolificacy gene of Javanese sheep. In: J.M. Elsen, L. Bodin and J. Thimonier (Ed.) Major Genes for Reproduction in Sheep. 2nd International Workshop, July 16-18,1990, Toulouse, France. Institut National de La Recherche Agronomique, Paris, France.

Carlson, C. and S. Scholz. 1991. The effect of increased supply of sheep on producer revenue. Small Ruminant Working Paper No. 126, Sungai Putih, North Sumatra, Indonesia.

Directorate General for Livestock Services. 1991. Statistical Book on Livestock. Directorate General for Livestock Services, Jakarta.

Gatenby, R.M., E. Romjali, A.J. Wilson and A.D. Pitono. 1992a. Parasitic problems of sheep in rubber plantations. Paper presented at the Seminar on Livestock Services for Smallholders, November 15-21, 1992, Yogyakarta.

Gatenby, R.M., E. Romjali, A.J. Wilson, M. Hutauruk, J. Glenn and A.D. Pitono. 1992b. Comparison of three drugs to control pancreatic fluke (Eurytrema pancreaticum) in sheep. Small Ruminant CRSP Working Paper No. 137, Sungai Putih, North Sumatra, Indonesia.

Gatenby, R.M., E. Romjali, M. Doloksaribu, L.P. Batubara and G.E. Bradford. 1993. Long-term productivity of Sumatra thin-tail and Virgin island crossbred ewes at Sei Putih, North Sumatra. Small Ruminant CRSP. Working Paper No. 142. Sungai Putih, North Sumatra, Indonesia.

Handayani, S.W., J.L. Gilles and M.F. Nolan. 1990. Peasant household production in plantation areas: A case study of Deli Serdang plantation, North Sumatra, preliminary report. Annual Research Report 1989-1990. Small Ruminant CRSP Sub-Balai Penelitian Ternak Sungai Putih, Sumatra Utara, Indonesia, pp 109-118.

Haryanto, B. and A. Djajanegara. 1992. Energy and protein requirements for small ruminants in the humid tropics. In: Patrick Ludgate and Sibylle Scholz (Ed.) New Technologies for Small Ruminant Production in Indonesia pp 19-24. Winrock International Institute for Agricultural Development, Morrilton, Arkansas, U.S.A.

Iniguez, L., G.E. Bradford and Subandriyo. 1991a. Basis for a program of sheep genetic improvement in West Java. Small Ruminant CRSP Working Paper No. 131, Bogor, Indonesia.

Iniguez, L., M. Sanchez and S. Ginting. 1991b. Productivity of Sumatran sheep in a system integrated with rubber plantation. Small Ruminant Research 5:303.

Johnson, W.L. 1984. Nutrition and feed system research. In: R.D. Blond (Ed.) Partners in Research: A Five Year Report of the Small Ruminant Collaborative Research Support Program. pp 70-77. UC Printing Department, Berkeley, California, U.S.A.

Karo-Karo, S., T.D. Soedjana, E. Sembiring and H.C. Knipscheer. 1990. Marketing profile of small ruminants in North Sumatra. Annual Research Report 1989-1990. Small Ruminant CRSP Sub-Balai Penelitian Ternak Sungai Putih, Sumatra Utara, Indonesia, pp 94-108.

Karo-Karo, S. and S. Scholz. 1991. Partial budget analysis of feeding supplements. Small Ruminant Working Paper No. 125, Sungai Putih, North Sumatra, Indonesia.

Knipscheer, H.C., T.D. Soedjana and A.J. De Boer. 1983a. New small ruminant technology for small farms in Indonesia: The impact of flock size. Small Ruminant CRSP Working Paper No. 6, Bogor, Indonesia.

Knipscheer, H.C., M. Sabrani, A.J. De Boer and T. Soedjana. 1983b. The economic role of sheep and goats in Indonesia: A case study of West Java. Bulletin of Indonesian Economic Studies 17:74.

Ludgate, P. and A. Priyanti. 1990. Outreach Pilot Project On-farm Research Activities Annual Report for 1988-1989. Small Ruminant CRSP Working Paper No. 109, Bogor, Indonesia.

Nolan, M.F. 1984. Sociological analysis of small ruminant production systems. In: R.D. Blond (Ed.) Partners in Research A Five Year Report of the Small Ruminant Collaborative Research Support Program. pp 77-82. UC Printing Department, Berkeley, California, U.S.A.

Sabrani, M., S. Mawi, T. D. Soedjana and H.C. Knipscheer. 1982. A profile of the sheep and goat market in West Java, Indonesia. Small Ruminant CRSP Working Paper No. 1, Bogor, Indonesia.

Sabrani, M. and H.C. Knipscheer. 1982. Sheep and goat markets in Central Java: A profile. Small Ruminant CRSP Working Paper No. 5, Bogor, Indonesia.

Scholz, S. 1991. The economics of treating parasites in small ruminants. Small Ruminant CRSP Working Paper No. 130, Sungai Putih, North Sumatra, Indonesia.

Soedjana, T.D. 1992. Small ruminant marketing in Java. Indonesian Small Ruminant Network Newsletter 3(1):2.

Soedjana, T.D., A. Priyanti and P.J. Ludgate. 1992. Small ruminant marketing channels in Indonesia. In: Patrick Ludgate and Sibylle Scholz (Ed.) New Technologies for Small Ruminant Production in Indonesia. pp 85-88. Winrock International Institute for Agricultural Development, Morrilton, Arkansas, U.S.A.

Suradisastra, K. and Sri Wahyuni. 1989. The significance of women in small scale sheep farming activities in West Java. A paper presented at Women's Role in Agriculture. Pusat Penelitian dan Pengembangan Pertanian, Bogor, Indonesia.

van Eys, J.E., I.W. Mathius, H. Pulungan, M. Rangkuti and W.L. Johnson. 1984. Small ruminant production in West Java: Results of one year monitoring by the nutrition village monitoring program. Small Ruminant CRSP. Working Paper No. 34, Bogor, Indonesia.

Verwilghen, J., T. van Schie, A.D. Pitono and E. Sembiring. 1992. Production of sheep in villages adjoining rubber plantations. Small Ruminant CRSP Working Paper No. 133, Sungai Putih, North Sumatra, Indonesia.

Wahyuni, S., E. Juwarini and K. Suradisastra. 1983. Women's involvement in small ruminant production in Cirebon, West Java. Small Ruminant CRSP Working Paper No. 14, Bogor, Indonesia.

Wahyuni, S., M. Gaylord and H.C. Knipscheer. 1985. Women's decision making role in small ruminant production: The conflicting views of husband and wives. Small Ruminant CRSP Working Paper No. 43, Bogor, Indonesia.

Wahyuni, S. and M. Gaylord. 1985. Women's role in small ruminant production: Motivation, perception and problems. Small Ruminant CRSP Working Paper No. 57, Bogor, Indonesia.

EMBRAPA/CNPC-SR/CRSP: Successful Partnership in Northeast Brazil

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Abstract
The semiarid region of Northeast Brazil, situated in the so-called drought polygon and occupying an area of 1,556,000 square kilometers is, socially and economically speaking, considered one of the poorest regions of the world. Due to harsh environmental conditions in this area, sheep and, particularly, goats, are socially and economically important for the rural population. Joint collaborative research between EMBRAPA/CNPC and SR-CRSP using a multidisciplinary approach has produced a substantial amount of technologies and management practices for hair sheep and goats raised under semiarid conditions. Laboratory development and formal training of graduate students from the United States, Brazil, and other developing countries were also considered as major contributions of the project. It is concluded that even more substantial results would have been expected if the program had not been withdrawn from Northeast Brazil.

Introduction
The semiarid region of Northeast Brazil is comprised of nine states of the Brazilian territory. It occupies an area of 1,556,000 km^2 or approximately 18.3 percent of the total area of Brazil.

This area is characterized by important social and economic problems, aggravated by a high concentration of human population, the majority of which are seeking to escape from the dryer hinterland to live in the coastal area where the biggest cities are situated.

The situation is worsened by the overall low and erratic precipitation, soils of limited capability for intensive agricultural practices, and centuries of exploitative mismanagement of the ranges.

According to *Anuário Estatístico do Brasil* (1992), 46.3 percent of the total northeastern area has already suffered anthropic action with the state of Ceará being the most disturbed one with 84.3 percent of its area having received human intervention (Table 1).

The type of climate and vegetation which predominate in the dryer disturbed areas of Northeast Brazil are well suited for small ruminants, particularly goats, which make up a large share of grazing animals in the region, and represent 89.8 percent of the overall Brazilian goat population.

Table 1. Total and anthropic area in northeast Brazil.

States	Total Area (km^2)	Anthropic Area (km2)	Anthropic Area (%)
Maranhão	329,556	35,585	10.8
Piauí	251,273	109,116	43.4
Ceará	149,076	125,729	84.3
R. G. do Norte	53,167	30,059	56.5
Paraíba	53,958	37,769	70.0
Pernambuco	101,023	51,106	50.6
Alagoas	29,107	22,462	72.2
Sergipe	21,863	13,636	62.4
Bahia	566,978	294,370	51.9
Total	1,556,001	719,832	46.3

Source: *Anuário Estatístico do Brasil* (1992)

Socio-economic aspects of northeast Brazil

The Northeastern region of Brazil has a population of 42.5 million inhabitants representing 28.9 percent of the total Brazilian population. The impacts of the harsh environmental conditions of the area and the lack of adequate jobs and opportunities for its people as compared to other geographical regions of the country are seen in Table 2. The major conclusion is that as the total income rises, the participation of Northeasterners in that share decreases sharply. As a consequence, social welfare indices such as illiteracy and infant mortality rates are much higher in relation to other regions of the country, while life expectancy is lower (Tables 3 and 4).

Due to these aspects, Northeast Brazil was one of the pre-selected sites for USAID Title XII Small Ruminant Collaborative Research Support Program with the activities being started by the end of 1979 and the Memorandum of Understanding being signed in March 1980.

Table 2. Distribution of income levels of the active population, by region, in Brazil.[1]

Region	1,000 people					
	Without income	up to one minimum wage (MW)	Above 01 to 02 MW	Above 02 to 05 MW	Above 05 to 10 MW	Above 10 MW
North	1,654	475	442	655	305	217
Northeast	14,281	8,528	3,982	2,995	1,000	706
Southeast	19,570	7,215	6,595	9,999	4,959	3,756
South	7,187	2,479	2,467	3,334	1,392	1,005
Midwest	3,213	1,192	1,049	1,346	588	528
Brazil	45,906	19,887	14,535	18,329	8,244	6,212
NE/Brazil	31.1%	42.9%	27.4%	16.3%	12.1%	11.4%

[1] Population over ten years old.

Source: *Anuário Estatístico do Brasil* (1992)

Table 3. Illiteracy in people over seven years old and infant mortality by geographical areas, in Brazil.

Region	Illiteracy (%)		Infant mortality rate	
	Urban areas	Rural areas	Urban areas	Rural areas
North	14.3	N/A	72.2	72.3
Northeast	27.8	55.8	124.3	118.8
Southeast	9.1	23.9	75.2	71.8
South	8.7	15.9	63.1	59.7
Midwest	12.8	31.3	70.2	70.7
Brazil	13.5	37.8	85.2	92.9

Source: *Anuário Estatístico do Brasil* (1992)

Table 4. Life expectancy for different states and areas in Brazil

States and/or regions	Life expectancy (years)
Rio de Janeiro	63.2
São Paulo	63.6
South (PR, SC, RS)	67.0
Minas Gerais and Espirito Santo	62.2
Northeast	51.6
Federal District (Brasilia)	65.9

Source: *Anuário Estatístico do Brasil* (1992)

Overall description of small ruminants production systems in Northeast Brazil

The exploitation of small ruminants in this semiarid region is based, in the majority of the cases, on traditional methods.

In general, goats as well as sheep are described as "Sem Raça Definida" or "Crioulo." However, there are some local types or breeds in the region. These include "Moxotó," "Marota," "Canindé," and "Repartida" for goats, while "Morada Nova," "Santa Inés," and "Somalis" are the hair sheep breeds more commonly found. A detailed description of those types and/or breeds can be found in Shelton and Figueiredo (1989), and Figueiredo et al., 1990.

Goats, sheep, and cattle are generally allowed to graze freely in the native "caatinga" vegetation which has a high diversity of plant species allowing the animals to exercise their selective feeding behavior principally during the rainy season. On the other hand, during the dry season, which lasts normally seven to eight months, animals cannot thrive on the amount and quality of the forage available and large losses occur. High losses due to respiratory diseases and gastrointestinal helminths are also important production constraints in the region (Santa Rosa et al., 1986).

The ultimate importance of small ruminants in the overall production system in the semiarid Northeast Brazil is the fact that those animals provide not only meat and milk, even during the recurrent droughts which frequently hit the region, but they represent an immediate source of cash that the poor rural population may use to buy other subsistence food crops.

The cooperative efforts of EMBRAPA/CNPC and SR-CRSP

The Brazilian Enterprise of Agricultural Research (EMBRAPA) was created by the Brazilian government in 1973 with the mission to generate and/or adopt adequate technologies for the agricultural development of Brazil.

In 1975, EMBRAPA's executive board decided to create the Brazilian National Goat Research Center (CNPC) located in the Northeastern state of Ceará, more precisely in the town of Sobral at 3.42°

South latitude and 40.21° West longitude. A young team of Brazilian scientists was then assigned to the new station with the mission to launch a strong research program and to build up the laboratory facilities.

The identification of research partners to work in a cooperative fashion was facilitated when the United States Congress passed the International Development and Food Assistance Act of 1975. This act was put forward as a way "to prevent famine and establish freedom from hunger," involving land-grant universities in the United States government's efforts to help lesser developed regions to solve food and nutrition related problems.

The facts that the Small Ruminant Collaborative Research Support Program was the first CRSP launched under the Title XII act and the beginning of a new research institution staffed by young and enthusiastic scientists was the key ingredient to start a mutually beneficial research joint venture.

The projects initially selected and the respective U.S. institutions involved were:

Animal Breeding	Texas A & M University
Animal Health	University of California, Davis
Animal Management	Tuskegee Institute
Animal Nutrition	North Carolina State University
Animal Reproduction	Utah State University
	California State Polytechnic University
Economics	Winrock International
Range Management	Utah State University
Sociology	University of Missouri-Columbia
Systems Analysis	Texas A & M University

The multidisciplinary approach emphasized by EMBRAPA to solve the complex problems related to small ruminant production was another convergent philosophic point between EMBRAPA/CNPC and SR-CRSP.

Later, the systems analysis project withdrew from Brazil and the animal management project was taken on by the Texas A & M University animal breeding project. This resulted in a total of eight projects involving the same number of U.S. institutions. This association lasted until 1987, even though, in some cases, individual institution linkages were kept up to 1988.

As a result of this joint research venture, several new technologies and management practices were developed and transferred to producers through papers published either in Brazil or in the United States, in English as well as in Portuguese. Institution building and laboratory building were also strong points in this collaborative effort and, in some cases, up to 20-25% of basic laboratory equipment were made possible through this partnership in a short period of time.

Last but not least, the formal training component of the program can be described as its most lasting influence. Due to this, several Brazilians, Americans and other nations' graduate students were trained either in Brazil or in the U.S., utilizing data generated by this collaborative work. These well-trained professionals are now engaged in small ruminant research and related activities, and they are helping to multiply the body of knowledge actually available on those species. A summary of major measurable accomplishments of EMBRAPA/CNPC - SR-CRSP in Northeast Brazil is presented in table 5.

Table 5. Summary of some measurable accomplishments of SR-CRSP in Northeast Brazil.

Accomplishments	Number
Books	2
Chapters in books	30
MS Thesis	13
Ph.D. Dissertations	15
Scientific papers	79
Abstracts	95
Technical communications	85
Short courses	18

Source: Small Ruminant Collaborative Research Support Program, 1988.

Even though there are several variables involved in the process of improving livestock production in any part of the world, generation and transfer of technology unquestionably play a major role in the process. The amount of information resultant of the cooperative efforts of EMBRAPA/CNPC and SR-CRSP have surely had an impact on the overall small ruminant production, even though this influence cannot be precisely measured. Keeping in mind the comments above and only for the sake of showing some comparative numbers, some production parameters pre and post the SR-CRSP in Northeast Brazil are shown in table 6.

Table 6. Selected comparative production parameters for small ruminants in Brazil.

Parameters	Year		
	1979 (A)	1989 (B)	Change (%)
	Flock population (1,000 head)		
Sheep (Northeast)	6,117	7,577	23.9
Sheep (R. G. Do Sul)	10,851	10,846	0
Sheep (Brazil)	17,806	20,041	12.6
Goats (Northeast)	7,429	10,477	41
Goats (Paraná)	181	273	50.8
Goats (Brazil)	8,070	11,669	44.6
	Slaughter (1,000 head)		
Sheep (Brazil)	730	871	19.3
Goats (Brazil)	368	773	100.5
	Offtake (%)		
Sheep (Brazil)	4.1	4.3	4.9
Goats (Brazil)	4.6	6.6	43.5
	Carcass weight (kg)		
Sheep (Brazil)	13.67	14.04	2.7
Goats (Brazil)	12.80	14.04	9.7

[1]Data from official slaughterhouses. It is estimated that those numbers represent only 20-25% of the animals actually slaughtered.
Source: *Anuário Estatístico do Brasil*, 1980; 1991

The above data demonstrate increases in terms of goat and sheep populations, as well as increases in offtake and carcass weight, principally for goats. Those figures may be linked to research results and transfer of technology in the last ten years.

Despite all the contributions from research and collaborative efforts such as EMBRAPA/CNPC and SR-CRSP, substantial results can only be expected if those are long duration programs. Unfortunately, the

SR-CRSP was discontinued in Brazil despite the fact that social indicators, such as the ones shown in this paper, continued to demonstrate that Northeast Brazil is one of the poorest regions in the planet and, would undoubtedly have benefited from continued aid for its sustainable agricultural development.

Literature Cited

Anuário Estatístico do Brasil. 1980. IBGE, Rio de Janeiro.

Anuário Estatístico do Brasil. 1991. IBGE, Rio de Janeiro.

Anuário Estatístico do Brasil. 1992. IBGE, Rio de Janeiro.

Figueiredo, E.A.P., M. Shelton, and M.E. Barbieri. 1990. Available genetic resources: the origin and classification of hair sheep. in: M. Shelton and E.A.P. Figueiredo (Ed.) Hair sheep production in tropical and sub-tropical regions. pp. 7-23. University of California Printing Department, Berkeley.

Santa Rosa, J., M.E.A. Berne, E.H. Johnson, and H.J. Olander. 1986. Doenças de Caprinos diagnosticadas em Sobral, CE. Anais da 1° Reunião Técnico Científica do Programa de Apoio a Pesquisa Colaborativa de Pequenos Ruminantes. Sobral, Ceará, Brasil.

Shelton, J.M. and E.A.P Figueiredo. 1989. Genetic resources and improvement programs. In: Johnson, W. L. and E.R. de Oliveira (Ed.) Improving meat goat production in the semiarid tropics. p.p. 33-48. University of California Printing Department, Berkeley.

Small Ruminant Collaborative Research Support Program. 1988. Communications 1978-1987. University of California, Davis.

Chapter 2. Andean Agropastoral Systems

Overview of Achievements of the SR-CRSP in Perú and National and Regional Impacts

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Abstract
SR-CRSP was conceived as a joint effort of research and training between AID and U.S. universities, with governmental agencies and universities of Perú. The program began its activities in Perú in 1980, with emphasis in research on sheep and alpacas in the highland region, goats in the Northern Coast, and pastures in the Coast and Sierra.

Among the successes achieved in the collaborative research of the SR-CRSP in the Peruvian highland region, we should mention not only the research results, but also the collaborative relations between Peruvian and U.S. scientists and the training of many Peruvian professionals who have contributed to the availability of small ruminant scientists in Perú. Also, the research has resulted in many scientific publications, which constitute an important source of knowledge in the area of small ruminant production.

The research has given very important benefits, such as the identification and control of important diseases of the goats, sheep, and alpacas. The field on range and pastures also received attention, focus on stocking rates, grazing management, range improvement the nutrition of free-ranging animals, and the management of cultivated forages. The productive and adaptative qualities of the "criollo sheep" have been objectively identified and revalued; and apopropriate selection methods are being tested for its genetic improvement. It has also deepened knowledge about the alpaca production. Also much technology has been validated for livestock production with the participation of the small peasant producer in communities.

The Small Ruminant Collaborative Research Support Program (SR-CRSP) in Perú
SR-CRSP was conceived as a joint effort of research and training between AID and U.S. universities, with governmental agencies and universities of Perú. The program began its activities in Perú in 1980, with emphasis in research on sheep and alpacas in the highland region, goats in the Northern Coast, and pastures in the Coast and Sierra.

SR-CRSP activities were governed by an agreement between the University of California, Davis, and the Instituto Nacional de Investigación Agraria y Agroindustrial (INIAA). At the same time, INIAA had signed agreements with the Universidad Nacional Agraria-La Molina; the Instituto Veterinario de Investigaciones Tropicales y de Altura (IVITA), belonging to the Universidad Nacional Mayor de San Marcos (UNMSM); Universidad Nacional del Altiplano-Puno; and the Universidad Nacional Pedro Ruiz Gallo-Lambayeque. The goal has been to develop collaborative research between scientist from Perú in order to develop research in Perú and from several U.S. institutions: Texas Tech University , Montana State University, Colorado State University, University of Missouri, and Winrock International.

There have been many efforts in Perú to improve the highland livestock, with results that have been of limited utility. This has been due, in part, to the erroneous application of the available knowledge but also, to the lack of operating information.

With this background, the Small Ruminant Collaborative Research Support Program (SR-CRSP) was initiated in 1980, which has provided for systematic research in different areas fundamental to the improvement of production.

Among the successes achieved in the collaborative research of the SR-CRSP in the Peruvian highland region, we should mention not only the research results, but also the collaborative relations between Peruvian and U.S. scientists and the training of many Peruvian professionals who have contributed to the availability of small ruminant scientists in Perú. Also, the research has resulted in many scientific publications, which constitute an important source of knowledge in the area of small ruminant production.

Production limiting factors

1. Feeding and nutrition

Highland livestock are totally sustained by the native rangelands, from which the forage is deficient, in both quantity and quality during the six-month dry season (May - October) of each year. There is a tendency to overstock the range, which results in a deterioration of the ecosystem and low animal productivity. In the rural communities sheep, alpacas, and llamas are usually maintained in the same herd, without consideration as to whether there exists competition or complementarity in their grazing habits.

2. Animal health

There is a high morbidity and perinatal mortality in sheep and alpacas; in the latter, this is principally attributable to infectious causes. In adult sheep, there are alterations of the reproductive and respiratory apparatus that diminish their productive function. Due to sheep importation without a good sanitary control, it is unknown if diseases from other countries have been introduced that would affect sheep or the alpacas that live in close association.

3. Reproduction

In both, sheep and alpacas, the number of young weaned per breeding female exposed to males is low. This results in low culling percentages (12-15%) and in low general productivity. The first lambing in females is at the age of 2.5-3.0 years. This delay in beginning reproductive activity is undesirable, especially in sheep in which the upper age limit for good production is 5.0-5.5 years. In alpacas the average useful life is 10 years, but it is desirable to begin the reproduction early for productive reasons.

4. Genotype

The genetic potential of stocks available in the country is not well characterized, and there is a lack of performance recording and selection programs.

5. Management systems

A common example illustrating what should not be done is the importation of exotic breeds of sheep without improving the nutritional environment in which animals are raised and produced. Another example is to ignore the scarcity of feed in the dry season and to overstock the range.

6. Socio-economic factors

The production systems are developed by and for human beings and therefore are influenced by the economic-social environment in which humans are located within an ecological zone. The resources to develop the system (education, motivation, technology, financial stability, etc.) differ between those for commercial producers and community producers. As a consequence, the generation of technological innovations, besides being ecologically beneficial, should be socially acceptable, economically feasible, and relevant to the community they serve.

Resarch accomplishments and their practical implication in the sheep and cameloids production

Range and pastures

1. Range improvement

1.1 A practical method has been improved for elaborating agrosto-edaphologic maps that permit differentiation of range sites according to their suitability for grazing.

1.2 The effect of climatic patterns on the growth cycle and nutritive value of the principal native grasses has been established.

1.3 Appropriate range site stocking rates have been established according to range condition and animal species.

1.4 Eighty percent of highland native rangelands are in very poor condition. Actually, there are procedures for their recuperation for different environmental conditions. Effective methods for flat and gently sloping overgrazed rangelands include applying phosphate at the beginning of the rainy season, scarifying the overgrazed area with a drill and then broadcasting orchard grass-clover seed, and, finally, covering the seed by using herds of camelids or sheep to trample it into the earth. With the foregoing techniques, it is possible to go from an initial stocking rate of only 0.5 sheep units/ha/year on the overgrazed range to four or five sheep units/ha/year.

2. Establishment of pastures to supplement the native range

The native range is deficient in nutrient quality and quantity, especially in the dry season. Under these conditions, the major nutrient demand by animals is not always met by available supplies. There are areas with topographic characteristics and watering availability that allow the establishment of high-production pastures. Actually, the species of grasses and legumes that can be seeded in different soils and latitude levels are known, as well as their productive yields. The pastures can carry between 20 and 40 sheep units /ha/year, according to the altitude.

These pastures are profit-producing if they are used only in critical periods of the animal production cycle: growing stage, lactation, and last third of gestation. This practice also contributes to recovery of the range.

3. Agricultural plots and soil fertility in peasant communities

In many peasant communities cropping is carried out in small plots, but due to the poor fertility of the soil, cultivating periods of two to three years are alternated with one to seven years of rest. It has been demonstrated that the seeding of legumes at the beginning of the fallow period helps recover soil fertility through nitrogen fixing. This permits reducing the rest period and thus obtaining additional forage for livestock, and, overall, it gives a better use intensification of scarce soil.

4. Use of shrubs for fuel and forage in peasant communities

In most peasant communities, the manure "bosta" is used as fuel in the family kitchen. The use of adapted shrubs, preferably legumes, seeded in the borders of the plots permits replacing the "bosta" as fuel and improving the structure and fertility of the soil, with a result increase in production of Andean crops.

Nutrition

1. Evaluation of native range

The predominant plant associations have been characterized, using a cover, biomass production, and nutritive quality as criteria.

2. Utilization of range by different animal species

2.1 Selectivity and opportunism

In native range the llama selects a major proportion of tall growing grasses in both the dry and rainy seasons while alpacas and sheep preferentially select the short grasses and herbs. The quality of the

selected diet, in terms of protein and digestibility, is higher in sheep, intermediate in alpacas, and lower in llamas. In mixed pastures (grasses/legumes), South American cameloids (SAC) consume less legumes than sheep.

2.2 Consumption and conversion factors

In general, the SAC consume 30% less than sheep. This difference reaches 50% under exclusive consumption of concentrate. It has been estimated that the potential consumption is 4.6, 2.3, and 2.6% of the live weight for sheep, alpacas, and llamas, respectively.

2.3 Digestibility

The SAC have a greater digestive capacity than sheep for low quality feeding, due principally to the greater retention time of feed in the digestive tract.

2.4 Efficiency of feeding conversion under concentrate feeding

Under intensive feeding with the use of concentrates, sheep have a greater feed conversion than cameloids. This is due to the greater relative feed intake and rate of weight gain.

2.5 Resistance to water stress

The SAC, compared with sheep, are more resistant to water deficit. The llama is more resistant than the alpaca, because it requires less water ingestion per kg of dry matter consumed.

Reproduction

1. Principal achievements in sheep

1.1 Presentation of estrus and ovulation in the breeds Junín, Corriedale, and Criollo under natural range (Study in potential of open ewes)

- In the three breeds, the number of sheep in estrus begins to increase in January, registering the largest proportion from March to July and then it diminishes until December, with the exception of the Criollo, which tends to show estrus all the year.
- The maximum peaks of estrus presentation occur in May-June for Corriedale and Criollo and in June for Junín.
- The number of sheep that ovulate is greatest during February and March in the Corriedale and Junín, while Criollo has a tendency to ovulate throughout the year.
- The ovulation rate is low , averaging 1.14 for the three breeds, which indicates a low potential to produce twins.

1.2 Females bred/females exposed (FB/FE)

1.2.1 Results of Junín Sheep vs. Criollo under range conditions

- FB/FE: Junín (84%) vs. Criollo (64.7%). In Junín there were no differences between ages, but in Criollo, females of 1.5 age had 37.3%, which contributed to lessening the breed average (64.7%).
- Average weight (Kg) of lambs at birth: Criollo (2.6 ±.5) vs. Junín (3.8±.4)
- Average weight (Kg) of sheep at parturition: Criollo (25.8±.3) vs. Junín (41.2±.3).

1.2.2 Results under irrigated pasture

- At the IVITA Station in the Mantaro Valley, it has been demonstrated that with mixed pastures (Rye Grass + Clover) one can obtain three parturitions in two years in Junín, Criollo, and Corriedale breeds, with no major differences among the three This corroborates the finding that differences in reproductive seasonally observed in natural rangelands are due principally to feed availability.

1.2.3 Results in herds of communities

- FB/FE/year/herd differed from 38.2 to 83.5%
- Twins average = 0
- Average weight of lambs at birth/herd differed from 2.3 to 4.0 Kg
- Average weight of ewes at parturition/herd differed from 26.1 to 35.4 Kg
- The major concentration of parturitions occurred from April to July, which indicates that most of thefertile services occur in the rainy season when there is more feed.
- The variation among herds is attributable to management differences among producers,which should be considered for extension purposes in communities

1.3 Studies in Junín, Corriedale, and Criollo males

- The ejaculated volume are similar in the three breeds. No seasonal variations were found.
- The sperm concentration/ejaculation is similar in Criollo and Corriedale, and higher than Junín.
- The sperm motility is higher in Criollo (56.4%) than in Junín (51.9%) and intermediate in Corriedale.

2. Principal achievements in Alpacas

- They have continuous estrus and ovulation induced by copulation.
- The one-year-old females show sexual activity similar to adults, but only the ones that reach 35 Kg of body weight reproduce successfully. In La Raya conditions, 50% offemales reach that weight at one year of age.
- Where males and females are herded together all year, the parturition is seasonal (January-March). On the other hand, if females and males are separated and are joined periodically, they produce kids year-round.
- Males lose sexual interest when they are with the same females for more than 15 days. Changing females periodically is required to maintain sexual activity.
- Based on the alpaca reproductive characteristics, a simple management system of males has been developed during breeding which increases the number of females bred/females exposed from 55% to 85%.

3. Practical implications

The former results have practical application for increasing the number of females bred/females exposed and also for the survival of the newborns. Under natural rangeland, it is important to adjust reproduction to the best season of the year in order to obtain maximum levels of estrus, ovulation, and survival of embryos and fetus, as well as to insure favorable conditions for the survival of lambs. The ewe needs a high nutrition level during the two last pregnant months; inadequate nutrition results in premature parturitions, low birth weights, reduction in ewe energy reserves, and poor milk production, and, as a result of all of this, low survival.

Genetic improvement

1. Research accomplishments in Central Sierra

1.1 Productivity of the existing sheep breeds

The Junín sheep (SAIS Tupac Amaru) and the Corriedale sheep (Central de Cooperativas de Cerro de Pasco) have been characterized in productive and reproductive terms.

Likewise, the productive parameters of the Criollo sheep have been defined in the same places. This has allowed us to quantify the degree of differences and comparative advantages that each of the evaluated groups possess under the same environmental conditions.

Because of their adaptation to the highland rangelands, Criollo ewes should be used in the development of plans for improving sheep in the country.

1.2 Selection systems

Genetic differences have not been found between some classification groups in the pyramidal selection system followed in SAIS Tupac Amaru, suggesting that the classification structure should be simplified.

The selection of Junín rams by individual weight at 16 months helped produce better fertility rates and ewe productivity in terms of weight of progeny. Likewise, selection based on scrotal circumference produced very similar responses. Both types of selection, independently or in combination in a selection index, could be applied, especially when we want to give emphasis to meat production.

The most important genetic parameters that can be used with selection purposes have been estimated in Junín and Corriedale sheep. The use of the estimated parameters in the elaboration of selection indices can facilitate significant responses to the selection of sheep in the Peruvian Central Sierra.

1.3 Crossing with Introduced Breeds

In SAIS Tupac Amaru, the Junín ewes bred to Targhee-Finn rams produced progenies with higher weight gains and staple lengths than the breedings with Targhee-Finn ewes to Junín rams. The pure Junín progeny and those of Targhee-Finn ewes rams produced more fleece and better fineness, respectively. However, in

terms of kilogram of weaned lamb per ewe exposed, the breeding of Junín x Junín produced the highest yield. The use of introduced rams of the above mentioned breeds did not contribute to the improvement of the Junín sheep production, indicating it will be more efficient to exploit the pure Junín sheep.

In SAIS Tupac Amaru, the progenies of Criollo ewes bred to Junín, Targhee, and Targhee-Finn rams were superior in live weight until second shearing than the pure Criollo progeny. However, the number of lambs born and weaned from Criollo x Criollo breeding was superior, resulting in only small differences in weight of lamb weaned per ewe exposed with a slight superiority for the crossing Junín x Corriedale. The Junín breed will be the best crossing alternative to improve the productivity of the Criollo sheep under the conditions of SAIS Tupac Amaru.

2. Research accomplishments in Southern Sierra

In Southern Sierra, research was developed giving emphasis to sheep and alpaca production.

2.1 Sheep

- Implementation of production recording in commercial herds of the zone, facilitating the selection process by performance and progeny, without affecting the production systems.
- Quantification of the impact of climatic variation on the production of the Corriedale breed in the highlands.
- It has been found that the Criollo sheep in the highlands present better reproductive characteristics—early age of reproduction and fertility—and better carcass yields at 18 months than the improved breeds of the zone.

2.2 Alpacas

- The herd of La Raya Experimental Center (in Puno) has been implemented; within this a herd was formed called "Nucleus of Genetic Studies in Alpacas." This herd has permitted a generation of a data base (1982-1989) for the development of studies in the area of genetic improvement.
- The alpaca fleece has been characterized in terms of its physical aspect and match fiber length and of yields of herds located at different altitudes.
- The different types of congenital malformations have been recorded in Puno herds, and the frequency of presentation of each of them has been determined.

Animal health

Accomplishments in sheep

1. Ovine Progressive Pneumonia (OPP)

1.1 Accomplishments on etipathogeny

Based on the former results, a program for control of the disease has been introduced consisting of systematic culling of all animals with clinical manifestations and those found positive to sheep lentivirus during annual testing. After working for five years, the morbidity and mortality by OPP in herds under the indicated management diminished compared to the control herds. These results permit extending thecontrol to other herds.

1.2 Achievements in diagnosis

a) Clinical and pathological criteria have been established for diagnosis of sheep pulmonary adenomatosis (SPA) and OPP.

b) The distribution of this respiratory complex has been determined by scientists in two livestock enterprises, in which the disease constitutes the principal cause of losses. The mortality rate at SAIS Tupac Amaru-Junín was 1.69% over the existing population of sheep and 1.37% at SAIS Aricoma-Puno.

2. Perinatal mortality in lambs

2.1 Lamb enterotoxemia caused by *Clostridium perfringens* Type A

This microorganism was isolated for the first time in lambs of this country and has been used in preparation of a commercial biologic product which will aid in control of the disease.

2.2 Neonatal pneumonia of lambs
Enteric infections in lambs are usually prevented by administering oral medicationto newborns. However, it has been found that 40% of cases in which lambs died of pneumonia in the first four days of life were due to false deglutition (oral medication is forced into the lungs rather than the stomach). These results suggest that better training and preventative care management would result in less lamb mortality.

3. Studies on sheep brucellosis
The semen quality and other aspects of rams from SAIS Tupac Amaru-Junín (633), submitted to a vaccination program with REV 1 (Br.melitensis) for 10 years and without epididymitis, were compared with rams of SAIS Picotani-Puno without a vaccination program and with presence of epididymitis in males. The semen quality was classified as excellent for 97% of rams of SAIS Tupac Amaru versus 77% for SAIS Picotani. The difference favoring SAIS Tupac Amaru indicates that vaccination of young rams should be extended to other similar enterprises.

4. Effect of La Oroya pollution on the health of sheep
It was determined that there was no relationship between concentration of heavy metals (arsenic, cadmium, copper, manganese, lead and zinc) in the liver and mortality due to the SPA/OPP complex, coenurosis, and pneumonias. However, it was established that the sheep population is acting as a sentinel species for contamination of the atmosphere in the neighborhood of the La Oroya melting plant. These results have important implications for Public Health.

5. Serologic studies for determining thepresence of infectious agents in sheep
This has already been briefly explained in the introduction.
5.1 Viral Antibodies
- *5.1.1* OPP Virus
- *5.1.2* Parainfluenza 3 Virus
- *5.1.3* Bovine Syncytial Respiratory Virus
- *5.1.4* Border Disease Virus
- *5.1.5* Blue Tongue Disease Virus

5.2 Antibodies to the agent of Sheep Enzootic Abortion
5.3 Antibodies to Leptospira interrogans
5.4 Antibodies to Toxoplasma gondii

6. Assay of medical plants for control of parasitic
Infections in sheep
- Use of "utashayli" for control of Melophagus ovinus on sheep.
- Efficiency of the artichoke (Cynara scolymus) and "jayashipita" against Fasciola hepatica in sheep of Central Sierra.
- Antihelmintic efficiency of squash seeds (Curcubita maxima Duch) in sheep of communities.
- These plants constitute an accessible resource to small producer for treatment of some parasitic diseases.

Accomplishments in South American cameloids

1. Perinatal mortality in Alpacas
This study relates field (clinic and pathological) and laboratory findings (bacteriological, parasitological, and histopathological studies) with samples of dead newborn alpacas during parturition of 1987, 1988, and 1989 at SAIS Aricoma, Picotani, CAT Santa Lucía (Puno), and SAIS Pachacutec (Junín). There are important findings that constitute real contributions to a better knowledge of mortality causes in newborn alpacas. For example, there is now a better understanding of etiopathogeny. In addition, there is a classification proposal for mortality causes, which is already being used in Puno. This will allow standardization of criteria, at least in the designation of such causes of death.

2. Serologic studies for determining the presence of infectious agents in Alpacas
2.1 Viral antibodies in Alpacas
- *2.1.1* Parainfluenza 3 Virus
- *2.1.2* Bovine Syncytial Respiratory Virus
- *2.1.3* Bovine Infectious Rinotraqueitis Virus
- *2.1.4* Border Disease Virus
- *2.1.5* Blue Tongue Disease Virus
- *2.1.6* Influenza A Virus

2.2 Antibodies to agents of Mycoplasma Genus
- *2.2.1* Mycoplasma mycoides subp. mycoides
- *2.2.2* Mycoplasma mycoides subsp. capricolium
- *2.2.3* Mycoplasma mycoides subsp. capri

2.3 Parasitic infections. antibodies to Toxoplasma gondii
These serologic findings indicate that our alpacas are infected with all of the agents listed above. The studies to correlate these findings with the clinical and histopathological manifestations indicate that the existence of these infections in alpacas could be due to the fact that these cameloids live together with other species of domestic animals, such as sheep and cattle. These findings in alpacas are valuable contributions to understanding infectious diseases of these animals. The existence of infections that were not even suspected in this species has been demonstrated. These are not new nor exotic diseases, but are those with which may have affected alpaca production for a long time.

3. Parasitic infections. Sarcocistiosis in Alpacas
3.1 Pathology of Sarcocystis aucheniae in alpaca.
3.2 Pathology of Sarcocystis aucheniae in canines.
3.3 Partial characterization of antigenic compounds and experimental clinical pathology of Sarcocystis aucheniae in alpacas.

4. Serologic studies for determining thepresence of infectious agents in Llamas
4.1 Parainfluenza 3 Virus
4.2 Bovine Syncytial Respiratory Virus
4.3 Border Disease Virus
4.4 Influenza A Virus

5. Serologic studies for determining the presence of infectious agents in Vicuñas
Sixty samples of blood serum from semi-confined vicuñas were processed to detect the presence of viral agents which occur in alpacas and llamas, but all samples tested negative . This is because vicuñas do not share their habitat with other domestic animals.

Accomplishments in goats

1. Caprine Arthritic-Encephalitis (CAE)
This disease was first reported in Peru in 1983. This infection caused by a retrovirus is prevalent in goat farms where husbandry is intensive, e.g., in Lima (56.5% of serum-reactors), Trujillo (62.6%), and Piura (58.5%). The disease probably entered through animals imported from the U.S. and Europe.

2. Serologic studies for determining the presence of infectious agents in Goats.
Serological identification has been made for various infectious agents detected for the first time in this country. These findings constitute an important contribution for a better knowledge of health problems in goats.
2.1 Influenza A Virus
2.2 Parainfluenza 3 Virus

2.3 Bovine Syncytial Respiratory Virus
2.4 Bovine Infectious Rinotraqueitis Virus
2.5 Border Disease Virus

3. Goat Mycoplasmosis
This was reported for the first time in Peru in 1985 (Noe et al). This disease is caused by Mycoplasma mycoides subsp. mycoides.

4. Goat Toxoplasmosis
In a completed serologic study, it was found that the major rate of serum-reactors was goats which aborted: 63% in Tumbes; 23% in Lima; 20% in Piura; 20% in Lambayeque; and 8% in Ica (Rivera et al., 1988).

Socio-economics

Principal accomplishments

1. Detailed knowledge of the production systems that comprise small ruminants has been achieved in associative enterprises (SAIS) and rural communities of the highland region and in small goat herds in the Northern Coast of the country. It has been established that in the agropastoral communities more than 60% of family hand labor is used in livestock activities vs. 25% in agricultural work. In addition, it was found that women's roles are predominant in livestock production, which should be taken into account for research-extension purposes in communities.

2. In the existing system of the alpaca fiber marketing, the middleman makes advances of money and provides other assistance to the producer; these services are not yet available from other institutions. This factor determines that producers stay in the system in spite of the low prices received for the product.

3. It has been established that pasture feeding supplementation during the last third of gestation in sheep and during growth and reproduction of female alpacas is a practice economically advantageous.

4. The comparison of small cooperative enterprises (10,000 animals) vs. big cooperatives (around 200,000 animals) in terms of growth, capital reproduction, and capital accumulation, and participation of the workers demonstrated that the principal variables that affect product yield are the participation of workers and their productive organization.

5. Tools have been developed for data processing by computer. From a simple herd model some programs have been prepared for the recording of quantitative and qualitative data, which facilitates their analysis.

Institution building

1. Training accomplishments

Training in Perú has been developed in close collaboration with INIAA and universities. The types of training sponsored by the program have covered a wide spectrum, from informal, on-the-job training of technicians at one extreme to training of research scientists through overseas doctoral programs at the other. Thanks to this, the veterinary faculty of the San Marcos University created the graduate school which confers the M.S. degree in Animal Production and Animal Health.

Table 1 sets out the number of students that were sponsored by the SR-CRSP in various types of degree programs in the USA. The emphasis on producing graduates with research capability is shown by the predominance of Master's and Doctoral level students.

Table 1. Degrees obtained by Peruvian students in the U.S.A. under the auspices of the SR-CRSP.

	Training Institution									
Degree	CPSU	CSU	UOM	MSU	OSU	TAMU	TTU	USU	Winrk	TOTAL
M.S.	1	—	4	1	2	1	4	3	3	19
Ph.D.	—	3	3	3	—	—	3	3	2	17
Total	1	3	7	4	2	1	7	6	5	36

CPSU=California Polytechnic State University
CSU=Colorado State University
UOM=University of Missouri
MSU=Montana State University
TTU=Texas Tech University
TAMU=Texas A&M Univeristy
USU=Utah State University
WINRK=Winrock International

Table 2, gives the number of students that were sponsored in degree programs in Perú, for B.S. and M.S. degrees.

Table 2. Degrees obtained by Peruvian students in Peru under the auspices of the SR-CRSP.

	Training Institution						
Degree	CSU	UOM	MSU	TTU	USU	Winrk	TOTAL
B.S	—	10	11	10	3	8	45
M.S.	1	—	7	11	2	1	22
TOTAL	1	10	18	22	5	9	67

Short courses intended to train technical support staff have been offered in Perú. A summary of these is given in Table 3. Also in the same table is given the regionalization courses of the SR-CRSP given in Perú (4), Bolivia (1), and Ecuador (1).

Table 3. Non-degree training courses supported by the Small Ruminant Program in Perú.

Short courses offered in Perú	8	246 attendees
Training courses, informal training in Perú	10	156 attendees
Meetings, congressed and other scientific and technical events	20	47 attendees
SR-CRSP Research Results in Perú (*)	5	400 attendees

(*)3 in Perú, 1 in Bolivia and 1 in Ecuador.

Table 4 gives the number of publications produced from the research carried out in Perú.

Table 4. Diffusion of the information Produced by the Small Ruminant Program.

	Thesis B.S./M.S./Ph.D			Journals	Conferences	Publications Technical Reports	Books or Chapters on Books	Summaries
MSU	11	14	3	8	2	18	4	47
Winrk	8	4	2	—	2	21	—	5
CSU	—	1	3	33	36	8	—	43
TTU	8	11	2	10	43	69	—	81
USU	4	15	2	1	5	22	1	26
UOM	10	6	3	9	15	32	4	1
Total	41	51	15	61	103	170	9	203

2. The andean small ruminant science network.
Since 1991, the SR-CRSP developed a leading role in establishment of the Small Ruminant Network (RERUMEN)in South America. Argentina, Chile, Bolivia, Ecuador, Venezuela and Perú were members. In October, 1992 by decision of the SR-CRSP the network was moved to Bolivia.
The main accomplishments from 1991 to 1992 were:
a. A bibliography data base of 8500 entries related to small ruminants.
b. A Database of 581 professionals dedicated to small ruminant research and production from the Andean countries of South America.

3. Newsletter
Three issues of a newsletter with the name RERUMEN, were published in 1991 and two in 1992. This publication has created great interest and a growing demand in the South American Region.

4. RERUMEN background
RERUMEN started the elaboration of collaborative research projects in topics of common interest to the South American countries, with emphasis on the Andean area, to present to financial institutions.

In the period 1991-92, RERUMEN made an excellent start in networking in a large region of the world, created a lot of interest in small ruminant research, and contributed significantly to people's abilities in Latin America to conduct their research programs.

The SR-CRSP format compared to other projects in Perú

The SR-CRSP represents the major systematic research effort that has been, so far, carried out on sheep, alpaca, and goat production in Perú.

The holistic, multidisciplinary, and collaborative nature of the SR-CRSP approach proved sucessful in understanding and finding solutions for the complex problems of the Andean Production Systems. Today many researchers and development workers in Perú recognize the importance of this methodology.

Research coordination and administration of the SR-CRSP in Perú were not bureaucratic and funding was flexible and opportune.

Peruvian scientists trained by SR-CRSP are currently working in their respective institutions, both in research and teaching. Their contributions were particularly important for the foundation of post-graduate programs at the Veterinarian Faculty in the San Marcos and Puno Universities. Also important is the development of research facilities in Peruvian institutions.

SR-CRSP has helped to develop a collaborative research network in small ruminants in South America.

In ten years, the SR-CRSP's research work generated a quantity of knowledge but time was not available before the phase-out of the program to validate the results through on-farm testing, demonstration, etc., before reliable Technical packages can be produced.

Future national and regional needs

Based on ten years of experience, the lessons learned, the infrastructures and links established, and the increased awareness of the importance of the small ruminant in Peru, future considerations for research in Peru are (in case the SR-CRSP returns to Peru):

- Concentrate research activities on solving practical problems of producers (feed-back).
- Emphasize technology validation with producers.
- Articulate and integrate non-governmental organizations (NGO's) and other organizations involved in direct technical assistance to producers into the SR-CRSP in order to facilitate technology transfer.
- Extend and improve the Small Ruminant Science Network for information exchange and collaborative efforts.

Literature Cited

Florez, A. 1990. Logros de Investigacion (1980-1989) del Programa de Apoyo a la Investigacion Colaborativa en Rumiantes Menores (SR-CRSP). University of California-INIAA. Lima. Peru.

McCorkle, C. 1990. Improving Andean Sheep and Alpaca Production. Recommendations from a decade of research in Peru. University of Missouri-Columbia,. U.S.A.

Florez, A. 1992. Red de Rumiantes Menores-RERUMEN. Directorio de profesionales. SR-CRSP. RERUMEN. INIAA-Lima, Peru.

Current Work and Future Plans
IBTA/CRSP Bolivia

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Introduction

Camelids, sheep, and cattle are raised in the Andean Highlands (Altiplano), and their productivity depends on the quality and quantity of native forage species. Systematic efforts to improve the low productivity rates of these species were initiated back in the fifties and have identified the feed supply and its variation as the major problem associated with the development of livestock industries.

Among others, the main factors that affect forage production, which severely influence livestock productivity are: high altitude, limited rainfall conditions with prolonged periods of drought, high radiation and irradiation losses, fragile soils susceptible to erosion, and large short-term temperature variations.

The Bolivian Altiplano

Location

The Andean highlands, known as the Altiplano, are located in a region which encompasses Southern Peru, northeast Chile, northwestern Argentina, and central Bolivia.. A large part of this plateau belongs to Bolivia.

The Bolivian altiplano is located between 69 31' west longitude and 14 15' south latitude (figure 1). It has an estimated area of 14,275,000 hectares, about 13% of the total area of Bolivia (Gandarillas, 1963).

Climate

Although the Altiplano presents a range of climates, it can be classified in two broad categories according to the rainfall: the humid region in the North and the dry region in the South. Cabrera (1968) defined the Altiplano's climate as dry and cold, with large temperature contrasts throughout the year, and rainfall during the summer. Monhein (1953) defined this area as a tropical mountain climate.

In the Altiplano of Bolivia, two marked seasons prevail: a dry winter followed by a rainy summer. Figure 2 shows precipitation patterns for three representative areas of the Altiplano: Northern Altiplano (Belen), Central Altiplano (Patacamaya, and Southern Altiplano (Villazon). Table 1 shows different climatic variables.

Table 1. Comparative meteorological observations of four Altiplano areas.

Area	Mean Temperature C	Mean Annual Precipitation	Mean Days with rain	Days with frost	Relative humidity %
North Altiplano	10	577	91	112	59
East Altiplano	11	362	60	131	54
Altiplano of the Desaguardero River	10	383	59	165	42
South Altiplano	9	178	33	192	33

Livestock
A range of domestic animals are found in the Altiplano. Animals of the Camelidae family, such as alpaca (Lama pacos) and llama (Lama glama), are the native domestic species. Wild representatives of this family such as vicuna (Lama vicugna) and guanaco (Lama guanicoe) can also be found. Sheep and cattle were introduced during the Spanish colonization and have evolved in adapted populations known as "criollos." In recent years efforts have been made to increase production of criollo animals by crossing them with improved breeds.

Vegetation
Lara and Alzerreca (1976) reported 150 native forage species existing in about 6,5000.000 hectares of natural grasslands. The same authors classified the native species into good palatable species (Bromus and Poas), less palatable species (Stipas and Festucas), toxic (Astragalus), and weeds (Bouteloa simplex, Tetraglochin cristatum, Ademia spinosissima, etc.).

Cardozo (1970) described four types of plant communities in the Bolivian Altiplano: a) "Bofedal" under high humidity year-round with common grasses such as Agropirum sp., Aciache pulvinata, and Distchils humilis; b) "Aijadero" (grasslands well covered by pasture), with species including Distichis sp., Nesella pubiflora, etc.; c) "Tholar" (degraded aijadero), composed of species of low palatability such as tholas and ichu (Stipa ichu); and d) "Degrade zones" composed of very low quality forage species such as Stipa spaciosa, Stipa pungens, Butelous simplex, and Stipa macronata.

Soils
There is a large variation in soil types in the highlands. Large areas of alkaline soils, with an abundance of sodium carbonate, are common in the northern Altiplano while sandy soils, with an abundance of salts, prevail in large areas of southern Altiplano. Cardenas (1969). Cardozo (1970) pointed out that the surface soil on the western and eastern Altiplano was originated from sedimentary clay soils with slow infiltration and poor drainage.

The SR-CRSP program in Bolivia
A Memorandum of Understanding (MOU), which defines the basis of agreement between the SR-CRSP and the government of Bolivia, was signed in May, 1991 by the Minister of Planning (Bolivia), Minister of Campesino Affairs and Agriculture (Bolivia), U.S. Ambassador to Bolivia, and the USAID Director in Bolivia. This MOU defines broadly the objectives and scope of this collaborative program.

The University of California, Davis, acting for and on behalf of the Regents of the University of California, is the competent authority under the provisions of the agreement.

Priorities and objectives
The Bolivian Institute for Agriculture Research (IBTA) has six research programs; the Livestock and Forage Research Program (LFP) is one of them, The LFP has been coordinating research activities with the SR-CRSP since 1992. Figure 3 is the organizational chart of IBTA/SR-CRSP.
The main objective of the IBTA/SR-CRSP program and the LFP are:

1. Expand the body of knowledge and extend its application to the solution of specific problems.
2. Expand the level of competence of SR-CRSP and Bolivian scientists to conduct research.
3. Develop and test appropriate technologies to improve food, fiber, and hide productions.
4. Improve small ruminant food, fiber, and hide production capabilities by smallholders in the Host Country.
5. Research Areas in IBTA/SR-CRSP.

The IBTA/SR-CRSP is oriented towards a interdisciplinary systems approach. Ideally a systems approach should be combined with on-farm trials.

Range and pasture management

Seven research activities in these areas were conducted:

- Physical and chemical characteristics of soils and their relation with vegetative communities.
- Vegetative characterization of grasslands in San Jose Llangas (SJL).
- Degree of adoption of alfalfa technology and its utilization by mixed herds sheep-cattle.
- Land utilization and characteristics of thola communities in SJL.
- Qualitative an quantitative studies of forage resources in SJL.
- Plant characterization of the Calientes community.

Main goals of these studies were:

- To obtain knowledge of:
  a) Relationship between soil types and plant communities.
  b) Degree of degradation of the pastoral areas.
  c) Grazing systems.
  d) Degree of salinization.
  e) Technology to control erosion.
  f) Adequate utilization of fallow fields.
  g) Types of pastoral areas.
- Determination of a methodology to estimate carrying capacity.
- Improvement of sheep and alpaca production.
- Reduction of the grasslands degradation and erosion.

Sociology

Sociology studies are oriented to understanding production strategies in order to identify the main problems to which research in biological aspects should respond, and to evaluate potential impacts of new technology. During 1992-93, the sociology program has conducted the following research:

1) Assessment of people's means of securing access to primary factors of production: land, labor and animals. Each "factor" has been the object of a detailed study.
2) Reconstruction of the environmental demographic and institutional history of San Jose, Llanga and the surrounding zone to identify significant episodes of change and their impacts.

Economics

The research activities are related to production strategies with gender specific analysis. Also, commercialization studies have been conducted on different levels and they will continue. Economics is also responsible for coordinating data input such that data will be easily accessible to future researcher. The specific activities are as follows.

- With production strategies:
  1) Animals: Conservation practices in San Jose Llanga. A trade-off is seen between generating income and conserving pasture land. First results suggest that the ability to conserve is related to the total resources owned by a family. In other words, families who own very few resources also tend to over exploit these at levels unsustainable.
  2) Crops: Gender specific technologies used in production. Within the systems research, we have observed a trade-off between producing crops and holding animals. Crops are riskier than animals.

The most important crop in San Jose are potatoes, and their production process has been studied intensively. First results demonstrate that women contribute in a major way to the production of potatoes. Within commercialization studies, commercialization occurs on three different levels, which have been studied:

1) Village level: In San Jose, milk is the most important animal product sold (due to an international project)l Sheep hides and some cheese are also an important marketed item.
2) Market level: In the province of Aroma, the most important markets are to be found in Lahuachaca,

Patacamaya, and Tablachaca. Although live animals are sold there preliminary results suggest that sheep hides constitute an important part of the trade.

3) Export level: A study of sheep hides for export was conducted. Sheep hides are considered a non-traditional exports. Also, studies at the lower marketing levels revealed that sheep hides are important cash crops.

Within data management, economics is working on putting all data collected into a unifying data management system. The aim is to make date easily accessible to other researchers as well as to assure that data is analyzed to its fullest potential.

Projection IBTA/SR-CRSP 1993-94

Site I. (San Jose Llanga)

The new proposed research activities for the period of 1993-94 in SJL are based on the experiences of the past year. Baseline data collection during the past year had been useful in shaping how we view the system at San Jose and the next activates for this region. The proposed workplans emphasize:

Economy

- Economic evaluation of sheep production in San Jose.
- Evaluation of sheep meat commercialization with control of herd quality.
- Effect of small ruminant production in the consumption and the income of producers.
- Commercialization of sheep hides in Aroma Province.

Sociology

- Ex-ante analysis of small ruminant production practices in collaboration with biology programs.
- Assessments of goals and aspirations of San Jose youth with respect to herding.
- Analysis of animal management practices in relation to labor allocation and decision making.
- Continued assessment of environmental risks faced by agropastoralists.

Range ecology

- Barley and alfalfa. Production and utilization of these fields in the fertile subirrigated riparian zone (in progress).
- Management of fallow fields
  a) The influence of land management practices on the vegetative composition fallow field (in progress).
  b) Improvement of fallow field vegetation.
- Sheep manure
  a) Production , storage, and disposition of sheep manure.
  b) Improvement of manure storage.
- Rehabilitation of saline rangeland
  a) Assessment of halophytic plants for vegetating degraded range sites.
- Management-induced degradation
  a) Assessment of relationships between access to land resources, grazing procedures, animal performance, and range degradation.

Site II. (Santiago de Machaca)

Research information collected during the past year in SJL have led to some new ideas for the general project in Santiago. The most important activities of the IBTA/SR-CRSP team in this new site will be:

Characterization of the resources

a) Soils and vegetation characteristics.
b) Herding and grazing strategies.
c) Demographic characteristics.

Research

a) Description of indigenous grazing strategies.
b) Vegetation manipulation and exclusion of grazing
c) Llama fattening scheme.
d) Economics viability of llama production.
e) Grazing analysis experiments.
f) Land tenure and access to land.

The goals are:

- The economics project will evaluate the potential viability of llamas fattening scheme (at the different ages), a strategy to develop a fattening agribusiness, and estimate the economic potential (ex-ante analysis) of llama production.
- The range management project will identify bottlenecks in forage availability, potential of forages, management of pasture with a fattening scheme in mid, and estimate the carrying capacity of the grazing areas.
- The sociology project will identify strategies employed by families to secure access to land. This involves examining the role of individual and communal rights local resource base.

Literature Cited

Cabrera, 1968. Ecologia vegetal de la Puna en : Coloquium Geographicum p. ferd. Dummters Verlog, Bonn. p.91.

Lara y Alzerreca, 1976. Forrajeras nativas del Altiplano. Instituto Boliviano de Tecnologia Agropecuaria I.B.T.A. y Herbario Nal. Boletan Experimental N'V-VII La Paz, Bolivia.

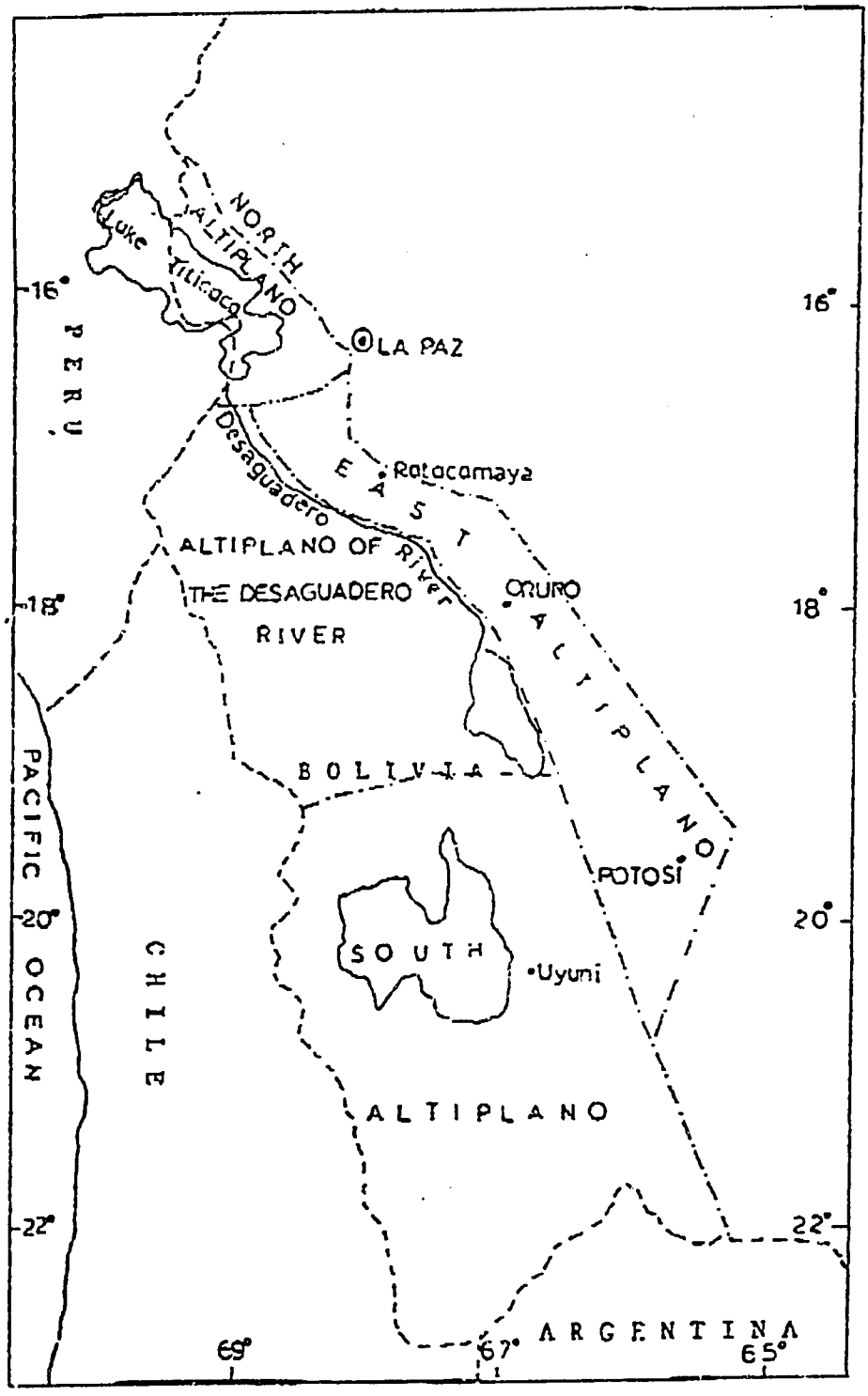
Cardozo. 1970. El Altiplano de Bolivia y la cria de ovejas. Ed. Universitaria Cochabamba, Bolivan. p. 165.

Cardenas, 1969. Distaciones bot nicas en: Amenidades Biolgicas. E. Los Amigos del Libro, Cochabamba, Bolivia. p.229.

Gandarillas, 1963. Informe anual de actividades. Estacin. Experimental de Patacamaya. Ministerio de Asuntos Campesinos y Agropecuarios. La Paz, Bolivia.

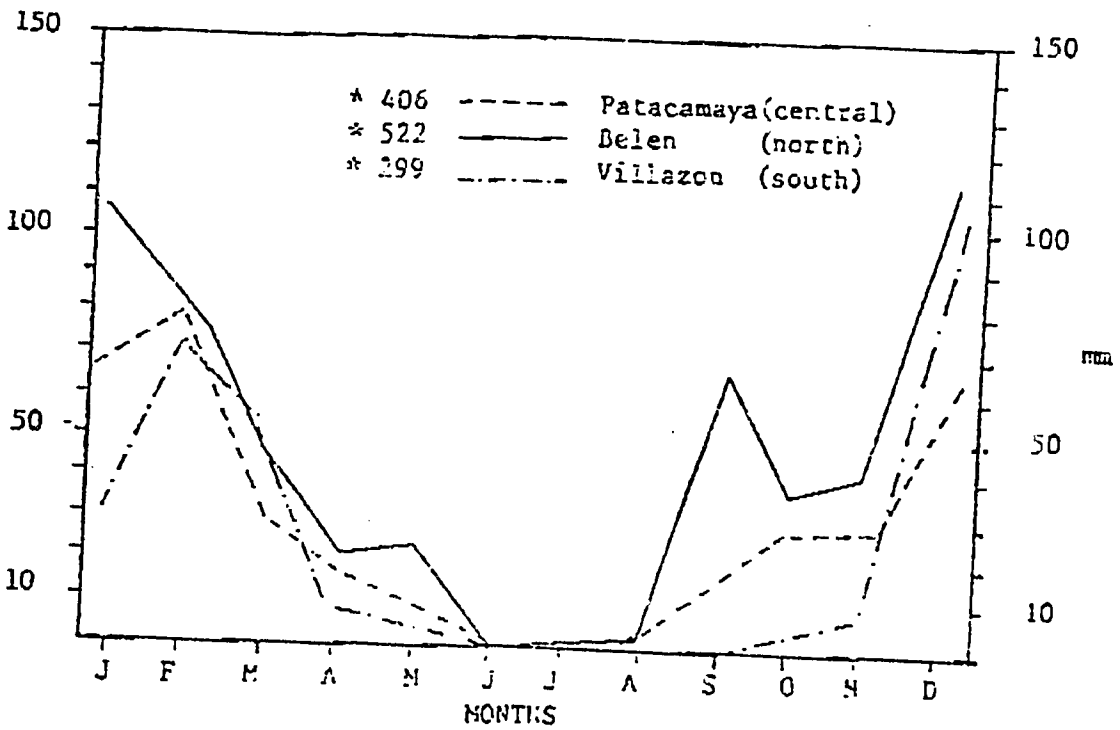
Monhein, 1953. Clasification climitica del Altiplano Boliviano. Ministerio de Asuntos Campesinos y Agropecuarios. Informe final de Consultoria. La Paz, Bolivia.

Figure 1. Bolivian Altiplano zonation.



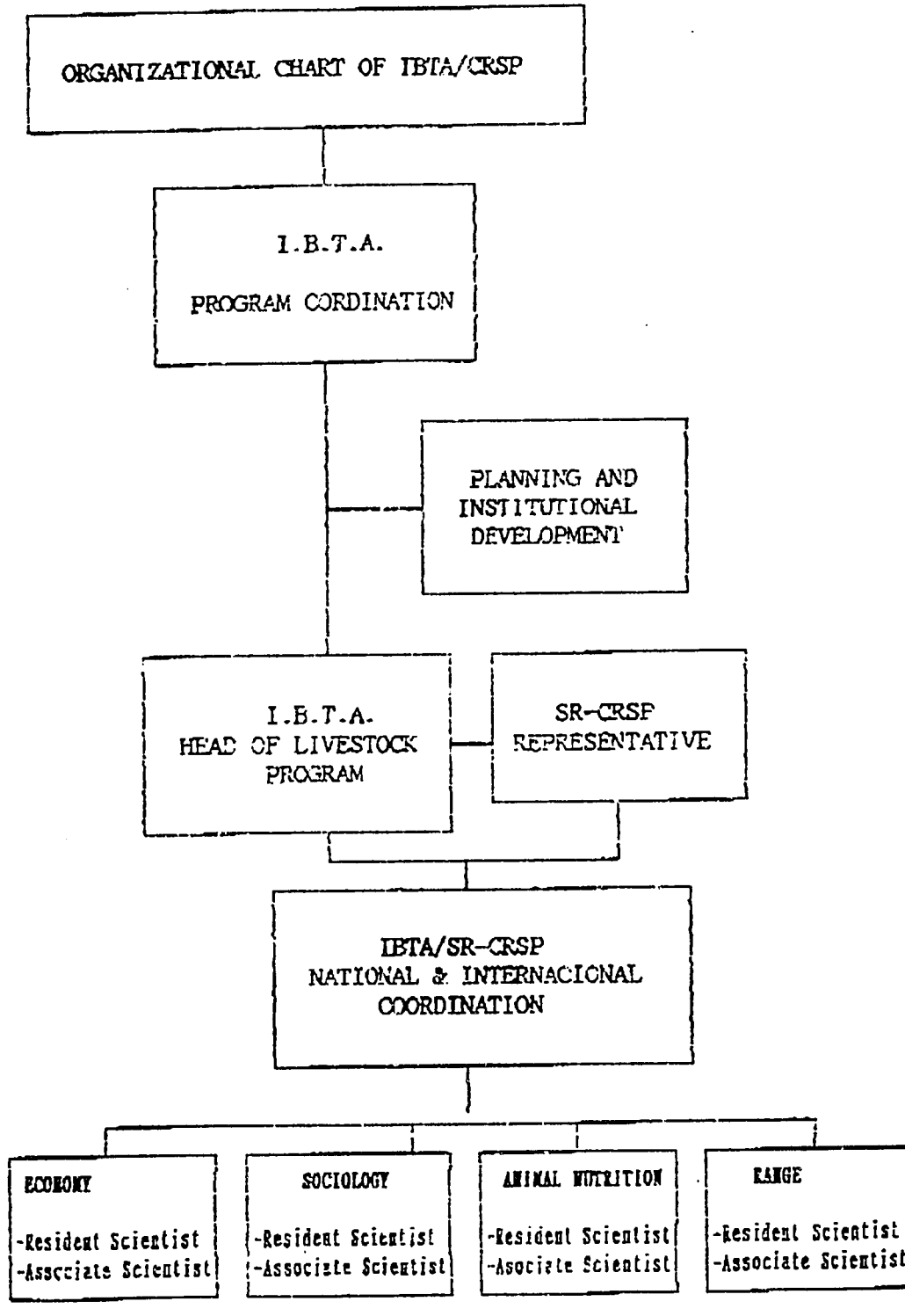
Source: Cardoza, 1970.

Figure 2. Curves of precipitation of three representative areas of the Bolivian Altiplano.



*Mean precipitation
Source: Ministerio de Asuntos Campesinos y Agropecuarios. La Paz, Bolivia, 1975.

Figure 3. The organizational chart of IBTA/SR-CRSP.



Comparative Nutrition Of Sheep And Camelids

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Abstract

Stomach anatomy and retention time of food in the digestive tract are different between South American Camelids (SAC) and sheep.This results in greater digestibility by SAC of low and medium quality forages. Yet, daily consumption in sheep is greater than SAC on a % body weight basis and also when compared on the basis of metabolic body weight. For example, in our research, llamas consumed 36% less forage per day than sheep under grazing conditions on cultivated pastures. In our rangeland study, alpaca consumed an average of 26% less forage per day, and llamas 31% less, than did sheep on a per metabolic body weight basis.

Forage selection also differs between sheep and SAC. On an improved pasture of ryegrass/legume, sheep consumed 2.6 times more legumes than SAC. On a rangeland site, llamas selected greater proportions of tall grasses than alpaca and sheep. Alpacas and sheep showed a high preference for short grasses and forbs. Low intake and high efficiency of utilization of low quality forage make SAC more efficient herbivores on the scarce and fibrous vegetation present in the high altitude rangeland of the Altiplano region of South America.

Introduction

The llama (*Lama glama*), alpaca (*L. pacos*), guanaco (*L. guanicoe*), and vicuna (*L. vicugna*) form a group of animals know as South American Camelids (SAC); only the former two are domesticated.

South American camelids occur primarily in four countries: Peru (3,975,000 head), Bolivia (2,802,200), Argentina (186,200), and Chile (99,500). The largest population of llamas and alpacas is in the Bolivian and Peruvian Altiplano of the Andes Mountains.

Altiplano husbandry is primarily an extensive production system with combined herds of small ruminants (SAC and sheep). At present, all llamas, about 80% of all alpacas, and 70% of all sheep are 2under the control of traditional pastoralists and agropastoralists.

Because SAC and sheep share forage resources in the Andean Region and are frequently managed together, there exists great interest in theie comparative nutrition, intake, and diet selectivity. This paper focuses on nutritional aspects of alpacas and llamas and comparison between SAC and sheep.

Digestive system

The stomach of SAC differs from that of sheep. Vallenas et al. (1971) described three distinct compartments. A transverse pillar divides the large, first compartment (C1) into cranial and caudal sacs. The C1 is connected to a smaller second compartment (C2). SAC have a ventricular groove which apparently has the same function as the reticular groove in advanced ruminants (Vallenas, 1965). The ventricular groove terminates at the tubular passage to the third compartment (C3), an elongated compartment slightly dilated

in its proximal end.

Two types of mucosa are found on the internal surface of C1 and C2. The recessed sacculus are covered by stratified squamous epithelium in the dorsal part. In llamas, about half of the total surface area (6700 cm) is occupied by a glandular area (Rubsamen, 1976, cited by Engelhardt and Holler, 1982). The surface of C3 is covered with glandular epithelium. The terminal one-fifth of C3 is thick and corresponds to the site of gastric glands, similar to the abomasum in sheep.

With respect to glandular mucosa, Rubsamen and Engelhardt (1978) reported that the main function of this glandular region in the third stomach of SAC is rapid absorption of solutes and water. Absorption rates reach two to three times that in the rumen of sheep and goats. Engelhardt and Rubsamen (1979) also reported a rate of absorption in C3 significantly higher than values measured in the omasum of sheep and goats, even when differences in body weight were considered.

Florez (1973)found that digesta was retained longer in alpacas (50.3 h) than sheep (43.2 h). San Martin (1987) reported retention in llamas of 63.2 h and 40.9 h for sheep. In a study of gastrointestinal transit time in ten mammal species, Clemens and Stevens (1980) indicated llamas retained larger particles for a longer period of time than cattle or horses.

Digestibility

Several trials of comparative in vivo digestibility between alpacas and sheep, and llama and sheep, have been reported (San Martin, 1987). Generally, on diets of low quality forages, SAC had greater digestion coefficients than sheep. For example, in diets with less than 7.5% crude protein (Table 1), differences between alpacas and sheep were greater than when dietary crude protein was above 10.5% (San Martin et al., 1985). Greater digestion coefficients were reported for llamas than for sheep on low and medium quality diets, but digestion coefficients were similar on high quality diets (Table 2) (San Martin, 1987).

Table 1. Comparative mean digestion coefficients (%) in alpacas and sheep in relation to protein level in the feed.

	Dietary crude protein					
	<7.5%			>10.5%		
Nutrient	N trials	Alpaca	Sheep	N trials	Alpaca	Sheep
Dry Matter	7	63.7	56.0	9	60.8	62.0
Crude Protein	5	42.1	36.1	9	60.0	61.9
Crude fiber	9	67.7	61.9	9	57.5	58.5

Table 2. Digestibility coefficients (%) in llama and sheep in relation to diet quality.

Nutrient	Quality*						Overall	
	Low		Medium		High		Llama	Sheep
	Llama	Sheep	Llama	Sheep	Llama	Sheep		
Org matter	51	41	60	52	73	75	62	56
Neutral detergent fiber	38	33	43	32	40	40	40	35
Acid detergent fiber	43	42	40	34	46	41	44	39
Crude protein	24	19	38	37	68	73	43	43

*Low: 7% crude protein (CP) and 2.2 Mcal digestible energy (DE)/kg dry matter; medium CP and 2.8 Mcal DE/kg D; high:15%CP and 3.2 Mcal D/kgDM.

Greater SAC efficiency may be related to longer retention time of digesta than in sheep (Florez, 1973; San Martin, 1987). Digestibility of high quality diets is relatively unaffected by retention time in the reticulo-rumen (Blaxter, 1963). Greater efficiency of digestion in SAC may be due also to more frequent contractions of the forestomach, the rumination cycle, and the ratio of salivary flow to forestomach size. These attributes provide for more efficient maceration, mixing and absorption of digesta. Greater digestibility values in SAC on low nitrogen feed could be explained by the ability to maintain higher ammonia concentrations in C1-C2 compared to sheep (Hinderer and Engelhardt, 1975; Engelhardt and Schneider, 1977). This would provide llamas with more nitrogen for microbial synthesis, thus improving digestibility.

Voluntary intake

Most intake information available for SAC comes from comparative studies with sheep under penned conditions. Feed consumption studies between SAC and sheep (Table 3) have shown an overall average dry matter (DM) intake by alpaca and llama of 1.8 and 2.0% of body weight (BW), respectively vs. 2.3-3.3% for sheep. Daily consumption by llama on a metabolic weight basis (g/kg BW0.75) was lower than for sheep (Table 3).

Voluntary intake studies under grazing conditions are scarce. Dry matter intake in terms of g per kg metabolic body weight under grazing conditions for llamas and alpacas range from 38 to 67 g, depending on type of pasture and season of use (San Martin, 1987). Similar to studies under penned conditions, consumption under grazing conditions is lower in SAC than sheep (Table 3). San Martin (1987) reported that, on a metabolic weight basis, llamas and alpacas had the same level of intake grazing improved and native range pastures, but intake values for llamas were 36% lower than for sheep on improved pasture and 31% lower on native range pastures. Alpaca intake on rangeland was 26% below sheep intake.

Table 3. Comparison of daily intake of South American camelids (SAC) with sheep in penned and grazing situations. Intake data are means ± standard deviations in parentheses.

	Daily Intake				
	alpaca	llama	sheep	comparative difference (%)	
Pen Study				(sheep-SAC)/sheep	
Intake: DM as % BW	1.83 (0.46)		2.29 (0.61)	20	
		2.0 (0.18)	3.3 (0.77)	39	
Grazing Study (cultivated pasture)					
Intake: g OM/kg $BW^{0.75}$		52.8 (3.87)	83.2 (12.97)	36	
Grazing Study (native range)				(sheep-alpaca) /sheep	(sheep-llama) /sheep
Intake: g DM/kf $BW^{0.75}$	50.0 (9.24)	46.8 (10.90)	68.1 (18.7)	26	31

Selectivity

San Martin (1987) studied the dietary composition of llamas, alpacas, and sheep under grazing conditions on three different pastures: an improved pasture (*Festuca rubra, Lolium perenne* and *Trifolium repens*); a *Festuca dolichophylla* range site (Fedo); and a *Pestuca rigida* range site (Feri). On the improved pasture, sheep ate at least 2.6 times more legumes than SAC (Table 4). This lower selectivity for legumes by SAC might explain why bloat has not been reported in SAC.

On the rangeland sites, preference for tall coarse bunchgrasses was highest for llamas, followed by alpacas then sheep (Tables 5 and 6). That alpacas were intermediate between llamas and sheep in selection of coarse forages suggests that alpacas are more selective grazers than llamas. San Martin (1987) showed that alpacas are more opportunistic and appear to be able to use a wide variety of forage types.

In the dry season, diet similarity was highest between llamas and alpacas on *Festuca rigida* range, and between alpacas and sheep on the *Festuca dolicophyla* site (San Martin, 1987). In a complementary grazing system, llamas and sheep offer the most efficient way to harvest available forage, while alpacas seem to be adequate for single-species use of rangelands.

Table 4. Diet botanical composition (%) of llama, alpaca and sheep during dry and rainy periods on cultivated pasture.

Plant group and species	Dry period			Rainy period			Overall means		
	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep
Grass	83	82	58	83	82	57	83[a1]	82[a]	58[b]
Festuca Rubra	46	46	37	56	50	38	51[a]	48[a]	38[b]
Lolium perenne	36	37	21	27	32	19	32[a]	34[a]	20[b]
Forbs	17	18	42	17	18	43	17[a]	18[a]	42[b]
Trifolium repens	17	18	42	13	15	40	15[c]	14[a]	41[b]

1 Average in the same row followed by a different letter differ significantly (P<0.05).

Table 5. Diet botanical composition (%) by plant group of llama, alpaca and sheep during dry and rainy periods on *Festuca dolicophylla* range.

Plant group and species	Dry period			Rainy period			Overall means		
	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep
Tall grass	38	24	17	45	28	20	4281	268	18b
Short grass	51[ab]	38[a]	43[ab]	42[ab]	29[a]	65[a]	46	34	54
Total grass	89[a]	62[b]	61[b]	87[a]	56[b]	86[b]	88	59	74
grass like plants	6	2	3	5	1	1	6[a]	2[b]	2[b]
Forbs	4[b]	35[a]	35[a]	7[b]	42[b]	13[b]	6	38	24

1 Average in the same row followed by a different letter differ significantly (P<0.05).

Table 6. Diets botanical composition (%) by plants group of llama, alpaca and sheep during dry and rainy periods on Festuca rigida range.

Plant group and species	Dry period			Rainy period			Overall means		
	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep	Llama	Alpaca	Sheep
Tall grass	47[ab]	38[b]	22[c]	32[b]	15[a]	18[cd]	2	6	20
Short grass	40[b]	4b[a]	32[c]	47[b]	29[c]	47[a]	44	38	40
Total grass	87[a]	83[a]	54[c]	84[a]	44[d]	65[b]	86	64	60
Grass like plants	2[a]	1[a]	0.5[b]	—	—	—	1	0.5	0.2
Forbs	12[c]	15[c]	45[b]	16[c]	56[a]	35[b]	14	J6	40

1 Average in the same row followed by a different letter differ significantly (P<0.05).

Conclusions

The present overview on the digestive efficiency, intake, and selectivity of domesticated SAC demonstrates that these species are better adapted to the harsh environments of the Andean region than sheep. However more basic research is needed in digestive physiology, foraging behavior, and nutritional requirements.

Literature Cited

Blaxter, K.L., 1963. The Energy metabolism of Ruminants. Hutchinson Scientific and Technical, London, 314 pp.

Clemens, B.T., and Stevens, C.B., 1980. A comparison of gastrointestinal transit time in ten species of mammal, J. Agric. Sci. Camb., 94:735-737.

Cumming, J.B., Munnell, J.P. and Vallenas, A., 1972. The mucigenous glandular mucosa in the complex stomach of two New World Camelids, the llama and guanaco. J. Morphol., 137: 71-110.

Engelhardt, Wv., and Holler, R., 1985. Structure and function of the forestomach in camelids a comparative approach. Acta Physiol. Scand., 124 (Suppl.): 542.

Engelhardt, Wv., and Rubsamen, K., 1979. Digestive physiology of camelids. The workshop of camels. Khartoum, pp.302-346.

Engelhardt, Wv., and Schneider, W., 1972. Energy and nitrogen metabolism in the llama. Anim. Res. and Develop., 5: 68-72.

Florez, J.A. 1973. Velocidad de pasaje de la ingesta y digestibilidad on alpacas y ovinos. (Rate of passage and digestibility in alpacas and sheep). Prog. Acad. Med. Vet., Univ. Nac. Mayor de San Marcos, Lima (B.S. Thesis), 46 pp.

Hinderer, S., and Engelhardt, Wv., 1975. Vica metabolism in the llama. J. Comp. Biochem. Physio). A, 52:619 622.

Rubsamen, K., and Engelhardt, Wv., 1978. Bicarbonate secretion and solute absorption in the forestomach of the llama. Am. J. Physio., 235: 1-6.

San Martin, F. 1987. Comparative forage selectivity and nutrition of South American camelids and Sheep. Texas Tech Univ., Lubbock, TX (Ph.D. Disertation), 146 pp.

San Martin, F., Farfan, K. and Valdivia, R., 1985. Digestibilidad comparativa entre alpacas y ovinos. (Comparative digestibility between alpacas and sheep.) V. Convencion Internacional sobre Camelidos Sudamericanos (abstract), Cusco.

Vallenas, A. 1965. Some physiological aspects of digestion in the alpaca (Lama pacos). In; R.W. Doughtery (Editor), Physiology of Digestion in the Ruminants, Butterworths, Washington, DC, pp. 147-158.

Vallenas, A., Cumming, J.D, and Munell, J.B., 1971. A gross study of the compartmentalized stomach of the two New World Camelids, the llama and guanaco. J. Morphol., 134: 339-424.

Van Soest, P.J. 1982. Nutritional ecology of the ruminant. O&B Books, Corvallis, OR, p. 374.

Retrovirus Diseases of Small Ruminants

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Abstract

Retrovirus infections of sheep and goats induce insidious, chronic diseases of the lung, joints, brain, or udder after a long incubation period. Ovine progressive pneumonia (OPP) and caprine arthritis-encephalitis (CAE) are caused by members of the lentivirus genus of Retroviridae, whereas ovine pulmonary carcinoma (OPC) is associated with a type D retrovirus. The lentiviruses that cause OPP and CAE are well-characterized, and sensitive diagnostic tests are available to detect viral products or antibodies in infected animals. The presumed causative agent of OPC has not yet been grown in cell culture, and no serologic tests for OPC have been described. Although the economic effects of the three retrovirus infections are difficult to quantify, they collectively represent some of the most important and challenging animal health problems in both the lesser developed and developed countries. Until new immunoprophylactic products or diagnostic tests are available, the control of retrovirus infections in sheep and goats will continue to be based on removal of infected animals and quarantine procedures.

Introduction

The Retroviridae, a large family of viruses of vertebrate animals which includes the notorious cause of AIDS in humans, have evolved a very complex relationship with their hosts. These viruses have the capacity to integrate into the host genome, cause a persistent lifelong infection, and escape the animal's immune response. There is a wide clinical spectrum of disease caused by various retroviruses, ranging from immunodeficiency to inflammatory disease of several body systems to neoplasia. When disease does occur, it often develops after a prolonged latent period and has a chronic progressive course. Means for prevention or treatment do not exist for most retrovirus infections.

Retroviruses cause a group of insidious, but economically important, diseases of sheep and goats. Two of these diseases, ovine progressive pneumonia (OPP, maedi-visna) and ovine pulmonary carcinoma (OPC sheep pulmonary adenomatosis, jaagsiekte), are chronic respiratory diseases of sheep that have been recognized for almost a century. The other, caprine arthritis- encephalitis (CAE) is a more recently recognized syndrome of arthritis in older dairy goats and encephalitis in kids. Despite difference in species affected and predominant clinical signs presented, OPP and CAE are both caused by members of the lentivirus genus of Retroviridae: OPP is caused by ovine lentivirus (OvLV) and CAE is caused by caprine arthritis-encephalitis virus (CAEV). OPC is associated with a yet uncultured type D retrovirus of sheep. Since several recent reviews on OPP, OPC, and CAE have been published (DeMartini et al., 1988, DeMartini et al., 1993; Cheevers and McGuire, 1988; Brodie et al., 1992b), this overview will highlight some of the contributions made by SR-CRSP scientists to the better understanding of these viruses and indicate the future directions for research necessary for their improved control or prophylaxis.

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Worldwide distribution of small ruminant retrovirus diseases

OPC and OPP are endemic in most countries of the world, with the notable exception of Australia and New Zealand, where they have not been reported despite surveillance efforts, and Iceland and Holland, where they have been eradicated. Both diseases often occur in the same flock and even in the same animal. The proportional prevalence of these diseases varies: in many European countries, with the exception of the United Kingdom where OPC predominates, OPP and OPC are both important clinical problems. In North America, OPP is very widespread with a seroprevalence averaging 50-90% in the Western states; OPC is a rare disease and only five cases have been reported within the last decade (Rosadio, 1988a). OPC has long been recognized as a major cause of mortality in the Andean highlands of Peru (DeMartini, 1988; Ameghino, 1990), but OPP was discovered relatively recently by SR-CRSP scientists as a contributing cause of respiratory disease (Snyder et al., 1983; Rosadio, 1984; Madewell et al., 1987). Pathologic and serologic surveys for these diseases in Peru indicated that on a large cooperative farm, OPC was the single most important disease of adult sheep and was responsible for almost a 2% annual death loss in this group (DeMartini et al., 1988). In a slaughterhouse survey, this disease also was found to occur in small-holder flocks (Ellis et al., 1993). Similarly, OPC has been studied for many years in South and East Africa. OPP and other OvLV-associated diseases have been more recently discovered in both regions (Rwambo, unpublished data) and their frequency remain to be elucidated.

CAE was first recognized as a disease common in dairy goats in North America and Europe (Cheevers and McGuire, 1988). It has also been recognized in goats of New Zealand and Australia. Although CAE lentivirus can be transmitted experimentally to sheep and OvLV can be transmitted to goats, no instances of natural cross transmission have been reported. In a global serological survey for CAE involving 112 locations in 14 countries (Adams et al., 1984), developed countries in North America and Europe had a seropositivity rate of 65-81% whereas among developing countries in Africa (Kenya, Sudan, South Africa, Somalia), South America (Peru), the Pacific Islands (Fiji), and North America (Mexico), the seropositivity rate was 0-9%. Interestingly, the great majority of the infected animals in the developing countries could be traced to goats imported from countries with a high seroprevalence; local mixed-breed goats were almost totally free of infection. This information formed the basis for eradication of CAE from Kenya, a project facilitated by SR-CRSP scientists. Also, studies demonstrating perinatal transmission of CAE primarily through milk formed the basis of a control program for CAE in the United States and other countries (Adams et al., 1983).

Effects of retrovirus infections on small ruminant production

To understand the effects of retrovirus infection on production of sheep and goats, it is first necessary to recognize the manifestations of disease. In turn, development of diagnostic procedures for both the disease and the virus require knowledge of the structure of the causative agent, immune and pathologic responses of the host to it, and mechanisms of transmission. During the past 12 years, these issues have received attention by SR-CRSP scientists, and some of the most significant advances will be summarized here.

The basic clinical and pathologic features of both OPP and OPC had been described prior to initiation of SR-CRSP research with these diseases. However, improvements in diagnosis and enhanced understanding of the pathogenesis and transmission of the virus infections necessitated research both with naturally and experimentally infected sheep. By intratracheal inoculation of virus-containing materials into neonatal lambs, OvLV-associated lymphoid interstitial pneumonia and type D retrovirus-associated OPC were both induced, the latter for the first time in North America (Lairmore et al., 1986, 1987; DeMartini et al., 1987; Rosadio et al., 1988b). The pathologic features of the induced diseases were investigated and compared, leading to definition of distinguishing characteristics. Furthermore, the multisystemic effects of OvLV were elucidated; arthritis, encephalitis, and mastitis were produced in the experimentally infected lambs in addition to lymphoid interstitial pneumonia. Immunoregulatory abnormalities were studied in lentivirus-infected sheep (Ellis and DeMartini, 1985a,b,c; Lairmore et al., 1988a) and goats (DeMartini et al., 1983). The pattern and specificity of antiviral antibody development were studied in the experimentally infected lambs using a Western immunoblotting assay (Kajikawa et al., 1990a).

Pathologic features and immune responses of sheep naturally affected with OPC in the U.S. and Peru were investigated and compared. The lung neoplastic process involved in OPC was generally similar and comparable to those of the experimentally infected lambs (Snyder et al., 1983; Rosadio et al., 1988a,b). A study involving 42 range sheep at risk for OvLV infection indicated that although lymphoid interstitial pneumonia was the most common finding, affecting 71% of the animals, many also had arthritis and encephalitis (Brodie et al., 1992a). Prenatal transmission of OvLV was studied in the offspring of 85 ewes from the same flock using a very sensitive polymerase chain reaction assay for detection of viral DNA (Brodie, unpublished data). An 11% infection rate of OvLV infection was found in the lambs, considerably higher than previously suspected. A similar assay is being used to investigate the possibility to venereal transmission by the semen of infected rams (de la Concha and DeMartini, unpublished data). The possible effects of OvLV on reproductive outcome remain to be investigated.

In addition to causing encephalitis in young kids and crippling arthritis in older bucks and does, CAE has other effects on production. Because the virus seems not to infect indigenous breeds of goats in the several countries examined, many developing countries limit importation of improved breed dairy goats from developed countries in North America and Europe unless they are CAE-free. This adds additional expense or even precludes attempts to efforts to improve milk and meat production by introduction of new breeds. Similarly, in the absence of an effective diagnostic test for OPC virus, many countries are hesitant to import animals from countries where OPC is endemic.

New techniques for diagnosis and control

The development of new diagnostic tests for retrovirus infection depends on knowledge of viral proteins and genes as well as host antibody responses. OvLV field isolates have been obtained from naturally infected sheep in the U.S., Peru, and Kenya (Lairmore, 1988b; Ameghino et al., 1990; DeMartini et al., 1993; Rwambo, unpublished data). Viral strains of the U.S. and Kenyan isolates have been compared at the nucleic acid and protein levels. Furthermore, monoclonal antibodies have been developed for viral proteins of OvLV and CAEV (McGuire et al., 1987; Marcom et al., 1991). These reagents and knowledge of virus strain differences have allowed the development of new sensitive assays for detection and comparison of viral proteins, viral nucleic acids, and host antibody responses. Assays developed for detection of viral antibodies include Western immunoblotting and an indirect ELISA (Kajikawa et al., 1990a; Brodie et al., 1993). Sensitive assays for virus detection include an antigen capture ELISA assay for OvLV capsid antigen, a rapid focal immunoassay for infectious virus, and a polymerase chain reaction (PCR) assay for detection of viral DNA (Marcom et al., 1992; Brodie et al., 1993). The usefulness of these assays in detection in clinical specimens has been verified in comparison with slower and more labor-intensive assays such as virus isolation or the agar gel immunodiffusion test for serum antibody (Brodie et al., 1993).

In the absence of vaccines (Pearson et al., 1987), OvLV and CAEV-induced diseases continue to cause substantial losses in productivity of sheep enterprises in countries throughout the world. Currently the only methods of control for these lentivirus-induced diseases are based upon serological testing and removal of infected animals supplanted by quarantining and flock certification programs (Brodie et al., 1992b). With a background of knowledge of viral genetics and host immune responses, as well as availability of molecular clones of the viruses, it should be possible to develop protective immunogens for infection. The critical *env* gene of one OvLV strain has been cloned, and immunologically relevant proteins encoded by this gene are being studied. Data from other lentivirus systems indicate that viral surface glycoproteins contain antigenic epitopes that induce anti-viral antibody and cell mediated immune responses (Pearson et al., 1989). However, because of low titers of neutralizing antibody in lentivirus-infected animals and a marked tendency for antigenic variation of viral neutralizing epitopes (McGuire et al., 1988), epitopes important in cell-mediated immunity are the main target of our approach. Defining the epitopes of viral surface glycoproteins is expected to provide the basis for development of protective immunogens for lentivirus infections in sheep and goats. Strategies for control of ovine lentivirus through genetic engineering of the sheep genome also have been considered, but are probably a more distant goal (DeMartini et al., 1990).

Since there are no diagnostic tests or vaccines for OPC, there are no effective means for controlling

this disease. The infectious agent has been identified as a type D retrovirus, based on ultrastructural, enzymatic, and immunological studies (DeMartini et al., 1988; Kajikawa et al., 1990b; He et al., 1992). Although a culture system for the virus is not yet available, molecular clones of the virus have been derived. These have been used to produce recombinant viral protein which may be useful in developing a sensitive serological assay for detection of carrier animals and their removal from the flock. Eventually, with increased knowledge of the viral agent and its mechanism of disease, an immunoprophylactic product for OPC is possible.

Literature Cited

Adams, D.S., P. Klevjer-Anderson, J.L. Carlson, T.C. McGuire, and J.R. Gorham. 1983. Transmission and control of caprine arthritis-encephalitis virus. Amer. J. Vet. Res. 44:1640.

Adams, D.S., R.E. Oliver, E. Ameghino, J.C. DeMartini, D.W. Verwoerd, D.J. Houwers, S. Waghela, J.R. Gorham, B. Hyllseth, M. Dawson, F.J. Trigo, and T.C. McGuire. 1984. Global survey of serological evidence of caprine arthritis-encephalitis virus infection. Vet. Rec. 115:493.

Ameghino, E., R.H. Rosadio, A.R. Ramirez, and J.C. DeMartini. 1990. Chapter 6. Diagnosis and control of diseases in sheep and alpaca in Peru. In Improving Andean Sheep and Alpaca Production; (C.M. McCorke, ed.) Columbia, University of Missouri. p. 141.

Brodie S.J., K.A. Marcom, L.D. Pearson, B.C. Anderson, A. de la Concha-Bermejillo, J.A. Ellis, and J.C. DeMartini. 1992. Effects of virus load in the pathogenesis of lentivirus- induced lymphoid interstitial pneumonia. J. Infect. Dis. 166:531.

Brodie, S.J., G.D. Snowder, and J.C. DeMartini. 1992. Ovine progressive pneumonia: Advances and prospects for control. Sheep Res. J. 8:116.

Brodie, S.J., L.D. Pearson, G.D. Snowder, and J.C. DeMartini. 1993. Host-virus interaction as defined by amplification of viral DNA and serology in lentivirus-infected sheep. In press. Arch. Virol.

Brodie, S.J., A. de la Concha-Bermejillo, G. Koenig, G.D. Snowder, and J.C. DeMartini. Maternal factors associated with prenatal transmission of ovine lentivirus. Submitted.

Cheevers, W.P. and T.C. McGuire. 1988. The lentiviruses: maedi/visna, caprine arthritis-encephalitis, and equine infectious anemia. Advances in Virus Res. 34:189.

DeMartini, J.C., K.L. Banks, A. Greenlee, D.S. Adams and T.C. McGuire. 1983. Augmented T lymphocyte responses and abnormal B lymphocyte numbers in goats chronically infected with the retrovirus causing caprine arthritis-encephalitis. Amer. J. Vet. Res. 44:2064.

DeMartini, J.C., R.H. Rosadio, J.M. Sharp, H.I. Russell and M.D. Lairmore. 1987. Experimental coinduction of Type D retrovirus - associated pulmonary adenomatosis and lentivirus-associated lymphoid interstitial pneumonia. J. Nat. Canc. Inst. 79:167.

DeMartini, J.C.. R.H. Rosadio, and M.D. Lairmore. 1988. The etiology and pathogenesis of ovine pulmonary carcinoma. Vet. Micro. 17: 219.

DeMartini, J.C., R.A. Bowen, J.O. Carlson, and A. dela Concha. 1990. Chapter 17. Strategies for the genetic control of ovine lentivirus infections, pgs. 293-314. In: Breeding for Disease Resistance in Farm Animals (J.B. Owen and R.F.E. Axford, eds). Oxon, U.K., C.A.B. International, 1991, 499 pp.

DeMartini, J.C., S.J. Brodie, A. de la Concha-Bermejillo, J.A. Ellis, and M.D. Lairmore. 1993. The pathogenesis of lymphoid interstitial pneumonia in natural and experimental ovine lentivirus infection. In press. Clinical Infectious Diseases.

Ellis, J.A. and J.C. DeMartini. 1985. Ovine interleukin 2: Partial purification and assay in normal sheep and sheep with ovine progressive pneumonia. Vet. Immunol. Immunopath. 8:15.

Ellis, J.A., A.E.V. Chavera, and J.C. DeMartini. 1993. Disease conditions in slaughtered sheep from small holder flocks in Peru. Small Ruminant Research 10:243.

Ellis, J.A. and J.C. DeMartini. 1985. Evidence of decreased concanavalin A induced suppressor cell activity in the peripheral blood and pulmonary lymph nodes of sheep with ovine progressive pneumonia. Vet. Immunol. Immunopath. 8:93.

Ellis, J.A. and J.C. DeMartini. 1985. Immunomorphologic and morphometric changes in the pulmonary lymph nodes of sheep with ovine progressive pneumonia. Vet. Path. 22:3241.

He, Y., S.J. Hecht, and J.C. DeMartini. 1992. Evidence for retrovirus capsid and nucleocapsid antigens in ovine pulmonary carcinoma. Virus Res. 25:159.

Kajikawa, O., J.E. Dahlberg, R.H. Rosadio, and J.C. DeMartini. 1990. Detection and quantitation of a type D retrovirus *gag* protein in ovine pulmonary carcinoma (sheep pulmonary adenomatosis) by means of a competition radioimmunoassay. Vet. Micro. 25:17.

Kajikawa, O., M.D. Lairmore, and J.C. DeMartini. 1990. Analysis of antiviral antibody to phenotypically distinct lentiviruses. J. Clin. Micro. 28:764.

Lairmore, M.D., R.H. Rosadio and J.C. DeMartini. 1986. Ovine lentivirus lymphoid interstitial pneumonia: Rapid induction in neonatal lambs. Amer. J. Path. 125:173.

Lairmore, M.D., G.Y. Akita, H.I. Russell, and J.C. DeMartini. 1987. Replication and cytopathogenicity of ovine lentivirus strains in alveolar macrophages correlate with in vivo pathogenicity. J. Virol. 61: 4038.

Lairmore, M.D., S.T. Butera, G.N. Callahan, and J.C.DeMartini. 1988. Spontaneous interferon production by pulmonary leukocytes is associated with lentivirus induced lymphoid interstitial pneumonia. J. Immunol. 140:779.

Lairmore, M.D., J.M. Poulson, T.A. Adducci, and J.C.DeMartini. 1988. Lentivirus- induced lymphoproliferative disease: Comparative pathogenicity of phenotypically distinct ovine lentivirus strains. Amer. J. Path. 130: 80.

Madewell, B.R., E. Ameghino, H. Rivera, L. Inope, and J. DeMartini. 1987. Seroreactivity of sheep and goats to small ruminant lentivirus-ovine progressive pneumonia virus. Amer. J. Vet. Res. 48:372.

Marcom, K.A., L.D. Pearson, C.S. Chung, J.M. Poulson, and J.C. DeMartini. 1991. Epitope analysis of capsid and matrix proteins of North American ovine lentivirus field isolates. J. Clin. Micro. 29:1472.

Marcom, K.A., S.J. Brodie, L.D. Pearson, and J.C. DeMartini. 1992. Analysis of ovine lentivirus infectivity and replication using a focal immunoassay and an antigen-capture ELISA. J. Clin. Micro. 30: 2852.

McGuire, T.C., A.L. Brassfield, W.C. Davis, and W.P. Cheevers. 1987. Antigenic and structural variation of the p28 core polypeptide of goat and sheep retroviruses. J. Gen. Virol. 68:2259.

McGuire, T.C., L.K. Norton, K.I. O'Rourke, and W.P. Cheevers. 1988. Antigenic variation of neutralization-sensitive epitopes of caprine arthritis-encephalitis lentivirus during persistent arthritis. J. Virol. 62:3488.

Pearson, L.D., M.L. Poss, and J.C. DeMartini. 1989. Animal lentivirus vaccines: Problems and prospects. Vet. Immunol. Immunopath. 20:183.

Rosadio, R.H., J.F. Evermann, and J.C. DeMartini. 1984. A preliminary serological survey of seroprevalence of viral antibodies in Peruvian sheep. Vet. Micro. 10:91.

Rosadio, R.H., M.D. Lairmore, H.I. Russell, and J.C. DeMartini. 1988. Retrovirus- associated ovine pulmonary carcinoma (sheep pulmonary adenomatosis) and lymphoid interstitial pneumonia. I. Lesion evelopment and age susceptibility. Vet. Path. 25: 475.

Rosadio, R.H., J.M. Sharp, M.D. Lairmore, J.E. Dahlberg, and J.C. DeMartini. 1988. Lesions and retroviruses associated with naturally-occurring ovine pulmonary carcinoma (sheep pulmonary adenomatosis). Vet. Path. 25: 58.

Snyder, S.P., J.C. DeMartini, E. Ameghino and E. Caletti. 1983. Coexistence of pulmonary adenomatosis and progressive pneumonia in sheep in Peru. Amer. J. Vet. Res. 44:1344.

Chapter 3. Mediterranean Sheep Production Systems

The SR-CRSP in Morocco 1981 - 1992: Achievements and Impacts

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Abstract

Since 1981, Morocco, represented by the Hassan II Agronomic and Veterinary Institute has been a host country of the Small Ruminant Collaborative Research Support Program. Research programs implemented concerned both agro-pastoral and pastoral systems under a Mediterranean climate. Disciplines involved included genetics, reproductive physiology, nutrition, range management, environmental physiology, sociology and parasitology. After 10 years of activities, the project has contributed signficantly to improving Moroccan human resources in the field of sheep and goat production. The project has also been very productive in terms of number of scientific publications. The project contributed to outreach/development mainly through a "technological package" publication on sheep. It is believed that the collaborative concept should be reinforced and can open new perspectives for joint ventures between United States and Moroccan universities.

Introduction

Morocco is the North African country with the largest small ruminant (SR) population. In 1987, Morocco had 16.1 million sheep and 5.8 million goats. This means a ratio of 0.9 SR per inhabitant. In Tunisia and Algeria, corresponding figures were 0.8 and 0.6, respectively. During the same period, SR meat represented 45% of the total red meat produced in Morocco. Projections for the year 2000 indicate that this percentage will remain nearly constant.

Small ruminant distribution within the country is quite variable, but, basically, the two species are raised in all ecosystems: rainfed regions, irrigated areas, rangeland, mountains, desert, etc. In terms of feeding systems, the most important ones for sheep are the agro-pastoral and the pastoral systems, but a small population of the D'man breed is raised under oasis conditions. Goats are mainly raised in the pastoral system. Average productivity per ewe per year is very low, ranging from 10 to 26 kg of liveweight for non-prolific breeds and from 30 to 35 kg for the prolific D'man sheep. Goat productivity on the average is much lower (7 to 16 kg).

Small ruminant production represents a significant source of income for farmers, particularly small-holders and those living in marginal areas. Small ruminant production is also important from the socio-cultural point of view.

These are some of the main reasons why Morocco and the USAID Small Ruminant Collaborative Research Support Program (SR-CRSP) decided to initiate a joint venture on sheep and goat production in a Mediterranean country. An initial agreement was established in 1981 and a complete Memorandum of Understanding was signed in 1982 between the Hassan II Agronomy and Veterinary Institute (IAV) and the Management Entity (ME) of the SR-CRSP. The project went on for 10 years and ended in September 1992. It is now followed by a linkage program which hopefully will continue for two or three years.

The Institutions Involved

From the U.S. side five universities were involved in the SR-CRSP project in Morocco:

- University of California-Davis, for genetics-reproduction
- North Carolina State University-Raleigh, for nutrition
- Utah State University-Logan and Texas Tech University-Lubbock, for range management
- University of Missouri-Columbia, for sociology

In Morocco, the institutions involved were the Hassan II Institut Agronomique et Vétérinaire, Rabat, and, to a lesser extent, the National School of Agriculture, Meknes.

IAV is the largest agricultural university in Morocco with two campuses (Rabat and Agadir) and eight colleges. In Rabat, the College of Agriculture and College of Veterinary Medicine are among the most active ones. Postgraduate studies in Animal Science, Veterinary Medicine, and Range Management have been developed for more than 20 years at both M.Sc. and Ph.D levels. So far, IAV has trained more than 80% of total Moroccan graduates in agriculture. IAV plays also a key role in research in the areas of animal production and health. It has a strong impact on development although, unlike American universities, extension services in Morocco are not directly linked to the university but are located within the Ministry of Agriculture. IAV has also a long experience of collaboration with several European and U.S. Universities and research institutions.

The National School of Agriculture at Meknes (ENA) is the second largest Moroccan College of Agriculture. During the last years, ENA has also developed a M.Sc. program in Animal Science. ENA and IAV maintain strong linkages in both training and research activities.

More than 30 faculty members from seven departments of IAV and ENA were involved in the project. The main research topics can be summarized as follows:

1) Evaluation of a crossbreeding program between a non prolific breed (Sardi) and a highly prolific breed (D'man).
2) Nutritive value of cereal and agro industrial by-products.
3) Environmental physiology of the Sardi, D'man, and their crosses.
4) Ecology, nutritive value, and utilization of rangeland feed resources.
5) Rangeland and human groups in the High Altas.
6) Epidemiology of parasites in sheep.

These topics have been chosen because of their importance for SR under the agro-pastoral and pastoral systems. Most research related to the first system was conducted in the Tadla area while the pastoral experimentation took place in several locations in the Middle Atlas mountains and in the high plateaux of the eastern part of Morocco. Programs developed included experimentations in research stations of IAV, ENA, and/or Ministry of Agriculture. Several surveys and on-farm trials were also implemented in different zones.

Accomplishments

The SR-CRSP project gave Morocco a unique opportunity to build a comprehensive research program that addresses some of the main issues for improving SR production. Although some key areas were not covered, namely Animal Health and Economics, the project was able to attract scientists from different but complementary disciplines who tried to establish collaborative work with their U.S. counterparts. The project was supported not only by the Moroccan and United States institutions involved in the SR-CRSP, but also by the USAID/Minnesota - IAV Project. Positive interactions (both scientific and financial) were developed and contributed to a better achievement of goals for the two projects.

Research facilities

Regarding research facilities, the SR-CRSP project was able to establish a sheep station in the Tadla area. This 265 ha farm is located in the central part of Morocco within the largest irrigated district of the country. However, since the farm is located at the edge of irrigated and rainfed zones, research conducted can simu-

late both the intensive irrigated mixed crop-livestock system and the extensive dryland system. Average annual rainfall under normal years is less than 300 mm.

Sheep facilities developed since 1982 include housing pens for more than 1,000 head of sheep, individual pens for nutrition and physiology studies, and a laboratory for reproductive physiology. The project also provided some support to improve forage production and farm management.

In 1982, two basic flocks of D'man (D) and Sardi (S) breeds were purchased from the Ziz and Draa Valleys and Marrakech, respectively, where these native breeds are normally raised. A crossbreeding program was then started. In 1988, a program for the development of a synthetic breed called DS involving 50% D and 50% S was inititated.

In addition to the Tadla farm, the SR-CRSP provided also some support to improve research facilities at the ENA experimental farm at Meknes and the range research station at Timahdit (Middle Atlas). Several pieces of equipment for laboratories at IAV and ENA were also purchased through the project.

Training

One of the most significant contributions of the SR-CRSP was in the area of training. Because both IAV and ENA are teaching and research institutions, the number of students that took benefit from the project was high. Indeed, 12 faculty members were able to complete their doctoral theses (Ph.D.) in areas such as nutrition, physiology, and genetics between 1981 and 1992 (Table 1). During the same period, an average of eight students per year completed their M.Sc, DVM, or B.Sc degrees in disciplines related to SR. At least 10% of these students were from other North African and Subsaharan countries. Consequently, the project has contributed importantly to improving Moroccan human resources in the field of sheep and goat production. Several trainees have been hired by extension services, professional associations, research institutions and have become major actors in agricultural development.

Table 1. Number of degree candidates supported by the SR-CRSP to complete their thesis during the period 1981-1992.

Level	Number of Candidates
Ph.D.	12
M.Sc. and DVM	54
B.Sc.	34
Total	100

Publications

The project has generated a considerable amount of basic information related to different Moroccan breeds of sheep and goats in terms of physiology, nutrient requirements, feeding behavior, breeding, and growth. Most of these data have been published in national and international scientific journals (Table 2).

The project has also collected considerable data related to sheep production, management, marketing, and farmers decisions. Surveys conducted by students generated an important body of knowledge on sheep and goat production systems in different areas of the country. The resulting information has been used subsequently, to initiate development actions adapted for different zones.

Table 2. Publications in national and international scientific journals between 1981 and 1992.

Discipline	Number of publications
Genetic/Reproduction/Physiology	39
Nutrition	27
Range Management	45
Total	111

Extension

Outreach/development has also been an important objective of the SR-CRSP in Morocco. We tried to maintain close relationships at the national and regional levels with the departments in charge of extension. Joint meetings were regularly organized to share results from research and/or to discuss plans for the future. Seminars, field days, and demonstrations also were organized in the Tadla and Middle Atlas areas. Several faculty members were invited to give talks to sheep and goat producers. These kind of activities remained however somewhat limited since the SR-CRSP is basically a research project, and the budget allocated to the outreach/development activities was always very low.

In addition to these activities, the project decided in 1986 that one efficient way to contribute to outreach/development is to prepare a "technological package" publication that can be used by extension agents and advanced farmers. The objective was to present in simple ways a comprehensive publication that covers most of the issues related to management and health with some very practical information concerning feeding, breeding, housing, etc. The focus was on the cereal-sheep agricultural system in Mediterranean countries. The preparation of this publication took more than three years. In 1989 an English version, entitled *Sheep production and management in a mediterranean climate: The agropastoral system of Morocco*, was published by the University of Califonia, Davis. One year later, the French version of this book was issued by IAV, *L'elevage du Mouton dans un Pays a Climat Mediterraneen.* This document has been extensively distributed throughout Morocco and also in North African, Middle East, and Subsaharan zones with similar conditions.

Conclusion

Within the SR-CRSP, Morocco has been the only host country represented by a university institution. This had some real consequences on the way the project activities were conducted and also on its overall productivity. The success of the project would not have been possible without the scientific and financial support from IAV. The collaborative mode is perceived by Morocco as the most promising and advanced way to build positive and strong relationships between U.S. universities and host country institutions. Although expectations may not have been the same on both sides, the overall benefit of this concept has been substantial.

After so many years of collaborative exercise, U.S. universities and IAV should now be ready for new joint ventures. Many countries in Subsaharan Africa and also in Central Asia could benefit from the joint efforts and expertise developed during the last 10 years in the United States and Moroccan institutions. Such partnership will provide another demonstration of the success of the SR-CRSP.

Utilization Of Moroccan Sheep Breed Resources To Increase Productivity

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Abstract

The development of irrigated agriculture in Morocco and the high demand for sheep meat has created a need for more prolific ewes than provided by traditional Moroccan breeds, which have evolved under extensive conditions and typically have a very low (<10%) twinning rate. The D'Man (D) breed, from oases South of the high Atlas, is very prolific, and has been investigated as a potential source of genes to increase productivity of Moroccan sheep for crop-livestock production systems. Crossed with the larger but less prolific Sardi (S) breed, the D'Man transmits its prolificacy additively, providing the opportunity to set mean prolificacy at any point between 1.0 to 1.2 and 2.0 to 2.4 (depending on season, nutrition, and ewe age). The D'Man also transmits early puberty, non-seasonal breeding, and high relative growth rates. As a result, the cross is more productive under a moderate level of nutrition and management than either pure-bred parent. It is suggested that 50% D'Man should be the maximum D'Man inheritance for Moroccan enterprises at this time, and that a composite breed would be a practical means of utilizing the advantages of this cross. Estimates of effects of level of feeding and management and interactions with levels of prolificacy are presented.

Introduction

Sheep production plays a key role in Moroccan agriculture. Sheep are the most important livestock species in the country, not only in terms of population, estimated at 16 million, but also because they are raised in all regions, across a range of climates, altitudes, and land use systems, and sheep meat is the preferred meat in the country.

There are several major breeds of sheep in Morocco (Boujenane et al., 1982; Lahlou-Kassi, 1983; Mason, 1967). They are well adapted to the generally arid conditions and climatic extremes of the region, but are characterized by low productivity. The main factors in this low productivity are:

- Relatively low reproductive rates, due to low conception rates (70-80%), low prolificacy (typically <1.1), and high lamb mortality (15-30%).
- Seasonal periods of limited quantity and low quality forage, which results in low growth rates and consequent low carcass weights (~12 kg).

These constraints are primarily nutritional and environmental, but the low prolificacy has a genetic basis as a result of long term natural selection in an environment unfavorable to survival of lambs born as multiples. The major breeds of the country also have a restricted breeding season which would limit accelerated lambing, but lambing more often than once a year is unlikely to be a recommended practice even in the more favorable regions with a mediterranean climate.

The D'Man (D) breed, in contrast, has evolved in a special production system, in oases in the Ziz and Draa valleys south of the Atlas mountains. The system is characterized by intensive irrigated agriculture and small farm size; for example, in the Draa valley, 76% of farmers have less than 2 ha of land. Alfalfa is the second most important crop, after cereals. Total numbers of sheep are estimated as 40,000 head in the Ziz valley and 100,000 in Draa. Flock sizes are typically less than 10 head. The D'Man breed has a mean litter size of 2.0 to 2.4, approximately double that of any other Moroccan breed, and apparently breeds year round (Bouix et al., 1974; Bouix, 1975; Lahlou-Kassi et al., 1989).

In recent decades a very extensive irrigated agriculture has developed in Morocco, totaling approximately 850,000 ha. Sheep are well integrated into the irrigated agriculture system, using stubble and straw from cereals, the dominant class of crop, but also other agricultural residues and byproducts. This system creates a need for more prolific stocks of sheep than the majority of Moroccan breeds, in order to realize an adequate return, in terms of increased output, for the increased inputs feasible in this production system. An increase in domestic meat production is also a national goal.

Results of breed evaluations by the SR-CRSP

The SR-CRSP breeding project in Morocco took, as a primary objective, assessment of the mode of inheritance of the high prolificacy of the D'Man breed and the potential usefulness of the breed for increasing productivity of sheep in the more favorable production systems of the region. Collaborative studies with nutritionists and physiologists have provided information on nutrient requirements and responses to increased inputs of the different genotypes, as well as the physiological basis for some of the differences in performance among them. Some of these results are presented in other papers in this proceedings. The work has been conducted at the IAV Farm at Tadla, 160 km from the Atlantic coast and 20 km from the Atlas mountains, on the Tadla plain. Rainfall in this irrigated region is 300 mm/year, and summer maximum temperatures regularly exceed 40°C.

Since the D'Man is a breed of small mature size and the Sardi (S) breed is not only popular in the Tadla region but is also the largest mature size Moroccan breed, the Sardi was chosen as the breed with which to cross the D'Man. Thus, the first phase of the project was devoted to the production of contemporary purebred, reciprocal F1, F2, and backcross animals. The analyses of performance of these breed types have shown that the D'Man breed transmits its prolificacy and ovulation rate additively in crosses with the Sardi (Table 1).

The data in Table 1 are for first and second lambings only and for seasons in which the level of nutrition was not quite as high as it had been earlier. Thus the mean litter sizes were lower than reported, for example, by Lahlou-Kassi et al. (1989). However, the rankings of the different groups are consistent with other data; we estimate the genetic litter size potential of the various groups as adults to be about 20% greater than the values in Table 1, i.e., approximately 1.25 for Sardi and 2.4 for D'Man, with the values for 25%, 50%, and 75% D'Man predicted by linear interpolation between the parent breed averages (Lahlou-Kassi et al., 1989; Derqaoui, 1992).

Table 1. Performance in pure breeds and crossbreeds for different traits.[a]

Breed type	% D'Man	Conception rate (%)	Litter size	Lamb wt. 60d (kg)	Lamb prod. 60d per ewe joined
Sardi	0	74	1.03	13.2	9.7
3/4S 1/4D	25	86	1.34	12.7	11.1
F1	50	94	1.49	12.0	14.0
F2	50	87	1.49	11.6	11.1
1/4S 3/4D	75	83	1.85	11.4	12.0
D'Man	100	85	2.00	9.9	11.4

[a]Boujenane et al., 1991

The additivity of litter size in this cross provides the opportunity to set mean litter size of flocks at any desired level between that of the Sardi and of the D'Man according to the production environment, particularly level of nutrition and management. The suggested method of exploitation is a higher percentage of prolific breed inheritance in more favorable production environments, a lower percentage in less favorable environments.

The results also showed that D'Man and D'Man crosses have earlier sexual maturity, longer breeding season and higher relative growth rates earlier in life. In fact, F1 DxS crosses out of Sardi dams grew as rapidly as pure Sardis to one year of age (Berger et al., 1989) although the data from the diallel cross (Table 1) show a more additive pattern; the difference suggests a favorable maternal effect of the Sardi breed, but this was not indicated by analysis of the diallel cross data. When the effects of the different components are combined, the D'Man x Sardi crosses are more productive than the Sardi in terms of total weight of lambs produced per ewe per year or per lifetime under the conditions in which the study was conducted (Boujenane and Bradford, 1991; Derqaoui, 1992)

Because systematic crossbreeding programs are logistically difficult, especially in small flocks, and because epistatic recombination effects on production traits are small (Boujenane et al., 1991), a synthetic breed developed from the D'Man by Sardi cross might be more practical than repeat crossing as a means of using these two breeds to improve the productivity of sheep flocks for the agropastoral system. This synthetic will receive early puberty, extended breeding season, and high litter size from the D'Man while receiving larger size and better fleece from the Sardi. Based on the excellent performance of DxS F1 and F2 sheep at the Tadla Farm, the development of a synthetic breed that has 50% D'Man and 50% Sardi inheritance has been initiated for potential use in the more favorable production environments and to provide rams to sire 25% D'man ewes, for systems where a lesser increase in twinning rate is desired. F1, F2, and F3 animals have been intermated at Tadla, and the resulting stock, when target numbers are achieved, will be selected for early breeding, twinning, and weight of lamb weaned per ewe.

Effects of variation in prolificacy in relation to level of feeding and management

Because much of Morocco is arid and subject to periodic drought as well as to normal seasonal variation in quantity and quality of forage, the question has been raised as to whether an increase in prolificacy is likely to be useful. To examine this question systematically, we have collected information from the Tadla Farm and from reports from other regions of Morocco, on lamb survival and growth rate of lambs born in litters of 1, 2, and 3 or more. From these we have evaluated the implications of various increases in prolificacy, for four different levels of feeding and management. The values assumed for these calculations and the results are presented in Tables 2 and 3. The distribution among litters of 1, 2, and 3 for the different mean litter sizes are based on data from the project at Tadla and reflect the fact that the D'Man and its crosses are somewhat more variable in litter size than is the case for other prolific breeds. Mean weaning weights at Tadla have fluctuated around those listed for "good" feeding and management. Knowledge of the quality and quantity of feed normally available at this farm, and performance in the best seasons, indicate that the levels of performance listed for the "very good" level are quite achievable with the genotypes produced in this project and resources available in agropastoral systems of the region. In fact, lamb survival rates assumed for this level have generally been found in the Tadla flock over a period of 10 years.

Table 2. Estimated effect of level of feeding and management on litter weight weaned per ewe for ewes giving birth to 1, 2, or 3 lambs.

	Litter size born								
	1			2			3		
Input level	% surv.[a]	90 d wt. per lamb[a]	90 d wt. per ewe[a]	% surv.	90 d wt. per lamb	90 d wt. per ewe	% surv.	90 d wt. per lamb	90 d wt. per ewe
Very good	96	19	18.2	92	16	29.4	80	14	33.6
Good	92	17	15.6	85	13	22.1	60	12	21.6
Fair	85	15	12.8	65	11	14.3	40	10	12.0
Poor	75	13	9.8	45	10	9.0	20	9	5.4

[a]Percentage survival and 90 d wt. per lamb are assumed values; 90 d wt. per ewe results from these assumptions.

Table 3. Effect of flock mean litter size on estimated number and weight of lambs produced for different levels of feeding and management.

Flock mean litter size	Litter size distribution(%) 1	2	3	Item[a]	Output per ewe, if input level is[b]: VG	G	F	P
1.05	95	5	—	N	1.00	.96	.87	.76
				90d	18.8	16.0	12.8	9.7
				PWG	16.3	17.6	17.7	16.8
1.25	75	25	—	N	1.18	1.12	.96	.79
				90d	20.3	17.3	13.1	9.6
				PWG	21.0	21.7	20.6	18.0
1.50	56	38	6	N	1.38	1.27	1.04	.80
				90d	23.4	18.5	13.3	9.2
				PWG	24.9	25.9	23.2	18.7
1.75	41	43	16	N	1.57	1.40	1.10	.79
				90d	25.5	19.4	13.3	8.2
				PWG	29.4	29.5	25.2	19.0
2.00	28	44	28	N	1.75	1.51	1.15	.77
				90f	27.5	20.1	13.2	8.2
				PWG	33.8	32.8	26.9	18.9
2.25	15	45	40	N	1.93	1.62	1.19	.76
				90d	29.4	20.9	13.1	7.7
				PWG	38.2	35.9	28.6	18.8

[a]N = No. lambs weaned/ewe. 90 d = total litter wt. at 90 d/ewe. PWG = total post weaning gain = (N x 35) - 90 d wt. No. weaned and 90 d litter weight based on assumption in table 2; postweaning gain assumes no postweaning mortality and all lambs sold at 25 kg.
[b]See table 2 for definitions.

The results in table 3, based on the assumptions given in tables 2 and 3, are believed to apply to the range of feeding and management conditions which may be encountered across the region. The following points are evidence from these results:

1. Number of lambs weaned increases with increasing litter size born at all levels of feeding and management assumed except the poorest level.
2. Estimated weight of lambs weaned per ewe increases 56% and 31% at "very good" and "good" levels, respectively, as litter size increases from 1.05 to 2.25, but increases very little under the assumption of "fair" conditions, and decreases with increasing prolificacy under "poor" conditions.
3. Considering output at weaning, increasing level of feeding and management from "poor" to "very good" approximately doubles gross output per ewe, at low prolificacy, and approximately quadruples it, at high prolificacy. This emphasizes the conclusion that, where increased inputs are feasible, more productive genotypes provide much greater potential returns from the increased inputs.
4. Considering postweaning gains, or total output per ewe when lambs are marketed at 35 kg (90d wt + PWG), results in much greater advantages for higher prolificacy, i.e., the greater output at weaning is augmented by the advantages of having more lambs to feed out to market weight. Furthermore, including postweaning gains, under the stated assumptions, extends the beneficial effects of increased prolificacy to systems with lower levels of input than consideration only of output at weaning. For example, weaning weight per ewe increases only 31% and 2% in "good" and "fair" systems, respectively, when litter size born increases from 1.05 to 2.25, while post weaning gain increases by 103% and 62% for these two systems.

Some relevant factors are not accounted for in the calculations in Tables 2 and 3. Differential fertility of ewes among management levels is not considered, i.e., the values presented are for ewes 100% of which lamb. Fertility would be expected to decrease as levels of feeding and management decreased, i.e., considering this variable would be expected to accentuate differences among levels (as well as lowering absolute values for all levels). Secondly, the extra costs of feeding more, lighter lambs to market weight are not considered; these would vary greatly among farms, regions, and years. Gross output values obviously overestimate the benefits of increased prolificacy. However, based on the viabilities and lamb weaning weights achieved at Tadla and observed in other flocks, we believe the rankings of the different combinations are valid.

The assumption of no mortality postweaning, and the implicit assumption that all lambs have similar growth potential postweaning, may not be valid, especially for lambs very small at weaning. For example, in a group with a mean weight of 9 kg at weaning, there would probably be at least a few individuals that would do poorly or die after weaning. However, for most of the multiples, the weaning weights, at least under "fair" or better conditions, should permit the stated assumptions to hold with reasonable postweaning conditions. The postweaning gain calculations also imply that all lambs are marketed, whereas in fact a substantial proportion of ewe lambs will be kept as replacements. This factor would accentuate differences in output between higher and lower productivity systems, since a higher proportion of the total number of lambs weaned would be needed as replacements for the lower productivity systems.

There is also the question whether lambs very small at birth (as occur in litters of three or more) have the same growth potential as normal birth weight lambs. Theriez (1991) noted that lambs lighter at birth will have higher carcass fat content than lambs of normal birth weight at a constant slaughter weight. This could be an economic consideration where lambs are slaughtered at a relatively high fat content, as in Europe and North America. It is unlikely to be a factor where lambs are slaughtered at a relatively low fat content, as in Morocco and throughout the region.

Overall, these calculations suggest large potential increases in productivity from increased prolificacy and from increased inputs and emphasize the importance of matching genetic potential for prolificacy to level of inputs. The circumstances under which increases in genetic potential and in inputs will be economically feasible will have to be worked out for specific regions and systems. However, based on knowledge of other sheep production systems, the potential for increased returns in Morocco, with extensive irrigated agriculture and high meat prices, appears excellent.

The examples of increased prolificacy listed in Table 3 could be achieved with use of the breeds involved in the SR-CRSP breeding research project in Morocco, i.e., with no introduction of exotic breeds. Whether exotic breed inheritance would result in greater benefit is not known. However, as indicated earlier, sheep in Morocco are kept in some very harsh environments, from the perspective of both nutrition and climatic extremes. The work of Benlamlih (reported in this symposium) shows that the Sardi is more resistant to heat stress and water deprivation than the D'Man, even though the latter has also evolved in a hot climate. Crosses with Northern European origin prolific breeds such as the Finn sheep and Romanov would contribute prolificacy equal to or greater than the D'Man, and larger mature size, but it seems unlikely that they would equal D'Man crosses in tolerance to 45°C conditions. In fact, because of the difference between the Sardi and D'Man in heat tolerance, and the lower individual weaning weights of higher % D'Man crosses (Table 1), it is suggested that 50% D'Man may be a practical upper limit, at least in the near future, which would limit mean prolificacy to about 1.75 to 1.8. We believe that this is adequate for the best management systems in Morocco at this time.

The SR-CRSP breed evaluation has focused on the D'Man and Sardi breeds. However, it may be assumed that the D'Man will transmit its prolificacy additively in crosses with other breeds, and there are other data to support this (Lahlou-Kassi and Marie, 1985). Other major Moroccan breeds include the Beni Ahsen, Beni Guil, and Timahdite.

Literature Cited

Berger, Y.M. G.E. Bradford, A. Essaadi, D.W. Johnson, M. Bourfia, and A. Lahlou-Kassi. 1989. Performance of D'Man and Sardi breeds of sheep on accelerated lambing. III. Lamb mortality, growth and production per ewe. Small Ruminant Research 2:307-321.

Bouix, J. 1975. Un des elements majeurs de la mise en valeur des palmeraies: la race ovine D'Man (One of the important factors in development in oases: the D'Man breed of sheep). Options Mediterr., 26:87-93.

Bouix, J., M. Kadiri, and A. Chari, 1974. Performances enregistrees dans les troupeaux pepineres de la race ovine D'Man (Performance records from nucleus flocks of the D'Man sheep breed). Al Awamia, 52:67-97.

Boujenane, I., A. Boudiab, and A. El. Aidi. 1982. Performance de production des races ovines locales Marocaine. Actes Inst. Agro. Vet. (Maroc) 2:24-48.

Boujenane, I., and G.E. Bradford. 1991. Genetic effects on ewe productivity of crossing D'Man and Sardi breeds of sheep. Journal of Animal Science 69:525-530.

Boujenane, I., G.E. Bradford, and T.R. Famula. 1991. Inheritance of litter size and its components in crosses between the D'Man and Sardi breeds of sheep. Journal of Animal Science 69:517-524.

Derqaoui, Lahsen. 1992. Onset of puberty and development of reproductive capacity in D'Man and Sardi breeds of sheep and their crosses. Doctoral Thesis, IAV Hassan II, Rabat, Morocco.

Lahlou-Kassi, A. 1983. Review of the Moroccan sheep breeds. Second OAU Expert Committee Meeting on Animal Genetic Resources in Africa. Bulawayo, Zimbabwe. 22 pp.

Lahlou-Kassi, A., Y.M. Berger, G.E. Bradford, R. Boukhliq, M. Tibary, L. Derqaoui, and I. Boujenane. 1989. Performance of D'Man and Sardi breeds of sheep on accelerated lambing. I. Fertility, litter size, post partum anoestrus and puberty. Small Ruminant Research 2:225-239.

Lahlou-Kassi, A. and M. Marie. 1985. Sexual and ovarian function in the D'Man ewe. pp. 245-260 in Genetics of Reproduction in Sheep. Ed. R.B. Land and D.W. Robinson. Butterworths, London.

Mason, I.L. 1967. Sheep Breeds of the Mediterranean. FAO/UN. Commonwealth Agricultural Bureau, Edinburgh.

Theriez, M. 1991. Consequences de l'augmentation de la prolificite sur l'elevage des ageneaux et sur la production de viande. INRA Prod. Anim. 4:116-168.

Physiological Differences Between D'Man And Sardi Breeds Related To Improving Sheep Productivity In Morocco

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Abstract

The physiological differences between D'Man, Sardi and D'Man x Sardi for regarding the onset of puberty, relative growth rate, and response to environmental constraints were examined.

Season of birth influenced age at puberty in Sardi and the D'Man x Sardi, but not in D'Man. Summer born D'Man and Sardi lambs reached puberty at the youngest and oldest ages, respectively, and the cross-breed at an intermediate age. The delayed onset of first ovulation in summer-born Sardi ewes was due to a delayed increase in LH secretion. Body weight had no effect on age at puberty.

The D'Man and D'Man x Sardi have a higher relative growth rate than the Sardi to three to six months of age. This more rapid maturing rate is associated with a higher voluntary feed intake, faster rate of passage in the rumen, and higher plasma levels of thyroid hormones and insulin. However, the D'Man are more sensitive to the effects of water or food deprivation and to the effects of summer heat stress than the Sardi sheep.

Introduction

The D'Man (D), a sheep breed from the oases of southern Morocco, is known for its reproductive characteristics, i.e., early puberty, aseasonality (seasonality) of breeding, high prolificacy, and short postpartum anestrus (Lahlou-Kassi et al., 1989; Boujenane et al., 1991). In addition, D lambs reach mature size faster than other Moroccan breeds (Berger et al., 1989). It was therefore of interest to evaluate the D breed and its crosses in other regions of Morocco. A program has been undertaken to develop a synthetic breed by crossing the D with the Sardi (S), a breed adapted to the semi-arid region of Tadla. This raises the question of the adaptation of the D and DxS cross-breds to the environmental constraints of the Tadla region.

This paper summarizes the major results obtained from experiments aimed to study the differences between the D, S, and DxS in terms of the age of onset of puberty, relative growth rate and responses to environmental constraints.

Onset Of puberty

Previous studies of the onset of puberty in the D, S, and Timahdit (T) breeds, and DxS and DxT crosses, indicated that this trait is transmitted in an additive manner in breed crosses (Lahlou-Kassi and Marie, 1985; Lahlou-Kassi et al., 1989). An experiment was designed to investigate both the effects of breed type and season of birth on the onset of puberty in D, S, and DxS ewe lambs.

Age at first ovulation and first estrus

D and S ewe lambs ovulated at the youngest and oldest age, respectively. The 3/4D-1/4S (3/4D) with added inheritance of this trait, 1/2D-1/2S (1/2D), 1/4D-3/4S (1/4D) ovulated at intermediate ages consistently

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(Table 1). In addition, ewe lambs born in January ovulated earlier than those born in June. On the other hand, D lambs were the first and S the last to exhibit signs of estrus. Winter-born lambs displayed signs of estrus earlier than summer-born lambs. Furthermore, June-born lambs reached puberty at different ages (P<0.001), i.e., 212.1±18.2, 274.4±13.8, 379.7±12.9, 417.9±18.2, and 404.3±14.9 days for D, 3/4 D, 1/2D, 1/4D and S, respectively. Among June-born lambs, D showed first estrus at seven months of age, while S did not show estrus and S after the next summer solstice. The DxS ewes showed a pattern that was intermediate between the parents.

Table 1. Least squares means and standard errors for age (days) at first ovulation and estrus.

Source of variation	n	First ovulation		First estrus	
		LS mean	SE	LS mean	SE
Overall mean	114	251.0	6.1	285.6	5.1
Breed Type					
D	16	192.8[a]	15.7	211.6[a]	12.9
3/4D	27	226.4[a]	12.2	252.8[b]	10.1
1/2D	27	269.5[b]	12.5	312.5[c]	10.3
1/4D	23	283.4[b]	13.7	328.1[d]	11.6
S	21	282.9[b]	13.8	323.1[cd]	11.4
Season of birth					
June	67	299.0[a]	7.9	338.3[a]	6.7
January	47	202.9[b]	9.3	233.0[b]	7.6

Means within a column with a different superscript differ (P<0.05).

Information on the performance of highly precocious and prolific breeds of sheep and their crosses (Quirke et al., 1985) indicates that these breeds transmit reproductive precocity to their progeny. However, the seasonal breeds such as S tend to reach puberty during their usual breeding season regardless of season of birth. The photoperiod experienced by the lambs during development can profoundly affects age at puberty (Foster, 1983).

Body weight at first ovulation and first estrus

D and S lambs ovulated at 19.3±3 and 27.9±1.1 kg, respectively. This difference reflects the difference in mature weight of the two breeds. Body weight at first estrus increased as the proportion of S genes increases in the breed cross, with D and S weighing 20.5±1.1 and 30.3±1.0 kg at first estrus, respectively. June-born females were older and heavier at first estrus than January-born females, except for the pure D'Man and 3/4D lambs. Body weight had no significant effect on age at puberty (Quirke et al., 1985). In contrast, Aboul-Naga et al. (1980) reported that ewe lambs growing at a faster rate will exhibit their first estrus at a lower age and heavier weight.

Ovulation rate at first estrus

The D'Man had the highest (2.12) and the S the lowest (1.15) ovulation rate, with the crossbreds averaging 1.46, 1.52, and 1.24 for 3/4D, 1/2D, and 1/4D, respectively. The differences among the DxS crosses were not significant. In contrast, Boujenane et al. (1991) showed that ovulation rate at the time of first mating, increased almost linearly with the increase in the proportion of D genes in DxS crosses.

Plasma LH secretion leading to first ovulation

LH pulse frequency was 0, 1, or 2/6h and mean LH concentrations ranged from .4±3 to .7±3 ng/ml from the beginning through the sixth week before the initiation of ovarian cycles. During the last month of the prepubertal stage, there was a gradual increase in both LH pulse frequency and mean LH concentration. The highest number of LH discharges (3 to 6) and LH concentrations (1.3±6 to 1.5±6 ng/ml) were observed during the week of first ovulation. In contrast, LH pulse amplitude did not change. LH pulse frequency was delayed in June-born S lambs and LH secretion was not sufficient to bring about ovarian follicle development and ovulation.

Conclusion

The results of this study show that genetic and environmental factors are of considerable importance in determining age of puberty in ewe lambs. The fact that S ewe lambs are more sensitive to seasonal effects suggests that responsiveness to ovarian estrogen negative feedback is high. The delayed onset of first ovulation in this breed is due to one delayed increase in LH secretion.

Relative growth rate

The rapid maturing rate of D compared to S is expressed not only as early puberty, but as higher percentage of mature body weight during the first year of age. Thus, the relative growth rate (absolute growth rate divided by the mean body weight) at three to six months of age was higher in D than in S (Bouzid, 1990). This growth potential is even better expressed in the cross-breds (Table 2).

As shown in Table 2, the greater relative growth rate in D and F1 vs. S is associated with higher voluntary food intake, faster rate of passage in the rumen and higher plasma thyroid hormone (T3 and T4) and insulin levels (Bouzid, 1990; Ounaini, 1991). When food was restricted to 1.5 times maintenance requirements in D and S (120 Kcal/ Kg^{75}/day), plasma T3 and insulin decreased, but the differences between the two breeds remained as in ad libitum fed lambs (Bouzid, 1990). These results suggest that the digestive and hormonal abilities to metabolize food energy are better in D than in S, and this allows higher food intake and relative growth rates in the D lambs.

Table 2. Physiological parameters in S, D, and F1 lambs during the period of 3 to 6 months age.

	Sardi	D'man	F1	Pooled SE
Absolute Growth Rate (g/d)	150	140	160	10
Relative Growth Rate (g/Kg/d)	7.9^a	9.6^b	10.3^b	0.4
Food Intake (Kcal/Kg^{75}/day)	184^a	200^b	198^b	5
Rumen Retention Time (h)	16.0^a	13.5^b	-	0.8
Plasma T3 (ng/ml)	1.3^a	1.7^b	1.7^b	0.1
Plasma T4 (ng/ml)	64	68	67	2
Plasma Insulin (microU/ml)	22^a	33^b	30^{ab}	3
Water Turnover (Kg/Kg^{75}/d)	228^a	260^b	275^b	10

Means within a row with a different superscript differ ($P<0.05$).

Adaptation to harsh environments

Sheep raised in arid and semi-arid regions are exposed to several constraints such as water shortage, food scarcity, which is often of low quality, and excess heat. The responses of S, D, and DxS to these factors were compared.

Effects of water and feed deficiencies

Under a thermoneutral environment and with water and food provided *ad libitum*, the body water turnover rate, which expresses the water needs, was lower in the S than in D and F1 sheep (Table 2). This difference

was observed in growing lambs (Jebbari, 1986) as well as in pregnant and lactating ewes (Benlamlih, 1988).

Water deprivation for 48h induced a more pronounced dehydration in D than in S ewes. Body weight decreased by 10% and 7% ($P<0.01$), and plasma osmolarity increased by 17 and 14 mosmol/Kg in D and S ewes, respectively (Taki 1992).

Likewise, food deprivation for 48h caused a body weight loss of 9% in D and 5% in S ewes (Taki 1992). Initial body weight was restored within 24h and 72h after refeeding in S and D ewes, respectively.

In ruminants, it is well-known that endogenously produced urea is partly degraded to ammonia in the digestive tract and partly excreted in the urine. The ammonia produced is a potential nitrogen source for microbial protein synthesis when nitrogen intake is low. The rate of endogenous urea degradation in the digestive tract was 80, 71, and 75% in S, D, and F1 fed a low protein diet, respectively (Abdellaoui, 1988).

The difference in water turnover, urea recycling rate, and responses to water or food deprivation between D and S can be related to their original management. The D is raised under confinement in the oasis. It has unrestricted accces to water and is usually fed with alfalfa. In contrast, the S sheep are frequently exposed to periods of water and food shortage, heat stress, and low quality feed under the extensive conditions of the Tadla region.

Effect of heat stress

One of the objectives of the crossbreeding program in Tadla was to develop an accelerated lambing system, i.e., three lambings every two years. The preliminary results revealed that the post-weaning growth was low during summer (Berger et al., 1989). To elucidate this seasonal difference in growth, a comparative study was conducted during both summer and winter using D, S, and F1 lambs from three to six months of age (Jebbari, 1986). The animals were fed similarly during two periods. The maximum temperature was 34 to 45°C in summer and 15 to 25°C in winter. To have two levels of heat stress during summer, animals were divided into two groups; one group had access to shade and the other group was exposed to the sun.

The overall mean growth rates were 153±6, 140±6, and 117±9 g/day ($P<0.01$) during winter, summer with shade, and summer without shade, respectively. Food intake did not change between seasons (2.3 Mcal/animal/day) and feed efficiency was 15.1, 17.6, and 20.3 Mcal/Kg gain, respectively. Therefore, the decreased growth observed during summer was not due to a decreased food intake but to a decrease in food conversion efficiency.

When growth was compared in the three genotypes, it appeared that D and F1 have higher relative growth than S under thermoneutral conditions as reported above (Table 2). During summer, the relative growth rate in the group with access to shade was similar to that during winter in all genotypes. In the group exposed to the sun, this parameter was decreased by about 17% in D and F1 but remained unchanged in S (genotype x treatment interaction : $P<0.05$). The plasma T3 and T4 were lower during the summer than during winter in all genotypes.

It is concluded that D and F1 are more sensitive to summer heat stress than S. On the other hand, the effect of the environment can be significantly reduced by the provision of shade.

Literature Cited

Abdellaoui, A. 1988. Influence du génotype, du stade physiologique et de la saison sur le recyclage endogène de l'urée et le renouvellement de l'eau corporelle chez le mouton. DVM thesis. I.A.V. Hassan II, Rabat, Morocco.

Aboul-Naga, A.M., A.S. El-Shobokshy and M. Gabr. 1980. Using Suffolk sheep for improving lamb production from subtropical Egyptian sheep. J. Agr. Sci.(Camb.) 95:333.

Benlamlih, S. 1988. Effect of heat stress and genotype on water turnover in pregnant and lactating sheep. In: Isotope Aided Studies on Livestock Productivity in Mediterranean and North African Countries. pp 39-46. I.A.E.A., Vienna.

Berger, Y.M., G.E. Bradford, A. Essaadi, D.W. Johnsson, M. Boufia and A. Lahlou-Kassi. 1989. Performance of D'man and Sardi breeds of sheep on accelerated lambing. III. Lamb mortality, growth and production per ewe. Small Ruminant Res. 2:307.

Boujenane, I., G.E. Bradford, and T.R. Famula. 1991. Inheritance of litter size and its components in crosses between the D'man and Sardi breeds of sheep. J. Anim. Sci. 69:517.

Bouzid, T. 1990. Relation entre la croissance post-sevrage, le niveau d'ingestion et les taux de T3, T4 et d'insuline chez les agneaux D'man et Sardi. DVM thesis. I.A.V. Hassan II, Rabat, Morocco.

Foster, D.L. 1983. Photoperiod and sexual maturation of the female lambs: early exposure to short days perturbs estradiol feedback inhibition of luteinizing hormone secretion and produces abnormal ovarian cycles. Endocrinology 112:11.

Jebbari, M.C. 1986. Etude physiologique de l'influence du stress thermique naturel sur la croissance des agneaux Sardi, D'man et leur croise. DVM thesis. I.A.V. Hassan II, Rabat, Morocco.

Lahlou-Kassi, A. and M. Marie. 1985. Sexual and ovarian function of the D'man ewe. pp. 245-260. In: R.B. Land and D.W. Robinson Eds.Genetics of Reproduction in Sheep. Butterworths, London.

Lahlou-Kassi, A., Y.M. Berger, G.E. Bradford, R. Boukhliq, A. Tibary, L. Derqaoui, and I. Boujenane. 1989. Performance of D'man and Sardi Sheep on accelerated lambing. I. Fertility, litter size, post-partum anoestrus and puberty. Small Rum. Res. 2: 225.

Ounaini, F. 1991. Relation entre la croissance post-sevrage et les processus digestifs, métaboliques et endocriniens chez les agneaux D'man, Sardi et croisés alimentés avec du foin. DVM thesis. I.A.V. Hassan II, Rabat, Morocco.

Quirke, J.F., G.H. Stabenfeldt and G.E. Bradford. 1985. Puberty in ewe lambs: onset of puberty and duration of the breeding season in Suffolk, Rambouillet, Finish Landrace, Dorset and Finn-Dorset ewe lambs. J. Anim. Sci. 60:1463.

Taki, H. 1992. Réactions a la privation d'aliment et la privation d'eau chez la chèvre et le mouton du Maroc. DVM thesis. I.A.V. Hassan II, Rabat, Morocco.

Feeding Systems for Sheep Integrated into Cereal Cropping Regions

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Abstract
Nutrition research conducted in Morocco indicated that early gestating ewes stocked at 16 head/ha may be maintained on wheat stubble without supplementation during the initial four weeks of grazing, or for a longer period and possibly even for the entire duration of the stubble grazing season if stocked at lighter rates. In general, reproductive performance was not enhanced by concentrate supplementation. However, improved body condition of the ewe resulted in heavier birth weight and greater weight gain of lambs. Energy dense by-products from the agro-industry such as almond hulls, carob pulp, sugar beet pulp, citrus pulp, and waste palm dates were evaluated for their nutritive value. Incorporation of these protein deficient by-products in growing and fattening diets supplemented with urea and/or sunflower meal were investigated in several digestion and performance studies. Level of incorporation of 30% for carob pulp, 40% for almond hulls, beet pulp and citrus pulp, and 50% for waste palm dates, sustained gains of 187 to 281 g/d, thus reducing the time to reach market weight. Lambs did not respond to levels of dietary protein recommended for temperate breeds. Feeding wheat straw-based diets to late-gestating and early-lactating ewes showed that straw intake was high (1.6% of BW), an indication of an adaptation to high fiber loads. Transient malnutrition, commonly experienced during periods of feed shortage, appeared to be an economically efficient strategy because weight loss was largely in internal organ. Furthermore, feed efficiency was greater during compensatory growth of re-fed lambs. Present productivity of sheep in rain-fed cereal-producing areas of Morocco remains low. However, dissemination and adoption by farmers of the alternatives described herein could markedly improve the economic return of the mixed crop/livestock farming systems.

Introduction
In Morocco, sheep are a very important component of the mixed crop/livestock farming systems, especially in the dryland cereal production areas. Farmers depend on their sheep for cash income. Feed resources, however, may be a seriously limiting factor for flock productivity. The research described herein focused on several strategies to improve sheep nutrition under Moroccan conditions: supplementation of gestating ewes grazing cereal stubble; supplementation of straw-based diets for gestating and lactating ewes; and evaluation of locally available agro-industrial by-products. In addition, the incorporation of these by-products as alternative feedstuffs in diets for growing and fattening lambs was investigated. The overall objective of this research was to develop appropriate feeding systems for breeds of sheep native to Morocco. Feeding systems designed to sustain adequate growth and performance of the more prolific local crossbred animals developed by the SR-CRSP will play an important role in their acceptance and dissemination to farmers.

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Cereal stubble utilization

Approximately 70% of the sheep (11 million head) are found in the rainfed and irrigated farming regions of Morocco where wheat is the major cereal crop. Following grain harvest in June, sheep are usually grazed on cereal stubble until the start of the rainy season in October or November. The stubble-grazing season coincides with the most prevalent mating and gestation periods of the ewes. Because straw is the major dietary component, low birth weights, high lamb mortality, and slow lamb growth are common during this period (Ismaili, 1983; Bouhafra, 1987; Guessous et al., 1989).

Several experiments were conducted to examine the effects of stocking rate and level, timing and source of supplementation on the quantity and quality of available feed, nutrient intake, body weight changes, and reproductive performance. Pregnant ewes of the Sardi breed and F1 and F2 D'Man X Sardi crosses were used (Guessous et al., 1991; Outmani et al., 1991; Benjelloun, 1992), as well as growing Sardi lambs (Guessous et al., 1987). Supplemental minerals and vitamins were provided for all animals in each experiment. Diet quality was estimated by analysis of extrusa samples collected from esophageally fistulated rams. Fecal output was measured by total collection or by measuring the fecal concentration of chromium after dosing Cr-mordanted fiber to the ewes. An experiment was designed to test the effects of supplementation on quantity and quality of available biomass and ewe live weight and reproductive performance. Stocking rate was set at 16 ewes/ha. Total biomass (Table 1) measured after straw removal was at the high range of the values (4.2 to 7.2 t/ha) reported in Morocco under similar conditions (Guessous et al., 1987, 1991; Outmani et al., 1991), and in Australian wheat-producing regions (Butler, 1981). Climatic conditions during the growing season, wheat variety, wheat and straw yield, fertilization rate, and importance of competing weeds probably accounted for a large part of the differences between studies. Outmani et al. (1991) reported that irrigation before harvest contributed to a high weed biomass (613 kg DM/ha). After 12 weeks of grazing, 51% of the initial wheat stubble biomass had disappeared (Table 1), whereas values of 79 and 77%, respectively, had been reported by Guessous et al. (1991) and Outmani et al. (1991) with a stocking rate of 24 ewes/ha. Stubble removal rates of 76% were reported using lambs with bodyweight (BW) of 36 kg, whereas 21.6 kg BW lambs only removed 68% of initial stubble (Guessous et al., 1987; 1989). Stocking rate, animal size, and, therefore, nutritional requirements appeared to influence stubble removal.

Variable amounts of grain were present at the beginning of the grazing periods (range: 24 to 289 kg DM/ha). Regardless of experimental conditions, by week 8 of grazing all residual grain had disappeared from the plots, suggesting that ewes consumed a diet containing sizable amounts of grain. Similar results were reported by Mulholland and Coombe (1979). In the experiment by Outmani et al. (1991), the large amount of residual grain contributed to significant ewe weight gains during the first four weeks of grazing.

Table 1. Biomass of wheat stubble, weeds, and wheat grain.[a,b]

Grazing week	Stubble (Kg DM/ha)	Weeds (Kg DM/ha)	Residual grain (Kg/ha)
0	6,963	183	24.4
4	5,106	253	11.2
8	4,241	236	0
12	3,396	36	0

[a]Adapted from Benjelloun (1992).
[b]Stocking rate of 16 ewes/ha.

The nutritive value of esophageal extrusa samples (Guessous et al., 1991) showed that grazing week was associated with a decline in crude protein (CP) concentration and in in vitro OM disappearance (IVOMD), whereas NDF increased (Table 2). After five weeks of grazing, the diet collected by sheep on stubble had the same composition as straw. Lower IVOMD values (range: 38.3 to 47.1%) than reported

here (Table 2) were observed by Guessous et al. (1987) and Outmani et al. (1991). In the latter study, both diet quality and DM intake were influenced by stocking rate and were higher at 12 than 24 ewes/ha. Lambs stocked at a rate of 24 head/ha without supplementation, however, did not show significant differences in feed intake up to week 10 after the start of the grazing period (Guessous et al., 1987).

Table 2. Nutritive value (%) of esophageal extrusa samples collected from rams grazing a weed-free wheat stubble.[1]

Item	Grazing week 3	7	11	SE
CP[b]	9.2	6.8	6.2	.30
NDF[c]	70.7	75.5	80.8	.52
In vitro OM disappearance[b]	62.6	59.2	47.5	1.25

[1]Adapted from Guessous et al. (1991).
[b]Quadratic and [c]Linear effect of grazing week (P < .01).

Irrespective of stocking rate, pregnant ewes and lambs gained weight during the first four weeks of grazing in every study. However, stocking rate influenced weight gain during that period (Outmani et al., 1991). Whether sheep maintained, lost, or gained weight after week 4 of grazing depended on stocking rate and/or supplementation, which is consistent with data shown in Table 3. As the season progressed, patterns of weight loss of unsupplemented ewes reflected differences in chemical composition of extrusa samples and suggested that both nitrogen (N) and energy became limiting dietary nutrients. Supplementation with 200 g sunflower meal (SFM) or 200 g cottonseed meal (CSM) from week 5 of stubble grazing enabled ewes to initially maintain their body weight and then to gain weight (Table 3; Management Entity, 1990). Adding 200 g whole barley as well as SFM or CSM from week 9 to week 12 or 16 allowed for greater weight gains (Table 3; Guessous et al., 1989; Management Entity, 1990).

Table 3. Changes in BW (kg) of ewes grazing wheat stubble.[1]

Item	Treatment[2] A	B	C	SE
Initial BW	44.8	43.6	44.6	.5
BW changes:				
1 - 4 wk	1.2	.7	1.1	.2
5 - 8 wk	-2.1	.2	-.1	.5
9 - 12 wk	-1.5[a]	1.2[b]	2.3[b]	.3
1 - 12 wk	-2.4[a]	2.1[b]	3.3[b]	.4

[1]Adapted from Guessous et al. (1991).
[2]A, no supplementation; B, supplemented with 200 g sunflower meal between wk 5 and 12; C, supplemented with 200 g sunflower meal between wk 5 an 12, and in addition with 200 g whole barley between wk 9 and 12.
[a,b]Means in the same row followed by different letters in their superscripts differ (P < .05).

The amount of biomass remaining on the plots, the condition of the animals, or the onset of the rainy season dictated the length of the stubble grazing period. Thereafter, ewes were pen-fed to meet their nutritional requirements. Reproductive performance of Sardi and F1 and F2 D'Man X Sardi ewes (ovulation rate, 168%; fertility, 99%; prolificacy, 139%) was not affected by concentrate supplementation during the stubble grazing period when stocked at a rate of 16 head/ha (Benjelloun, 1992). However, previous studies suggested a positive effect of concentrate supplementation on fertility due to a possible decrease in early embryonic death (Guessous et al., 1991; Management Entity, 1990). Concentrate supplementation usually had no effect on lamb birth weight whereas the opposite was observed for postpartum lamb gain (Outmani et al., 1991; Benjelloun, 1992). Conversely, a positive effect of supplementation (Management Entity, 1991) on lamb weight at birth (2.9 vs. 3.6 kg BW) had disappeared by three months of age (14.5 vs. 15.6 kg BW), but could have had a positive effect on lamb viability.

These experiments demonstrated that production of sheep grazing cereal stubble can be improved through strategic supplementation of the ewe after the initial four weeks of grazing. Alternatively, gestating ewes can be maintained on stubble for a longer period by adapting stocking rate to the available biomass.

Moroccan farmers then to extend the stubble-grazing period until the rains start in late October or early November. However, experimental data clearly indicate that stubble grazing should not exceed 80 days under heavy stocking. Application of this recommendation to other local conditions will depend on the amount of initial biomass available after grain and straw harvest. Surveys of private farms of the Tadla area revealed the existence of large fluctuations in available biomass among farms.

Under the present traditional system, farmers tend to initiate concentrate supplementation of the ewes at lambing. Results from several experiments suggest that supplementation programs should be initiated much earlier. In addition, the level of energy and protein supplementation should be increased during the last third of gestation.

By-product evaluation and utilization

In the traditional sheep production system of Morocco, lambs are kept with the ewes and graze on fallow fields or cereal stubble with little or no supplementation. High stocking rates and inadequate feed supply in terms of availability and quality are prevalent during most of the year. This results in long growing periods, low average daily gains (ADG), and poor ewe reproductive performance. Therefore, the establishment of feeding systems for growing and fattening lambs based on locally available feed resources that can be economically utilized, and resulting in carcasses acceptable to local markets, could markedly improve flock productivity and income. Several by-products from the agro-industry are available at competitive prices. By-products such as almond hulls, carob pulp, sugar beet pulp, citrus pulp, and waste palm dates were tested for their nutritive value and their incorporation into diets for growing and fattening lambs. These feeds are adequate energy sources but are deficient in N. Nitrogen enrichment of some of these by-products has been evaluated using urea, the cheapest source of N under Moroccan conditions, and sunflower meal, a natural protein becoming increasingly available at a competitive price.

Experiments with almond hulls, a by-product of the almond crop (*Prunus amygdalus*) that includes the exocarp and mesocarp of the fruit, have been reported by Rihani et al. (1992). Almond hulls had a chemical composition of 20.4% ADF, 26.3% soluble carbohydrates, and 7.8% CP. Digestibility coefficients for OM, ADF, and CP, respectively, were 64.0, 42.5%, and 3.1%. Three dietary levels of almond hulls (0, 20, or 40%), substituted for sugar beet pulp in isonitrogenous diets (14% CP) based on alfalfa hay, and including barley and SFM, were tested in a 90-d feeding trial involving 30 D'Man X Sardi lambs (22 kg initial BW, four months of age). Intake was greater for almond hull-containing diets (85, 94, and 97 g DM/(kg BW.75d), respectively). Feed efficiency (5.6 to 6.3 kg DM/kg gain), ADG (217 to 233 g/d), carcass weight (20.7 to 21.6 kg), or carcass yield (47.8 to 50.2%) were not affected by dietary level of almond hulls ($P > .10$). Gain and carcass yield of Sardi lambs (236 g/d; 49.9%) were greater ($P < .05$) than those of the crossbred lambs (208 g/d; 48.0%). Almond hulls, a by-product largely under-utilized, was a very palatable energy feed that can be used at levels of up to 40% in diets for growing-finishing lambs.

Carob pulp, a widely available by-product in the Mediterranean region, results from the separation of the seeds from pods of carob trees (*Ceratonia siliqua*). Carob pulp is high in soluble carbohydrates (47%) and pectins (8%). However, a low CP (4.5%), relatively high tannin (3 to 4%), and high lignin concentration (16%) could limit its use in diets for growing lambs (Guessous et al., 1988; Rihani et al., 1989b). The former authors observed improvements in both DM intake (116.9 g DM/(kg.75.d) and ADG (241 g/d) of D'Man X Sardi lambs when carob pulp was substituted for citrus pulp up to a dietary level of 30%. Feed efficiency (7.7 kg/kg gain) and carcass yield (54.6%) did not differ. In another trial (Management Entity, 1988; Ouchkif, 1988) with growing lambs fed diets containing 0, 20, 30, or 50% carob pulp, the 20% level resulted in the highest performance (intake: 96.5 g DM/(kg $BW^{.75}$d; ADG: 234 g/d; feed efficiency: 5.9 kg DM/kg gain; carcass yield: 44.5%). Feeding diets containing 30% carob pulp, 25% alfalfa hay, and variable amounts of barley and SFM showed that increasing the CP level from 12 to 16% did not necessarily improve intake and daily gain unless urea was included (Table 4). An increase in ruminal ammonia as a result of urea feeding may have overcome the proteolytic inhibition caused by tannins present in carob pulp. These results demonstrated that carob pulp can be used as an energy source for sheep. In addition, it appeared nutritionally and economically beneficial to provide approximately 28% of the total dietary N as urea.

Table 4. Effects on intake and daily gain of nitrogen source and level in diets containing 30% carob pulp for fattening lambs.[1,2]

Item	Treatment			
Diet CP (%)	12	14	16	16
CP from urea (%)	0	2	0	4
Intake, g DM/(kg $BW^{.75}$d)	101^a	99^a	103^a	109^b
ADG, g/d	184^a	187^a	190^a	209^b

[1]Adapted from El Maadoudi (1990).
[2]Other dietary ingredients included alfalfa hay (25%), barley (25 to 39%), sunflower meal (3 to 18%), and a mineral mix (2%).
[a,b]Means in the same row followed by different letters in their superscripts differ ($P < .05$).

Experiments with sugar beet pulp and citrus pulp have been reported by Rihani et al. (1986; 1989a). In Morocco, approximately 160,000 tons of dried beet pulp and 18,000 tons of dried citrus pulp are produced annually. Beet pulp had a chemical composition of 40% NDF, 2.7% ADL, 18% soluble carbohydrates, 9% pectins, and 10% CP and digestibilities for OM and NDF of 84.4 and 85.9%, respectively. Estimated energy values were 1.7 Mcal/kg DM for maintenance (NE_m) and 1.1 Mcal/kg DM for growth (NE_g). These characteristics make beet pulp a good supplement for crop residue-based or forage-based diets. Citrus pulp contained 2.7% ADL, 31% soluble carbohydrates, 11% pectins, and 6% CP. Digestibilities of OM and NDF were 87 and 82%, and estimated NE_m and NE_g values were 1.9 and 1.3 Mcal/kg DM, respectively. Citrus pulp would be a good dietary complement to nonprotein N such as urea. A performance study was conducted with D'Man X Sardi lambs (initial BW 36 kg) to test two levels of beet and citrus pulp, 40 and 75%. Diets were isonitrogenous, based on alfalfa hay, and included soybean meal and urea. Intake and ADG of either beet pulp (103 g DM/[kg $BW^{.75}$d] and 213 g/d) or citrus pulp (102 g DM/[kg $BW^{.75}$d] and 187 g/d) were greater at the 40% feeding level. Feed efficiency (8.2 to 9.2 kg DM/kg gain) and carcass yield (47.0 to 48.4%) did not differ. Compilation with data from an earlier study with lambs indicated that an optimal level for beet pulp may lie between 40 and 75%, whereas citrus pulp dietary level should not exceed 45% (Guessous et al., 1989).

Two studies were conducted to evaluate ammoniation of citrus pulp using urea or citrus pulp supplemented with horse beans (*Vicia faba*) vs. supplementation with urea as methods of N enrichment (Management Entity, 1990, 1991). Experimental animals were Sardi lambs in the first trial and young

D'Man X Sardi rams with ruminal and proximal duodenal cannulas in the second trial. Citrus pulp was incorporated at a level of 45% in all diets, which were isonitrogenous (11% CP); a low protein (6% CP) oat-vetch (*Avena sativa-Vicia sativa*) grass hay incorporated at 43% of diet DM, molasses (10%), and a mineral mix (2%) comprised the other dietary ingredients. Chromic oxide (.5% of the diet) was used in the second trial as a digesta marker.

Ammoniation of citrus pulp with urea resulted in lower ADG (143 g/d) than supplementation with urea (173 g/d) or with horse beans (189 g/d). Compared with the other diets, lambs fed the horse bean-supplemented diet ate less (89 g DM/[kg $BW^{.75}$d]) but gained more weight (189 g/d), resulting in a greater feed efficiency (6.3 kg DM/kg gain). Ammoniation with urea resulted in a lower feed efficiency than supplementation with urea (8.7 vs. 7.4 kg DM/kg gain). Carcass yield (49 to 51%) was not affected by dietary treatment. Ruminal digestion was not affected by diet whereas total tract digestion of OM and NDF were 7 to 8% lower ($P < .05$) for the diets supplemented with nonprotein N than for the horse bean-containing diet. Net microbial N synthesis and microbial efficiency were lower for the urea-supplemented diet than for the horse bean-supplemented or urea-ammoniated diets, which had similar values.

Ammoniation of citrus pulp with urea did not offer any substantial advantage to direct addition of urea to the diet, which compared favorably with the horse bean-supplemented diet. Similar results concerning nonprotein N supplementation of citrus pulp-based diets were described recently by Rihani et al. (1993). Economical aspects of urea vs. natural protein supplementation should be considered when making recommendations to farmers.

A survey of farm practices in an oasis of the Tafilalet region indicated that approximately 25% of the dates produced were used as livestock feed (meat and pit) because of their inferior quality. Waste palm dates were high in soluble carbohydrates (43%) and relatively low in NDF (25%). However, waste palm dates contained little (3.7 to 4.4%) CP (Khal, 1982; Rihani et al., 1989a). A performance study was conducted with 24 D'Man X Sardi lambs (initial BW 21 kg) fed isonitrogenous (16% CP) diets containing, respectively, waste palm dates (44, 51, and 57%), alfalfa hay (40, 40, and 40%), soybean meal (16.4, 8.2, and 0.0%) and urea (0.0, 1.3, and 2.6%). Intake (94 g DM/(kg BW.75d), feed efficiency (5 kg DM/kg gain), and digestibilities of DM (71%), CP (71%), and NDF (56%) did not differ among diets. Lambs gained more weight (281 g/d) on the diet containing no urea, followed by the diet having a combination of soybean meal and urea (251 g/d). The third diet, containing urea only as source of supplemental N, still produced acceptable gains (213 g/d).

Nitrogen supplementation of waste palm date diets with either urea only or urea plus a relatively small amount of natural protein less ruminally degradable, is nutritionally beneficial and could prove profitable.

Substantial amounts of energy-rich by-products, which are either wasted, underutilized, exported, or simply unknown to farmers, can be used as major ingredients in fattening diets to produce lamb carcasses of nearly 22 kg at six months of age. This represents an 80% increase from the current average carcass weight of 12 to 14 kg. In addition, most of these by-products can replace grain, a more expensive and sometimes imported concentrate feed, as energy supplements for ewes during critical periods of the production cycle such as mating, late gestation, and early lactation.

Protein requirements for growth and fattening of lambs

The creation of the D'Man X Sardi breed of sheep required knowledge of the nutritional requirements of these animals. Research focused on protein requirements, because under Moroccan conditions conventional protein sources are expensive and in short supply. The determination of the minimum dietary protein level necessary to sustain adequate growth and fattening with locally available feedstuffs would therefore reduce feed costs and increase economic return.

The response of D'Man X Sardi lambs to four dietary protein levels (10, 12, 14, and 16% CP) was evaluated in a 105-d feeding trial (Tazi, 1992). Diets were based on alfalfa hay (13%), oat-vetch hay (12%), citrus pulp (20%), beet pulp (25%), a mineral-vitamin mix (2%), and various proportions of wheat bran and SFM. Dietary CP level had no effect on DM digestibility (68.5%) and energy digestibility (69.7%)

whereas CP digestibility increased linearly (P < .001; 61.3, 67.3, 72.5, and 75.6%). Fecal N excretion (5.9 to 6.3 g/d), and N retention (4.8 to 6.6 g/d) were unaffected by diet. On the other hand, urinary N excretion increased linearly from 3.8 to 14.0 g/d (P < .001), and N retained as a percentage of N intake decreased linearly from 34.9 to 20.7% (P < .03) with increasing CP. Intake (92.3 to 98.4 g DM/(kg $BW^{.75}$d)), ADG (202 to 228 g/d), feed efficiency (6.4 to 7.3 kg DM/kg gain), and carcass yield (48.8 to 50.0%) were not affected (P > .10) by dietary CP increments. D'Man X Sardi lambs did not respond to levels of dietary CP recommended for temperate breeds of sheep. Moroccan breeds of sheep may have lower N requirements and a greater ability to utilize diets containing moderate amounts of N.

Straw utilization by pregnant and lactating ewes

In the cereal-producing regions of Morocco, wheat straw is an important crop residue usually fed to ewes during late gestation and lactation after the cereal stubble grazing period (about September) and until the start of the rainy season and the resumption of fallow-land grazing (about January). Cereal straw has many nutritional limitations (Benata, 1977; McCann, 1985); nonetheless, its nutritive value seemed to be higher during dry years. Straw must be supplemented with both energy and N to prevent abortion, ensure normal fetus development, lamb birth weight, and adequate milk production of the ewe for rapid lamb growth.

In an experiment conducted by Kabbali et al. (1990), 48 gestating ewes of the Timhadit breed were housed in individual pens and fed six diets consisting of chopped wheat straw (800 g/d), barley, molasses, sunflower meal, urea, minerals, and vitamins. These diets were synthesized to meet recommended daily allowances (INRA, 1989) of 65, 82, and 100% for energy, and 75 and 100% for N (dietary levels of 8 and 10% CP, respectively). During the last four weeks of gestation, ewe daily gain increased with increasing levels of both energy (102, 131, and 159 g/d) and CP (111 and 150 g/d). However, the extent of BW increase was greatest at the higher CP level, resulting in a significant CP X energy interaction. At 8% CP, ewe daily weight gain increased from 90 to 123 g/d, then leveled off as energy increased from 1.1 to 1.4 or to 1.7 Mcal ME/d. Conversely, at 10% CP, ewe daily gain increased from 116 to 140 and then to 194 g/d with increasing energy level. These differing responses were attributed in part to enhanced microbial activity owing to a greater N supply and thus better diet utilization. After lambing, all ewes lost weight. Rate of weight loss of the ewes (-130 g/d) and birth weight of the lambs (3.2 kg) were not affected by supplementation. However, ewes fed the 100% level of both energy and CP produced more milk, resulting in heavier lambs (7.4 kg) at 30 d of age. Supplementation did not affect straw intake during the last four weeks of gestation. After lambing, only CP supplementation resulted in increased straw intake. Straw intake was high (avg: 1.6% BW), a characteristic of native breeds of sheep which have adapted to very high fiber loads and that are known to consume higher levels of straw than temperate breeds.

In another study, 56 Timhadit ewes (Management Entity, 1991) fed wheat straw-based diets were used to determine the effects of protein source (urea vs. SFM), protein level (7 vs. 9% CP) and energy level (80 and 120% of daily requirements) on ewe BW change and lamb birth weight during the last month of gestation, and on lamb growth during the first month after lambing. Preliminary results indicated that wheat straw intake by the ewes was not affected by energy level or source and level of CP. Ewe weight gain was highest at the higher energy level; however, neither level nor source of CP affected ewe weight gain. Lamb growth during the first 30 d showed varying responses. More studies are required to better understand the effects of energy level, and protein level and source on straw utilization and ewe and lamb performance.

Feeding strategies and compensatory growth in lambs

In Morocco, lambs survive on their body reserves during periods of feed shortage or drought in most production systems and replenish body storage when adequate feed resources are available. The consequences of such patterns of growth on feed efficiency and body composition are important factors to consider when defining feeding strategies for periods of feed shortage.

Two experiments were conducted by Kabbali et al. (1993a,b) to examine the effect of feed shortage and excess on lamb growth and body components. In trial 1, 24 D'Man and 20 Timhadit male lambs were allowed to reduce their body weight from 25 to 20 then to 17 kg, and were subsequently re-fed to the initial

25 kg BW, to assess changes in body components. The pattern of weight loss and compensatory growth simulated seasonal weight changes that are commonly experienced wherever animals are exposed to a wide variability in feed availability. In trial 2, 31 D'Man, 44 Timhadit, and 31 Ile de France X D'Man male lambs were fed to measure the effects of alterations of level of intake and compensatory growth on changes in weights of organs and body composition. Mean reduction in BW from 25 to 20 kg was associated with a greater loss of visceral organs (30%) and internal fat than carcass loss (19%). Further BW loss (from 20 to 17 kg) involved alteration of carcasses to a greater extent than internal organs. Carcass loss consisted of 53% water, 28% fat, and 15% protein. Refeeding was associated with a rapid increase in organ weights. Liver and kidneys regained all their weight whereas other internal organs recovered only 90% of their original weight. Refeeding was accompanied by an increase in water and a decrease in fat of both carcass and noncarcass components. At the same slaughter weight, re-fed animals had leaner carcasses than those animals which were fed to maintain BW. Allowing lambs to lose weight during transient periods of feed shortage could be an economically efficient strategy because weight loss was largely in internal organs. Re-fed lambs recovered these losses during a period of compensatory growth with better feed efficiency.

Conclusions

Nutritive research during the tenure of the Small Ruminant Collaborative Research Support Program in Morocco demonstrated that several feeding strategies could improve markedly the overall feeding systems and, thus the productivity of sheep in non-irrigated cereal-producing regions of Morocco. It appears that improved feeding will involve cash expenditures to purchase supplements from off-farm sources and changes in the management of animals and allocation of feed resources, particularly for the highly prolific D'Man x Sardi crossbreds developed by the SR-CRSP. Adoption of the most suitable feeding strategies will depend on the relative cost of feed resources, land area available for grazing, amount of utilizable biomass, and number of animals to be grazed. However, intensification of sheep production will require concurrent improvements in reproductive efficiency, health, and overall animal management. Finally, findings from this collaborative endeavor can be applied to a large portion of the Mediterranean basin, thus emphasizing the leading role played by Morocco in those areas of research.

Literature Cited

Benata, M. 1977. Etude de la valeur alimentaire des pailles récoltées traditionnellement au Maroc. Influence de la complémentation azotée. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Benjelloun, J. 1992. Influence de la complémentation des brebis sur chaumes sur leurs performances de production et de reproduction. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Butler, L. G. 1981. Supplementary feeding of Merino wethers grazing weed free stubble pasture. Aust. J. Exp. Agric. Anim. Husb. 21:272.

Bouhafra, L. 1987. Contribution à la caractérisation de l'organisation des productions ovines en relation avec le bovin laitier dans le périmètre irrigué du Tadla. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

El Maadoudi, E. 1990. Supplémentation azotée de régimes contenant la pulpe de caroube ou la pulpe d'agrumes pour ovins en croissance-engraissement. Mémoire de 3éme cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Guessous, F., A. El Hilali, and W. L. Johnson. 1988. Influence du taux d'incorporation de la pulpe de caroube sur la digestibilité et l'utilisation des rations par les ovins à l'engraissement. Reprod. Nutr. Dev. 28:93.

Guessous, A. Outmani, E. Dahbi, J. E. Garrett, and W. L. Johnson. 1987. Utilization of wheat stubble by sheep: Effect of protein supplementation on intake, diet composition and animal weight. 38th EAAP Annu. Mtg., Lisbon, Portugal.

Guessous, F., J.-M. Luginbuhl, N. Rihani, and K. R. Pond. 1991. Influence of supplementation on the performance of gestating ewes grazing wheat stubble pastures. Anim. Feed. Sci. Technol. 35:95.

Guessous, F., N. Rihani, A. Kabbali, and W. L. Johnson. 1989. Improving feeding systems for sheep in a Mediterranean rain-fed cereals/livestock area of Morocco. J. Anim. Sci. 67:3080.

INRA. 1989. Ruminant Nutrition: Recommended Allowances and Feed Tables. (R. Jarrige, Ed.). John Libbey Eurotext, Paris.

Ismaili, D. 1983. Caractérisation de l'élevage ovin dans une zone bour du Tadla (Commune des Beni Oukil). Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Kabbali, A., W. L. Johnson, D. W. Johnson, R. D. Goodrich, and C. E. Allen. 1993a. Effects of compensatory growth on some body component weights and on carcass and noncarcass composition of growing lambs. J. Anim. Sci. 70:2852.

Kabbali, A., W. L. Johnson, D. W. Johnson, R. D. Goodrich, and C. E. Allen. 1993b. Effects of undernutrition and refeeding on weights of body parts and chemical components of growing Moroccan lambs. J. Anim. Sci. 70:2859.

Kabbali, A., and K. R. Pond. 1990. Protein and energy supplementation of wheat straw diets for pregnant ewes. J. Anim. Sci. 68(Suppl. 1):598 (Abstr.).

Khal, M. 1982. Les dattes en alimentaion animale: valeur nutritive et conditions d'utilization dans la vallée du Draa. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Management Entity. 1988. Small Ruminant Collaborative Research Support Program Annual Report 1987-88. Univ. of California, Davis.

Management Entity. 1990. Small Ruminant Collaborative Research Support Program Annual Report 1989-90. Univ. of California, Davis.

Management Entity. 1991. Small Ruminant Collaborative Research Support Program Annual Report 1990-91. Univ. of California, Davis.

McCann, L. 1985. Valeur nutritive de quelques aliments marocains. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Mulholland, J. G., and J. B. Coombe. 1979. Supplementation of sheep grazing wheat stubble with urea, molasses and minerals: quality of diet, intake of supplements and animal response. Aust. J. Exp. Agric. Anim. Husb. 19:23.

Ouchkif, M. 1988. Influence d'incorporation de proportion élevées de pulpe de caroube sur la digestibilité et l'utilisation de la ration par les agneaux à l'engraissement. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Outmani, A., J.-M. Luginbuhl, F. Guessous, and W. L. Johnson. 1991. Utilization of wheat stubble pastures by gestating ewes. Small Rumin. Res. 4:257.

Rihani, N., W. N. Garrett, and R. A. Zinn. 1993. Influence of level of urea and method of supplementation on characteristics of digestion of high-fiber diets by sheep. J. Anim. Sci. 71:1657.

Rihani, N., F. Guessous, and A. Berrami. 1989a. Utilisation de quelques sous-produits de l'agro-industrie pour l'engraissement des ovins. Hommes Terres et Eaux:18:83.

Rihani, N., F. Guessous, and W. L. Johnson. 1986. Nutritive value of dried citrus and beet pulps produced in Morocco. J. Anim. Sci. 63(Suppl. 1):428 (Abstr.).

Rihani, N,. F. Guessous, and K. R. Pond. 1989b. Effect of protein level and the feeding value of carob pulp containing diets for sheep. J. Anim. Sci. 67(Suppl. 1):493 (Abstr.).

Rihani, N., F. Guessous, M. Elhata, and J.-M. Luginbuhl. 1992. Nutritive value and utilization of almond hulls in diets for sheep. J. Anim. Sci. 70(Suppl. 1):190 (Abstr.).

Tazi, M. 1992. Effect du niveau azoté du régime sur l'utilization de l'azote et les performances d'agneaux croisés D'Man X Sardi en croissance-engraissement. Mémoire de 3ème cycle Agron. Hassan II. Inst. Agron. Vet. Rabat, Morocco.

Chapter 4. Animal Health: Vaccine Development

Strategy for Development of Multivalent Virus-vectored Vaccines for Small Ruminants

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Abstract
Substantial losses in small ruminant productivity are associated with infectious and parasitic diseases. A new approach to the control of these diseases is based upon the use of multivalent virus- vectored vaccines which would be capable of immunizing sheep or goats against several agents with a single vaccination. A recombinant capripoxvirus-vectored vaccine should protect animals against sheep and goat pox, as well as other economically important diseases such as Rift Valley fever, Nairobi sheep disease, and haemonchosis. Preparation of a multivalent vaccine requires the development of a virus vector, identification and cloning of genes that encode immunologically relevant proteins of each disease agent, and the use of molecular biologic techniques to insert one or more of these genes into the capripoxvirus vaccine delivery vector. Each vaccine must be tested first under laboratory containment conditions, then under field conditions. No major obstacles to the development of such multivalent vaccines for use in developing countries are foreseen.

Introduction
Infectious and parasitic diseases are a major constraint to small ruminant production in lesser-developed countries both through direct losses and by limiting introduction of improved breeds (Alexander et al., 1989; Board on Science and Technology for International Development, 1982). Annual losses of $ 4 billion, due to mortality and morbidity, represent approximately one-fourth of the total value of livestock production in sub-Saharan Africa (Animal Agriculture, 1992). These losses can be expected to increase as a consequence of 1) increasing use of marginal lands for livestock production due to increasing human population pressure and 2) increased pressure on the already strained economies of most developing countries of Africa, resulting in an inability to subsidize research and vaccine production laboratories. One sustainable way to rectify this situation is by increasing the efficiency of meat, milk, and fiber production by disease reduction, improved animal genetics, or improved nutrition.

During the first decade of the Small Ruminant Collaborative Research Support Program (SR-CRSP), the major disease problems affecting sheep, goats, and camelids in selected sites were identified and methods were developed for improving their diagnosis and control by employing existing technology (Alexander et al., 1989). In the 1990-95 SR-CRSP Strategic Plan, the animal health component was directed towards the development of new methods of disease prevention by the application of biotechnology. The overall goal was to design, produce, and test recombinant vaccines for major diseases of sheep and goats by applying recent advances in DNA technology, immunology, and microbial genetics. The vaccines will be based on a hybrid virus that contains genetic material from multiple disease agents so that one immunization protects against several diseases. Such vaccines can be considered the ultimate "technology packages." SR-CRSP social scientists and economists plan to assess vaccine production capacity and potential economic

impact of these new multivalent vaccines in African countries. In this overview, we present a summary of the rationale, methodology, and major issues involved in development of multivalent virus-vectored vaccines.

Problem approach

The infectious and parasitic diseases responsible for most livestock losses in Africa have been identified and univalent vaccines or other control strategies have been developed for some of them. Nevertheless, losses continue because of a lack of effectiveness, cost, or refrigeration requirements for the vaccines or due to a failure to implement effective disease control strategies (Pritchard, 1988). The major goal of our research is to apply the tools of biotechnology to develop multivalent recombinant vaccines which will each protect against several diseases of sheep and goats. These vaccines are expected to be thermostable, thus not requiring a "cold chain," and be economical to produce and use. Delivery of the vaccines by means of a virus vector, which undergoes replication in the host, will enhance their capacity to induce long-lasting protection.

The diseases targeted for investigation in the SR-CRSP Strategic Plan are those which meet the following criteria: 1) diseases of sheep and goats which received priority status in internationally-sponsored surveys and reports, 2) diseases for which control strategies are unavailable, ineffective, or cost-prohibitive, 3) diseases amenable to improved control through biotechnology, and 4) diseases caused by agents with which the SR-CRSP Animal Health scientists have prior experience and competence. Based on these criteria, the diseases selected for attention include sheep and goat pox, caused by a capripoxvirus; Rift Valley fever and Nairobi sheep disease, both caused by bunyaviruses; and haemonchosis, caused by a nematode parasite.

In our SR-CRSP project, the first foreign gene to be included in the multivalent vaccine was a glycoprotein gene of Rift Valley fever virus (RVFV), an important cause of abortion and mortality among ruminants in Africa and the Middle East. The next goal was to include the glycoprotein gene of another Nairobi sheep disease virus, a cause of high mortality and abortion in sheep and goats in many areas of East Africa and perhaps other African countries. Currently, the only method to prevent Nairobi sheep disease is by control of the tick vector with expensive, labor-intensive, and environmentally unacceptable methods. Hemonchosis was selected as a vaccine priority because it is probably the most important parasitic disease of small ruminants throughout the world, including the United States. Furthermore, current control measures for this intestinal nematode are plagued with problems of anthelminthic drug resistance, labor expense, and environmental concerns.

Development of multivalent virus-vectored vaccines requires attention to three problem areas: 1) identification, evaluation, and testing of a safe and effective virus vector for the delivery of foreign genes; 2) identification and cloning of vaccine genes of disease agents that encode proteins important in inducing a protective immune response to the agent, and 3) construction of each recombinant virus containing these genes and its evaluation in animals. These research areas will be considered separately.

Selection, development, and evaluation of a virus vector

Selection of a virus to use as an antigen delivery vector for multivalent vaccines is based on efficacy and safety considerations. These include immunogenicity and pathogenicity in the target animal species, exposure to related viruses that may result in interfering immune responses, and the possibility that virus vaccine strains may revert to virulence. Advantages of poxviruses over many other virus vectors are high immunogenicity, antigenic stability, heat stability, economy of production, and simplicity of administration. Vaccinia virus, a poxvirus used as a vaccine in humans during the successful global smallpox eradication campaign (Fenner, 1988), has been developed as a vaccine vector (Bostock, 1990; Mackett, 1990; Moss, 1991; Mahr and Payne, 1992). Many of the recombinant virus-vectored vaccines developed to date, including very effective vaccines for rinderpest in cattle (Yilma, 1988) and Venezuelan equine encephalitis in horses (Bowen et al., 1992), use vaccinia virus as a vector. Rabies has been eradicated in southern Belgium using a field-bait delivery system employing a recombinant vaccinia-rabies vaccine (Brochier et al., 1991). However, vaccinia virus infection can be pathogenic for humans, especially immunocompromised people with AIDS, a widespread problem in Africa. Therefore, an alternative poxvirus was sought for use in small ruminants.

Capripoxvirus (CPV) is a promising vector for use in sheep and goats in Africa, Asia, or the Middle East where sheeppox or goatpox is a problem. It is an especially attractive vaccine delivery candidate in these areas of the world because attenuated strains of the virus are already in widespread use as vaccines. Foreign genes of other infectious agents can be inserted into CPV to develop a hybrid (recombinant) virus (rCPV) vaccine which should induce a protective immune response against capripoxvirus and to the disease agents from which the foreign genes were derived. As described in an accompanying paper, this has been accomplished by our SR-CRSP project for RVFV.

One CPV gene insertion site, the non-essential thymidine kinase gene, is already developed, but alternative sites must be identified if CPV is to be used as a virus vector for a multivalent vaccine. Some possible insertion sites already have been identified (Bostock, 1990). In addition, we are investigating the use of a serine protease inhibitor (serpin) gene which encodes a 38 kDa protein in cowpox virus. A unique feature of the serpin gene site, if it functions in CPV as it does in cowpoxvirus, is that its interruption by gene insertion may confer two important qualities on the rCPV: enhanced immunogenicity and reduced virulence of the virus, as previously reported when the TK gene of vaccinia was interrupted by gene insertion (Buller et al., 1988). A plasmid containing the sequences of cowpox virus serpin gene will be used to identify the homologous locus in CPV DNA. Once appropriate insertion plasmids have been constructed, the serpin locus can be used in tandem with the TK gene for insertion of vaccine genes into the CPV genome for development of multivalent vaccines.

Raccoon poxvirus (RCNV), an indigenous virus of raccoons in North America which is apparently nonpathogenic for humans, may be useful as a virus vector for sheep in countries in which sheeppox does not occur. To evaluate the use of RCNV as a virus vector in sheep, the immunogenicity and safety of a rabies G protein gene RPV construct (rRCNV-G) were studied (DeMartini et al., 1993) This vaccine has been shown previously to induce neutralizing antibody and protection against a rabies challenge in dogs, raccoons, and other non-livestock animals after oral immunization. Twenty adult sheep were inoculated with rRCNV-G or wild type RCNV (wt-RCNV) by intradermal (ID), intramuscular (IM), and oral (PO) routes. In-contact (sentinel) animals were included with each group. Sheep were re-inoculated with rRCNV-G seven weeks after the primary exposure. High titers of neutralizing antibody (NAb) to rabies virus developed within four weeks following primary ID inoculation with rRCNV-G; markedly lower titers of antibody resulted from IM or PO routes of exposure. Re-immunization increased the rabies NAb titers 5 to 50 fold in the ID and IM groups, but not in the PO group. Development of NAb to RCNV generally paralleled NAb to rabies virus. Prior exposure to wt-RCNV apparently inhibited the NAb response to rabies virus in sheep exposed to rRCNV-G by the ID route. The practical significance of immunity to the vaccine vector requires further study. There was no evidence for horizontal transmission of rRCNV-G or wt-RCNV in sentinel sheep. These results suggest that the RCNV vector is a safe and effective means of immunizing sheep to a recombinant expressed rabies protein by the ID and IM routes and suggest that wt-RCNV is relatively innocuous in sheep.

Selection of disease agent genes for insertion into the virus vector

Many existing univalent vaccines were developed empirically, and they often consist of inactivated preparations or attenuated live strains of the pathogen. To produce recombinant vaccines, it is necessary to identify and clone gene fragments that encode immunologically relevant microbial proteins which are capable of eliciting a protective immune response for each disease agent to be included in the vaccine (Arnon and Van Regenmortel, 1992). Knowledge of the biochemical and genetic structure of such proteins is increasing at a rapid rate, but the identity of protective antigens is still not known for many microbial pathogens. Two solutions to this problem are: 1) use nucleotide sequence information or cloned genes for a related disease agent, or 2) obtain the information by separating the constituent proteins of a pathogen, assessing immune responses to each, determining which are important in inducing protective immune responses by using native peptides purified from the organism or recombinant peptides expressed using techniques of molecular biology, and finally cloning and characterizing the gene for relevant proteins.

The strategy to identify and clone relevant genes of Nairobi sheep disease (NSD) virus is based on a successful recombinant vaccinia vectored vaccine developed for the related virus Rift Valley Fever (RVF). The RVF vaccine is based on the viral envelope glycoproteins of RVF virus; the analogous peptides of NSD virus have been identified and characterized (Rwambo et al, in preparation, 1993). The three RNA segments of NSDV will be purified and used to prepare a bacterial plasmid expression library containing cDNA inserts of the virus. Clones that contain the surface glycoproteins 1 and 2 encoded by the M segment will be selected, analyzed genetically and immunologically, and used in preparation of a rCPV. The immunoprotective capacity of the rCPV constructs will then be evaluated in sheep. Since NSDV and RVF are structurally similar viruses, it is likely that immunogenic viral proteins and host immune responses will be similar. This will simplify and facilitate development of immunologic screening assays and design of virus challenge experiments in immunized sheep.

A vaccine for haemonchosis would be of significant benefit to small ruminant owners, a benefit that would be enhanced by its inclusion in a multivalent vaccine. Recent immunization trials using parasite gut homogenate induced a significant protective immune response (Jasmer and McGuire, 1991). It is hypothesized that the parasite ingests antibody and immune cells as it feeds on blood and that these immune components kill or injure the worm. The current problem is to identify the active component in the homogenate component in the homogenate and progress on this research is reported in an accompanying paper.

A useful byproduct of the necessary research in recombinant technology is the development of new reagents and diagnostic tests for major diseases that affect small ruminants in Africa. These new diagnostic tests may be based on recombinant proteins, monoclonal antibodies, or nucleic acid detection methods (PCR, hybridization). They can be used as sensitive means of detecting infected carrier animals and invertebrate vectors (ticks, flies, and mosquitoes), and they may also be useful in differentiating vaccinated animals from those naturally exposed to pathogenic or cross-reacting disease agents.

Production and testing of a recombinant virus-vectored vaccine

Once a suitable virus vector is available and the disease agent genes to be inserted are identified and cloned into a suitable insertion vector, the recombinant (hybrid) virus must be prepared (Table 1). This is accomplished by a technique known as homologous recombination in which cells are simultaneously infected with the insertion vector containing the gene of interest and with capripoxvirus. A useful insertion vector for CPV is p1114, a poxvirus insertion vector containing pox virus thymidine kinase gene flanking sequences and the *E. coli* xanthine-guanine phosphoribosyl transferase gene (*gpt*), which is a dominant selectable marker for the construction of recombinant poxviruses. Mycophenolic acid inhibits the growth of poxviruses, including capripoxvirus. When the *gpt* gene is inserted with the foreign gene of interest into capripoxvirus, the rCPV will grow in the presence of mycophenolic acid and can be selected from the non-recombinant capripoxvirus. When a rCPV is identified, it is evaluated by Southern blots to demonstrate the presence of the inserted gene and by Western blots with monoclonal or polyclonal antibodies to demonstrate the expression of the encoded protein. The rCPV will then be grown in cell culture and stocks of the virus prepared and titered.

The final stage in development of a multivalent virus-vectored vaccine is to test the product in animals, first in containment and then in the field. The design for these experiments will take safety issues into account (Glosser, 1988). Animals lacking antibodies to the disease agent protein of interest will be inoculated with a suitable dose of the rCPV. After a booster inoculation, the animals will be checked for antibody to the protein using ELISA, Western blotting, and serum neutralizing antibody procedures. If antibodies are detected, inoculated and control animals will be challenged with the virulent pathogen and the efficacy of the rCPV vaccine assessed. Some animals also will be challenged with capripoxvirus alone to determine whether the immunogenicity of the rCPV was affected by the gene insertion. When control and vaccinated sheep and goats are challenged with capripoxvirus, they will be evaluated for increases in body temperature and typical lesions. In addition, virus titers will be determined on sequential blood samples and

samples from any lesions that appear. Successful immunization with rCPV may require optimization of the dose of vaccine and route of administration. Optimization would require additional vaccine trials in sheep and goats.

Table 1. General approach to development of a recombinant virus-vectored vaccine.

1. Identify structural proteins of a microbe or parasite responsible for eliciting a protective immune response in the host animal. Convalescent serum antibodies are useful correlates of protection, and monoclonal antibodies are useful in detection and characterization of relevant proteins of the disease agent. These antibodies also can be used to purify native proteins to study their immunogenicity *in vivo*.

2. Isolate and purify the nucleic acid (DNA or RNA) of the disease agent and prepare a genomic or cDNA library in a suitable bacterial plasmid.

3. Screen the library for a DNA fragment containing the gene encoding the protein of interest using antibody or DNA hybridization procedures. Isolate, grow and purify positive colonies. Confirm the identity of the gene by generating nucleotide sequence information or by inducing protein expression in bacterial cells and by comparing the recombinant protein with native protein in biochemical and immunogenicity studies.

4. Subclone the gene in an appropriate insertion plasmid that contains homologous poxvirus sequences (TK or serpin genes) and selection (gpt, antibiotic resistance) or marker (beta-galactosidase) genes.

5. Prepare a recombinant poxvirus by transfecting cell cultures with the insertion plasmid containing the foreign gene and simultaneously infecting cells with the poxvirus. Homologous recombination between the DNA of the plasmid and the poxvirus results in a recombinant poxvirus containing the gene of interest.

6. Evaluate *in vitro* expression of the disease agent protein in cells infected by the recombinant poxvirus.

7. Evaluate the capacity of the recombinant poxvirus to induce immunity in sheep or goats both to the disease agent of interest and to the poxvirus itself. Correlation of antibody formation in immunized animals with protective immunity can be investigated.

Literature Cited

Arnon, R. and M. H. V. Van Regenmortel. 1992. Structural basis of antigenic specificity and design of new vaccines. FASEB J. 6:3265.

Alexander, A.F., J.C. DeMartini, T.C. McGuire, and H.J. Olander. 1989. Animal health research in the Small Ruminant Collaborative Research Support Program. J. Anim. Sci. 67:3103.

Animal Agriculture in Sub-Saharan Africa. 1992. Winrock International Institute for Agricultural Development.

Board on Science and Technology for International Development, Office of International Affairs, National Research Council, for the Bureau for Science and Technology, U.S. Agency for International Development. 1982. *Priorities in Biotechnology Research for International Development*, Workshop Proceedings, National Academy Press, Washington D.C.

Bostock, C.J. 1990. Viruses as vectors. Vet. Microbiol. 23:55.

Bowen, R.A., W.F. Short, C.B. Cropp, J.T. Roehrig, J. Matthews, P.K. Kinney, J.C. DeMartini, and D.W. Trent. 1992. Protection of horses immunized with recombinant vaccinia-venezuelan equine encephalitis vaccine. Vaccine Research 1:111.

Brochier, B., M.P. Kieny, F. Costy, P. Coppens, B. Bauduin, J.P. Lecocq, B. Languet, G. Chappuis, P. Desmettre, K. Afiademanyo, R. Libois and P.P. Pastoret. 1991. Large-scale eradication of rabies using recombinant vaccinia-rabies vaccine. Nature 354:520.

Buller R.W.L., G.L. Smith, K. Cremer, A.L. Notkins, and B. Moss. 1985. Decreased virulence of recombinant vaccinia virus expression vectors is associated with a thymidine kinase- negative phenotype. Nature 317:813.

DeMartini, J.C., H.M. Bickle, S.J. Brodie, and J.J. Esposito. 1993. Evaluation of immunogenicity and safety of a recombinant raccoon poxvirus rabies glycoprotein vaccine in sheep. In press. Arch. Virol.

Fenner, F., D.A. Henderson, I. Arita, Z. Jegek, and I.D. Ladnyi. 1988. Smallpox and Its Eradication, World Health Organization, Geneva.

Glosser, J.W. 1988. Regulation and application of biotechnology products for use in veterinary medicine Rev. Sci. Tech. Offi. Int. Epiz. 7:223.

Hruby, D.E. 1990. Vaccinia virus vectors: new strategies for producing recombinant vaccines. Clin. Microbiol. Reviews 3:153.

Mackett, M. 1990. Vaccinia virus recombinants. Advances in Gene Technology, Vol. 1, pp21-54. JAI Press, Ltd., London.

Mahr, A. and L. G. Payne. 1992. Vaccinia recombinants as vaccine vectors. Immunobiol. 184:126.

Moss, B. 1991. Vaccinia virus: a tool for research and vaccine development. Science 252:1662.

Pritchard, W.R. 1988. Ways that veterinary medicine can help alleviate hunger in Africa. J. Amer. Vet. Med. Assoc. 192:1701.

Jasmer, D.P. and T.C. McGuire. 1991. Protective immunity to a blood-feeding nematode (*Haemonchus contortus*) induced by parasite gut antigens. Infection and Immunity 59:4412.

Yilma, T., D. Hsu, L. Jones, S. Owens, M. Grubman, C. Mebus, M. Yamanaka, B. Dale. 1988. Protection of cattle against rinderpest with vaccinia virus recombinants expressing the HA or F gene. Science 242:1058.

Current Status of Capripoxvirus Multivalent Vaccine for Small Ruminants

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Abstract

A long-term goal of our SR-CRSP project is the development of a safe and reliable virus vector to deliver multivalent vaccines to sheep and goats. An initial aim was to evaluate attenuated capripoxvirus as a virus vector. Major progress was made by constructing and isolating a recombinant capripoxvirus (rCPV-RVFV) which expressed a foreign gene encoding protective glycoproteins from Rift Valley fever virus (RVFV). Plaque purified rCPV-RVFV was competent in replication and expressed and processed with fidelity the RVFV glycoproteins encoded by the inserted genes. Since both wild type capripoxvirus and RVFV cause disease in goats and sheep, the rCPV-RVFV virus vector should induce protective immunity against both viruses. If protection occurs, the efficacy of this bivalent virus-vectored vaccine will be further documented and other genes encoding protective proteins from important pathogens can be added.

Introduction

Over the past few years, we have been engaged in an effort to develop improved vaccines for use in small ruminants (Rurangirwa et al., 1987; Pearson et al., 1989; Rurangirwa et al., 1991). As indicated in an accompanying paper, the current strategy is to develop multivalent virus-vectored vaccines for sheep and goats. This strategy requires identifying an improved viral vector that would efficiently deliver appropriate genes from important pathogens of small ruminants to the animal and would be cost-effective, multivalent, and pose little hazard to humans. One possibility is capripoxvirus, which causes goat and sheep pox and is restricted in its host-range to ruminants (Davies, 1976; Romero et al., 1993). These pox diseases are economically important in countries throughout Africa and Asia (Kitching et al., 1987). Attenuated capripoxvirus has been used as a successful vaccine in Kenya for many years (Davies and Mbugwa, 1985). The virus has been partially characterized molecularly and gene insertion sites have been described (Gershon and Black, 1989). These features made it an excellent starting point for development of a virus vector.

Capripoxvirus is a genus of poxviruses that includes the group of very closely related viruses which cause sheep pox, goat pox, and lumpy skin disease of cattle. These diseases are widespread in Africa and the Asian subcontinent, but they are exotic to the U.S. The severity of outbreaks is variable, depending largely on the level of pre-existing immunity. However, the overall impact of these diseases is very large, and they severely affect subsistence farmers who are dependent upon small ruminants (Kitching and Taylor, 1985). The viruses are potentially less hazardous to humans than other less host-specific poxviruses, such as vaccinia virus. In addition, we have used an attenuated strain of sheep pox virus, which is already in widespread use as a vaccine in East Africa. A procedure was identified to insert foreign passenger genes into capripoxvirus, so that it will express those passenger genes when it is inoculated into animals. Thus the modified virus will

immunize against pox, and against the pathogens from which the passenger gene was derived. In addition, insertion of a passenger gene into the capripoxvirus thymidine kinase gene should further decrease the virulence of the virus (Buller et al., 1985). Passenger genes currently being used in in vitro studies of this vector are from Rift Valley Fever Virus (RVFV).

RVFV is an arthropod-borne member of the phlebovirus genus (Family: Bunyaviridae) which is widely distributed in Africa where it causes endemic and epidemic disease in sheep, goats, cattle, and humans (Shope et al., 1982). The disease was first described in Kenya by Daubney and Hudson (1931). Subsequently, the virus was isolated from the blood of a sick lamb. Infection of small ruminants with this virus results in abortions and a high rate of perinatal mortality. Live attenuated RVFV vaccines are available for use in livestock and they are effective in inducing resistance to challenge with wild type RVFV. The disadvantages of the live attenuated vaccines are that they cause abortions and they require the maintenance of a cold chain during delivery due to the thermolability of the virus. Delivery of the RVFV glycoprotein genes in a multivalent virus-vectored vaccine would not cause abortion and would eliminate the need for a cold chain.

Virus vector

The KS-1 capripoxvirus strain which was used is a sheep poxvirus isolated in Kenya during a low-morbidity (approximately 10%) outbreak that involved both sheep and goats (Davies, 1976). The virus was first isolated in lamb testis cells and freeze dried. It was obtained from Dr. D. Black, Institute of Animal Health, Pirbright, U.K., after three further passages in baby hamster kidney cells and four passages in lamb testis cells (Kitching et al., 1987). The virus does not cause disease in sheep, goats or cattle, but it induces protection against lumpy skin disease in cattle (Romero et al., 1993) and against sheep and goat pox disease in sheep and goats (Kitching et al., 1987). The KS-1 strain does not spread from inoculated to susceptible animals. Although a local lesion may develop at a site of inoculation, this strain does not cause viremia. It has also been tested and proven safe for use in pregnant sheep inoculated in the first from one to three months of gestation.

Recombination plasmid

The plasmid used for homologous recombination with the capripoxvirus was a vaccinia insertion plasmid, p1114, supplied by Dr. M. Mackett, Patterson Institute for Cancer Research, Manchester, England. This plasmid contains the *E. coli* xanthine- guanine phosphoribosyl transferase gene (*gpt*) which is a dominant positive selectable marker for the construction of recombinant poxviruses (Falkner and Moss, 1990). The *gpt* gene is under control of the P19 early promoter of vaccinia virus. After insertion of the *gpt* gene the foreign gene of interest into capripoxvirus, the recombinant poxvirus will grow in the presence of mycophenolic acid, in contrast to wild type capripoxvirus. This allows the recombinant virus to be selected from nonrecombinant virus. The *gpt* gene and the cloning site for foreign genes in p1114 are flanked by thymidine kinase gene sequences designed to direct insertion by homologous recombination into the thymidine kinase gene of vaccinia virus. The plasmid was predicted to recombine with the capripoxvirus thymidine kinase gene because of the significant homology with the vaccinia virus thymidine kinase gene.

RVFV glycoprotein genes

The genes encoding RVFV glycoproteins 1 and 2 were contained in a plasmid pSCRV6 obtained from Dr. M. S. Collett, Molecular Genetics Inc., Minneapolis, Minnesota. This plasmid was derived by modification of pSC11, a standard, widely-used insertion plasmid for vaccinia virus. pSCRV6 contains the complete genes for both envelope glycoproteins (G1 and G2) of RVFV (Kalach et al., 1988). The RVFV glycoprotein genes were excised from this plasmid and ligated into the cloning site p1114, which was then used to insert these genes into capripoxvirus by homologous recombination.

Homologous recombination and recombinant virus selection

Lamb testis cells were grown to 75% confluency in 6-well plates and infected with capripoxvirus at a multiplicity of one. The cells were washed two hours later and a solution containing 10 ug of plasmid DNA, 3 ug of capripoxvirus DNA, and 25 ug of LipofectinR was added. Following incubation at 37°C for eight hours, positive selection medium was added containing 25 ug/ml mycophenolic acid, 250 ug/ml xanthine, 10-4 M hypozanthine, 10-7 M aminopterin, and 1.6X10-7 M thymidine. Culture fluids were harvested and recombinant capripoxvirus (rCPV-RVFV) was plaque-purified three times on cells with positive selection medium.

Presence of foreign genes in rCPV-RVFV

Following plaque purification of rCPV-RVFV, the viral DNA was isolated and examined in Southern blots for the presence of the *gpt* and RVFV glycoprotein genes. Probes were made by isolating these genes from the respective plasmids following restriction endonuclease digestion. Both probes hybridized with rCPV-RVFV DNA, but not with DNA from wild type capripoxvirus DNA.

Expression of RVFV glycoproteins by rCPV-RVFV

Cells infected with rCPV-RVFV were examined for expression of RVFVglycoprotein in immunofluorescence and immunoblot assays. For immunofluorescence, a monoclonal antibody (R1-4D4) was used and cytoplasmic fluorescence was found in rCPV-RVFV infected cells, but not in wild type capripoxvirus infected cells. In addition, an isotype control monoclonal antibody failed to react with rCPV-RVFV infected cells. Immunoblots with the monoclonal antibody and antisera to RVFV identified bands similar to those described for glycoproteins 1 and 2, indicating that the rCPV-RVFV was making glycoproteins similar to those found in wild type RVFV.

Future research

We anticipate that the goats and sheep to be inoculated with rCPV-RVFV expressing RVFV glycoprotein genes will be protected against both capripoxvirus and RVFV challenge. This expectation is based on the successful use of poxvirus vectors in other animals (Yilma et al., 1988), the success of the attenuated capripoxvirus as a vaccine against capripoxvirus, the ability of the RVFV glycoprotein genes expressed in vaccinia virus to induce a protective immune response (Collett et al., 1987), and the recent success using a recombinant capripoxvirus expressing rinderpest virus genes to protect cattle against challenge with rinderpest virus and lumpy skin disease virus (Romero et al., 1993). Obviously, we have constructed a prototype virus-vectored vaccine which should induce protective immunity to two virus diseases in sheep and goats. If our assumption is correct, then appropriate genes from other pathogens of sheep and goats can be added to increase the valency of this virus- vectored vaccine.

Literature Cited

Buller, R.M.L., G.L. Smith, K. Cremer, A.L. Notkins and B. Moss. 1985. Decreasedvirulence of recombinant vaccinia virus expression vectors is associated with a thymidine kinase-negative phenotype. Nature 317:813.

Collett, M.S., K. Keegan, S.-L. Hu, P. Sridhar, A.F. Purchio, W.H. Ennis, and J.M. Dalrymple. 1987. Protective subunit immunogens to Rift Valley fever virus from bacteria and recombinant vaccinia virus. In: B. Mahy and D. Kolakofsky (Ed.) The Biology of Negative Strand Viruses. Elsevier Science Publishing, New York.

Daubney, R. and J.R. Hudson. 1931. Enzootic hepatitis or Rift Valley fever. An undescribed virus disease of sheep, cattle and man from East Africa. J. Pathol. Bacteriol. 34:545.

Davies, F.G. 1976. Characteristics of a virus causing a pox disease in sheep and goats in Kenya, with observations on the epidemiology and control. J. Hyg., Camb. 76:163.

Davies, F.G. and G. Mbugwa. 1985. The alterations in pathogenicity and immunogenicity of a Kenyan sheep and goat poxvirus on serial passage in bovine foetal muscle cell cultures. J. Comp. Path. 95:565.

Falkner, F.G. and B. Moss. 1990. Transient dominant selection of recombinant vaccinia viruses. J. Virol. 64:3108.

Gershon, P.D. and D.N. Black. 1989. The nucleotide sequence around the capripoxvirus thymidine kinase gene reveals a gene shared specifically with leporipoxvirus. J. Gen. Virol. 70:525.

Kakach, L.T., T.L. Wasmoen and M.S. Collett. 1988. Rift Valley fever virus M segment: Use of recombinant vaccinia viruses to study Phlebovirus gene expression. J. Virol. 62:826.

Kitching, R.P. and W. P. Taylor. 1985. Transmission of capripoxvirus. Res. Vet. Sci. 39:196.

Kitching, R.P., J.M. Hammond, W.P. Taylor. 1987. A single vaccine for the control of capripoxvirus infection in sheep and goats. Res. Vet. Sci. 42:53.

Pearson, L.D., M.L. Poss and J.C. DeMartini. 1989. Animal lentivirus vaccines: Problems and prospects. Vet. Immunol. Immunopathol. 20:183.

Romero, C.H., T. Barret, S.A. Evans, R.P. Kitching, P.D. Gershon, and D.N. Black. 1993. A single capripoxvirus recombinant vaccine for the protection of cattle against rinderpest and lumpyskin disease. Vaccine 11:737.

Rurangirwa, F.R., T.C. McGuire, A. Kibor and S. Chema. 1987. An inactivated vaccine for contagious caprine pleuropneumonia. Vet. Rec. 121:397.

Rurangirwa, F.R., T.C. McGuire, L. Mbai, L. Ndung'u and A. Wambugu. 1991. Preliminary field test of lyophilised contagious caprine pleuropneumonia vaccine. Res. Vet. Sci. 50:240.

Shope, R.E., C.J. Peters and F.G. Davies. 1982. The spread of Rift Valley fever andapproaches to itscontrol. Bull.W.H.O. 60:299.

Yilma, T., D. Hsu, L. Jones, S. Owens, M. Grubman, C. Mebus, M. Yamanaka and B. Dale. 1988. Protection of cattle against rinderpest with vaccinia virus recombinants expressing the HA or F gene. Science 242:1058.

Identification of Genes Useful for Control of Parasitic Diseases of Small Ruminants

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Introduction

Hemophagous nematode parasites cause some of the most important parasite diseases of man and domestic animals throughout the world. This group of nematodes includes hookworms of man and animals (*Ancylostoma* spp., *Necator* spp., *Bunostomum* spp., *Uncinaria* spp., etc.), stomach and nodular worms of large animals (*Haemonchus* spp., *Ostertagia* spp. and *Oesopagostomum* spp.), strongyles of horses (*Strongylus* spp. and various small strongyles) and several other hemophagous nematodes of lesser significance (Miller, 1979; Georgi and Georgi, 1990). All are phylogenetically related and belong to the nematode order Strongylida (Georgi and Georgi, 1990). The stomach worm *Haemonchus contortus* is the hemophagous nematode parasite that we have investigated in our research. This worm is considered to be the most important nematode parasite of small ruminants in tropical and subtropical regions, and morbidity and mortality losses caused by this parasite are estimated in the tens of million dollars (U.S.) annually in lesser developed countries (Aberejola et al., 1979; Preston and Allonby, 1979).

Methods to control *H. contortus* and other hemophagous nematodes are complicated by the high fecundity of the parasites which can produce thousands of eggs each day per female (Fleming, 1988). This leads to heavy pasture and soil contamination by infective larvae which can rapidly re-establish infections in the host. Control is further complicated by the high capacity of these nematodes to develop resistance to anthelmintics. Strains of *H. contortus* have developed resistance to most contemporary anthelmintics, including Ivermectin (Prichard et al., 1980; Egerton et al., 1988). Since development of resistance outpaces the identification of anthelmintics for this and other parasites (Wescott, 1986), alternative forms of control are needed.

Vaccine approach

An important alternative approach to the control of hemophagous nematodes is through vaccination. The only effective vaccine developed against a hemophagous nematode was based on irradiated third stage larvae of *Ancylostoma caninum* (Miller, 1978). Unfortunately, occasional hypersensitivity reactions leading to death reduced the application of this vaccine (Miller, 1978). For nematodes such as *H. contortus*, effective immunity is developed against infection in small ruminants (Jarrett et al., 1959; Christie et al., 1964; Wilson and Simson, 1974; Munn et al., 1987; Neilson and Van der Walle, 1987). Although this immunity is incomplete, it protects infected animals against clinical disease and significantly reduces parasite egg production. Although variable success has been achieved in inducing immunity to *H. contortus* in young animals (Wilson and Simson, 1974; Munn et al., 1987; Neilson and Van der Walle, 1987), successful trials included the use of live infections followed by anthelmintic treatment and immunization with fractions of various stages of *H. contortus*. Live infections terminated by anthelmintics induce significant immunity in lambs <6 months old (Christie et al., 1964) but the procedure suffers from the lack of a reliable source of infective larvae.

Progress toward identifying protective antigens of *H. contortus* has been made by considering the blood-sucking behavior of the worm, which causes the greatest damage to the host. This feeding mechanism, however, also provides an important strategy for vaccination. If an immune response were directed against the parasite gut, the blood-sucking process could deliver this immune response and disrupt normal gut function, decreasing parasite survival and reproduction. There are several lines of evidence indicating that such a strategy could be effective against hemophagous nematodes. The first is that an immune response against gut surface antigens of *Boophilus* ticks has produced remarkable levels of protection against tick challenge infections in cattle (Opdebeeck et al., 1988; Opdebeeck et al., 1989; Rand et al., 1989; Willadsen et al., 1989). Furthermore, recombinant gut surface antigens of this tick are also protective (Rand et al., 1989) The second is that immunization trials by us (Jasmer and McGuire, 1991; Jasmer et al., submitted) and others (Munn et al., 1987; Tavernor et al., 1992a, 1992b; Munn et al., 1993; Smith, 1993) using putative gut antigens of *H. contortus* resulted in significant protection of lambs against challenge infections of this parasite. Here, we describe our progress toward identification of *H. contortus* gut antigens that can induce protection against challenge infections.

Induction of immunity to *H. contortus* using wholegut

In initial experiments (Jasmer et al., 1991), whole gut, excluding the esophagus, was dissected from adult female *H. contortus*. These purified gut preparations were homogenized and used to vaccinate two-month-old Saanen kid and yearling pygmy goats. Following challenge, adult worm populations were reduced by 65% in the Saanen goat group and by 89% in the Pygmy goat group while the fecal egg counts were reduced by 95% in both experiments for immunized compared to control goats. In addition, the number of eggs occurring in uteri of female worms from immunized kids was also significantly reduced compared to female worms from control goats. These experiments demonstrated that immunization with parasite gut antigens protected kid goats against the establishment of adult parasites and decreased the fecundity of surviving female parasites. Among antigens recognized by antibodies from the protected goats, gut microvillar membrane antigens were conserved among several species of strongylid nematodes and expressed in multiple life cycle stages.

The importance of these results were four-fold. First, the reduction in worm numbers has the potential to reduce clinical disease by preventing the establishment of adult worms. Second, the reduced fecal egg output of immunized animals could significantly reduce transmission of this parasite. Third, both the reduction in worm numbers and fecal egg output was achieved in young animals which are the most important in pasture transmission and experience the most severe clinical disease. Fourth, research progress on gut antigens of H. contortus may have application to multiple life cycle stages and parasitic nematode species.

Development of monoclonal antibodies (mabs) to gut surface epitopes

Isolated gut homogenates were used to immunize mice as spleen donors for hybridoma production (Jasmer et al., submitted). Antibodies in 25 supernatants (isotypes included IgG1, 2a, and 2b) reacted with surface determinants on microvilli of freshly isolated H. contortus gut. Of the surface reactive mabs analyzed, seven identified antigens on western blots of adult H. contortus gut samples, which will be described subsequently. In dot blot analysis, it was determined that epitopes recognized by the remaining 18 surface reactive mabs were sensitive to denaturing (heating and ionic detergents) and reducing conditions (2-mercaptoethanol), suggesting that they are conformational epitopes.

Characterization of antigens recognized by surface reactive mabs

The mabs recognizing denatured and reduced gut surface antigens can be separated into two groups. A group of six mabs had similar reactivity on tissue and western blots and are represented here by one mab designated 42/10.6.1 (IgG 2a). This mab reacted with several worm tissues, including the gut surface, body wall, and weakly to cuticular regions. On western blots, this mab reacted to at least 18 protein bands ranging in size from about 175 to 18 kDa. Thirteen proteins were identified by this mab in isolated gut samples, and

these comigrated with proteins detected in whole worm extracts. Gut proteins recognized by this mab appeared to be located in membrane preparations and excretory/secretory products of adult *H. contortus*. Another mab designated 42/53.3.5 (IgG 1) reacted exclusively with the microvilli of adult *H. contortus* gut in fixed cryosections and to the surface of the gut of fresh samples. This mab recognized a 46 kDa protein, although occasionally a band was also observed at about 100 kDa. The 46 kDa protein was also enriched in the crude membrane and excretory/secretory fractions of adult worms. It was shown by competitive ELISA that the epitopes recognized by the two mabs are distinct from phosphorylcholine. Furthermore, the epitope recognized by each mab was destroyed by periodate treatment, indicating that these epitopes are carbohydrates.

Phylogenetic conservation of *H. contortus* gut surface epitopes

Experiments were carried out to determine if epitopes recognized by 42/10.6.1 and 42/53.3.5 mabs were phylogenetically conserved. These mabs were first used in indirect immunofluorescent analysis on histological sections of several nematode species. The 42/10.6.1 mab bound to the gut and other tissues of multiple adult and larval strongylid and rhabditid nematode species (Table 1), including third stage larvae of *Ancylostoma caninum* and all stages in a mixed population of *C. elegans*. Nematode species expressing this epitope represent three superfamilies (Ancylostomatoidea, Strongyloidea, and Trichostrongyloidea) in the Strongylida, and one species is from the order Rhabditida (*C. elegans*). It was also determined on isolated gut tissue that this mab bound to gut surface antigens of *O. ostertagi*. The universal occurrence on these species suggests that the epitope may be common on gut membrane proteins, and perhaps gut surface proteins, of all species within these groups. In contrast, this mab did not bind to adult *Trichinella spiralis* or *Fasciola hepatica*. The 42/53.3.5 mab bound exclusively to microvilli and ES products of adult *H. contortus*, indicating this epitope is species, stage, and tissue specific.

Table 1. Summary of life cycle stage and species conservation of the 42/10.6.1 and 42/53.3.5 epitopes.

	Species					
	Hc	Oo	Tc	HS	Ac	Ce
mab	A/L3	A/L3	A/L3	A	L3	L1-A
10.6.1	+ / +	+ / +	+ / +	+	+	+
53.3.5	+ / -	- / -	- / -	-	-	-

A, adult; L1 and L3, larva. Species, Strongylida: Hc, *Haemonchus contortus*; Oo, *Ostertagia ostertagi*; Tc, *Trichostrongylus colubriformis*; HS, small horse strongyles, species undetermined; Ac, *Ancylostoma caninum*. Ce, *Caenorhabditis elegans*. +, positive reactivity to gut (adult) or internal organs (larvae). -, reactivity no greater than isotype control mab.

Induction of immunity to *H. contortus* with immunoaffinity isolated gut antigens

Both mabs 42/10.6.1 and 42/53.3.5 were used to immunoaffinity isolate antigens from adult H. contortus worms. Numerous proteins were isolated from the 42/10.6.1 antibody column, and, without obvious exception, all isolated antigens reacted with this mab on subsequent western blot. In contrast, four proteins of 100, 52, 46, and 30 kDa were repeatedly isolated from the 42/53.3.5 antibody column. Three of these proteins (100, 52, and 46 kDa) were identified by both the 42/10.6.1 and 42/53.3.5 mabs. N-terminal peptide sequences were determined for each of the proteins isolated with the 42/53.3.5 mab and are as follows: A M X L Q F/D T V T X D/N/P D N (52 kDa protein), T G E L P/I F P/E G E T X L/N K N/F (46 kDa protein), and X I V L T Q X P A S L (30 kDa protein), where X = undetermined and / = either heterogeneity or ambiguity.

Antigen preparations isolated from the 42/10.6.1 or the 42/53.3.5 mab immunoaffinity columns were each used to immunize goats. Both preparations induced immunity that resulted in significant reductions of mean total worms (45 and 60%, respectively) in the immunized group compared to the control group ($p<0.05$) (Table 2). Lower mean fecal egg counts were observed for the immunized compared to control groups in both trials, at all time points tested; however, differences were not statistically significant ($p>0.05$). We consider this level of immunity to be moderate, although very significant, because the resu' identify specific gut surface antigens that induced protection against a blood-sucking nematode parasite. In addition, this protection was achieved by antigens that have a broadly conserved gut surface epitope recognized by mab 42/10.6.1. To improve on the level of protection may require either different antigen presentations and/or additional protective antigens presented in combination with those already identified.

Table 2. Reductions in *Haemonchus contortus* worm and fecal egg counts in goats immunized with Ag isolated from the 42/10.6.1 and 42/53.3.5 immunoaffinity columns.

Antigen		Counts (s.d.) Total worms	Reduction	Eggs/g.	Reduction
42/10.6.1					
	Immunized	577(527)[a]	45%	4,526(4,941)[a]	27%
	Control	1.050(370)[b]		6,163(3,135)[a]	
42/53.3.5					
	Immunized	330(309)[a]	60%	1,081(896)[a]	54%
	Control	815(545)[b]		2,327(1,595)[a]	

[a,b] Means with different superscripts differed significantly ($p<0.05$) within each experiment using the rank sums test.

Cloning of a gene putatively encoding the 46 kDa gut surface antigen

Polyclonal goat sera to antigens isolated by the 42/53.3.5 mab were pooled and used to screen an adult *H. contortus* cDNA expression library. The initial screen identified 20 clones encoding proteins that ranged in size from ca. 40 to 100 kDa on western blots. The larger proteins might represent precursors to either or both the 46 and 52 kDa protein. DNA sequence obtained from putative 5' ends of six clones have identified single open reading frames that would encode protein sequences listed in Figure 1. One of these gene sequences (Hcga13) encodes a 100 kDa fusion protein. The gene sequence has an open reading frame, in frame with ß-galactosidase, which would encode a predicted amino acid sequence with strong similarity to the amino terminal sequence of the 46 kDa protein (see below). Identity was observed at each position between predicted and determined amino acid sequences, with the exception of the histidines which had a weak signal in protein sequencing. The 3' end of the cloned sequence has a poly A+ tract suggesting inclusion of the 3' end of the gene. Our results suggest that Hcga13 encodes the 46 kDa protein or a related family member. As should be recalled, the 42/53.3.5 mab recognized both 46 and 100 kDa proteins in worm extracts, and it is possible that the 100 kDa protein is a precursor for the 46 kDa protein. In addition, the combined size of the 46 and 52 kDa proteins approaches 100 kDa, and it is possible that these proteins isolated by the 42/53.3.5 mab are both derived from a common 100 kDa precursor.

Conclusions

Our results demonstrated that gut surface antigens of *H. contortus* induce protective immune responses that significantly reduced adult worm populations in challenge infections (Jasmer et al., 1991; Jasmer et al., submitted). Similar and more dramatic reductions in worms and fecal egg counts have been reported by others using related approaches (Travernor et al., 1992a, 1992b; Munn et al., 1993; Smith, 1993). Signifi-

cantly, antigens identified here which induce protective immunity possess an epitope which is broadly conserved among a large number of nematodes in the orders Strongylida and Rhabditida. Antigens isolated by the 42/53.3.5 mab also have this conserved epitope and represent a subpopulation of proteins isolated by the 42/10.6.1 mab. Since the 42/10.6.1 mab binds to gut microvilli of numerous species of parasitic nematodes, it could be used to isolate protective antigens from these species. Demonstration that the epitope recognized by 42/10.6.1 occurs on other tissues and in ES products raises the possibility that the protective immune responses observed are not restricted to the gut of the worm. Identification of specific antigens that induce protection against H. contortus infections provided reagents for isolation of parasite genes encoding protective gut antigens. Availability of genes expressing proteins which induce protective immunity will facilitate further evaluation of their vaccine potential.

Literature Cited

Aberejola, O.O., T.W. Schillhorn van Veen, and C.O. Njoku. 1979. Ovine and caprine diseases in Nigeria: A review of economic losses. Bull. Anim. Hlth. Prod. Afr. 27:65.

Christie, M.G., M.R. Brambell, and W.A.G. Charleston. 1964. Resistance to a challenge infection with *Haemonchus contortus* conferred by previous experience of immature stages only. J. Comp. Path. 74:427.

Egerton, J.R., D. Suhayda, and C.H. Eary. 1988. Laboratory selection of *Haemonchus contortus* for resistance to ivermectin. J. Parasitol. 74:614.

Fleming M.W. 1988. Size of inoculum dose regulates in part worm burdens, fecundity, and lengths in ovine *Haemonchus contortus* infections. J. Parasitol. 74:975.

Georgi, J.R., and M.E. Georgi. 1990. Parasitology for Veterinarians. W. B. Saunders Co., Philadelphia.

Jarrett, W.F.H., F.W. Jennings, W.I.M. McIntyre, W. Mulligan, and N.C.C. Sharp. 1959. Studies on immunity to *Haemonchus contortus* infection—Vaccination of sheep using a single dose of X-irradiated larvae. Am. J. Vet. Res. 20:527.

Jasmer, D.P., and T.C. McGuire. 1991. Protective immunity to a blood feeding nematode (*Haemonchus contortus*) induced by parasite gut antigens. Infect. Immun. 59, 4412.

Jasmer, D.P., L.E. Perryman, G.A. Conder, S. Crow, and T.C. McGuire. Submitted. Protective immunity to *Haemonchus contortus* induced by immunoaffinity isolated antigens that share a phylogenetically conserved carbohydrate gut surface epitope. Journal of Immunology.

Miller, T.A. 1978. Industrial development and field use of the canine hookworm vaccine. Adv. Parasitol. 16:333.

Miller, T.A. 1979. Hookworm infection in man. Adv. Parasitol. 17:315.

Munn, E.A., C.A. Greenwood, and W.J. Coadwell. 1987. Vaccination of young lambs by means of a protein fraction extracted from adult *Haemonchus contortus*. Parasitol. 94:385.

Munn, E.A., T.S. Smith, M. Graham, C.A. Greenwood. A.S. Tavernor, and G. Coetzee. 1993. Vaccination of merino lambs against haemonchosis with membrane-associated proteins from the adult parasite. Parasitol. 106:63.

Neilson, J.T.M. and M.J. Van der Walle. 1987. Partial protection of lambs against *Haemonchus contortus* by vaccination with a fractionated preparation of the parasite. Vet. Parasitol. 23:211.

Opdebeeck, J.P., J.Y.M. Wong, L.A. Jackson, and C. Dobson. 1988. Hereford cattle immunized and protected against *Boophilus microplus* with soluble and membrane- associated antigens from the midgut of ticks. Para. Immunol. 10:405.

Opdebeeck, J.P., J.Y.M. Wong, and C. Dobson. 1989. Hereford cattle protected against *Boophilus microplus* with antigens purified by immunoaffinity chromatography from larval and adult ticks. Immunology 67:388.

Preston, J.M. and E. W. Allenby. 1979. The influence of breed on the susceptibility of sheep to *Haemonchus contortus*. Res. Vet Sci. 26:134-.

Prichard, R.K., C.A. Hall, J.D. Kelly, I.C.A. Martin and Donald AD. 1980. The problem of anthelmintic resistance in nematodes. Aust. Vet. J. 56:239.

Rand, K.N., T. Moore, A. Sriskantha, K. Spring, R. Tellam, P. Willadsen and G.S. Cobon. 1989. Cloning and expression of a protective antigen from the cattle tick *Boophilus microplus*. Proc. Natl. Acad. Sci. USA 86:9657.

Smith, W.D. 1993. Protection in lambs immunized with *Haemonchus contortus* gut membranes. Res. Vet. Sci. 54:94.

Tavernor, A.S., S.T. Smith, C.F. Langford, M. Graham, and E.A. Munn. 1992a. Immune response to Clun Forest sheep to vaccination with membrane glycoproteins from *Haemonchus contortus*. Para Immunol 14:671.

Tavernor, A.S., S.T. Smith, C.F. Langford, E.A. Munn, and M. Graham. 1992b. Vaccination of young Dorset lambs against haemonchosis. Para. Immunol. 14:645.

Wescott, R.B. 1986. Anthelmintics and drug resistance. Veterinary Clinics of North America: Equine Practice 2:367.

Willadsen P., G.A. Riding, R.V. McKenna, D.H. Kemp, R.L. Tellam, J.N. Nielsen, J. Lahnstein, G.S. Cobon, and J.M. Gough. 1989. Immunologic control of a parasitic arthropod: Identification of a protective antigen from Boophilus microplus. J. Immunol. 143:1346.

Wilson, G.I., and K.S. Simson. 1974. Immunity to Haemonchus spp. in lambs: The immunizing effects of various methods of larval administration. Res. Vet. Sci. 17:390.

Figure 1. Analysis of open reading frames from *H. contortus* clones. A. Predicted amino acid sequences of ORFs encoded by 5' cloned DNA sequences identified with antibody to 42/53.3.5 antigens. B. Comparison of underlined (Hcga 13 ORF) and amino terminal amino acid sequence (46 kDa).

A

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Hcga1,7- PQKVCDSSKAKTDPIIKKMCESGHAWDVFPTYDIFKVNEYGNVLDQITKNDVYDSEAFI
Hcga8 - KIQLTKAKGYDGGASFSPDGEKIVFHASRLTTKDKIDIYDHLLENDLVA
Hcga9 - RKTEAYFNSDDTYLVFQATGYGVDCEQIYRLELSRPVETLAKISTGIGI
Hcga13- GTGELHFPGETHLKNVRQLTFEHRNTEAYFNSDDTYLVFQLLPSHHQNRVSIGDLN
Hcga15 - FSYDDSKIILQATGYGTTCDQIYELDLNVDPRKQIMKRMST
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B

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T  G  E  L  H  F  P  G  E  T  H  L  K   N- Hcga 13
*  *  *  *  -  *  :  *  *  *  -  :  *   :
T  G  E  L  X  F  P  G  E  T  X  L  K   N- 46 kDa protein
                  E                 N   F
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*, Agreement between predicted and determined amino acids;
:, agreement between predicted and the most likely determined amino acid, based on relative signal (possible residues represented by lower signals are shown below);
-, neither histidine was correctly identified in the actual sequence.

Constraints to the Integration of the CCPP Vaccine into Kenya's Animal Health Delivery System

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Abstract

A viable vaccine against (Contagious Caprine Pleuropneumonia) CCPP has been available in Kenya since 1987. However, the vaccine has not been widely distributed and its impact is unclear. SR-CRSP scientists carried out a socio-economic study from March through November 1992 to identify constraints to the production and delivery of CCPP vaccine in Kenya. Informal and formal interviews were held with over 50 individuals, including farmers, scientists, veterinary service personnel, Ministry (MOLD, MORST) and Kenya Agricultural Research Institute (KARI) representatives, business men and women, and veterinarians. Information was also gathered from the Department of Veterinary Services (DVS) annual reports for 1989-1991, Ministry and consultancy reports, and associated literature. Results suggest an animal health system that: 1) does not have a well-developed infrastructure to track, identify, and control animal diseases; 2) tends to place greater emphasis on cattle, rather than small ruminant health care; and 3) is not well linked in terms of research, development, and extension services.

Introduction

Animal health is key to successful livestock production in developing countries. However, limited resources and lack of adequate veterinary services severely constrain the ability of these countries to improve livestock productivity and returns to producers. As fertile land available for agriculturally based (crop and livestock) activities diminishes, marginalization of landholders increases, and movement into environmentally fragile lands increases, the need to find viable and sustainable animal health production and delivery systems increases as well.

The development and delivery of vaccines are key to controlling and preventing major animal health diseases (e.g., Rinderpest, Foot, and Mouth). In the present paper, a case study from Kenya on production and delivery of a vaccine against CCPP (Contagious Caprine Pleuropneumonia) is provided. The vaccine, while technically a viable preventative measure against CCPP, has not been well integrated into Kenya's animal health care system. The purpose of the case study was to explore the factors that have impeded the diffusion of the vaccine. Results suggest an animal health system that: 1) does not have a well-developed infrastructure to track, identify, and control animal diseases; 2) tends to place greater emphasis on cattle, rather than small ruminant health care; and 3) is not well linked in terms of research, development, and extension services.

CCPP: A brief history

Contagious Caprine Pleuropneumonia (CCPP) is a major disease of goats. Outbreaks of CCPP have been shown to result in 60 to 80% morbidity and mortality in susceptible flocks (Macowan, 1976). At times,

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these figures may reach rates of 100% (Rurangirwa et al., 1984). The disease is recognized as a major cause of goat losses in Africa, the Middle East, the Mediterranean littoral, India, and Pakistan (Rurangirwa et al., 1987b).

CCPP has been reported as the most serious infectious disease of goats in Kenya (Rurangirwa and McGuire, 1991b). Disease-infected goats can be treated with antibiotics (tetracycline). If treated early, recovery is possible, although as Rurangirwa and McGuire (1991a) report, surviving goats have pneumonic lesions that may decrease productivity levels. Once under stress, immunity in the animal may break down, increasing the probability of an additional CCPP infection. As well, treatment is costly, e.g., anywhere from Ksh 10.00 to 40.00 per animal (U.S. $.50 to $2.00), and early diagnosis (and, thus, treatment) is often difficult.

The main causative agent of CCPP in Kenya has been attributed to the F38 mycoplasma strain (MacOwan and Minette, 1976). Efforts to find a less costly and alternative form of treatment (and prevention) led to the development of a vaccine against the disease in the 1980s. KARI (Kenya Agricultural Research Institute) and SR-CRSP (Small Ruminant Collaborative Research Support Program) scientists reported that they could protect against CCPP using sonicated antigens of the F38 strain of mycoplasma incorporated in an oil adjuvant (Rurangirwa et al., 1984). Studies indicated that vaccinated goats were immune to CCPP challenge and that length of immunity was at least six months.

While oil-based adjuvants enhance protection, they are not considered appropriate for use in animals intended for human consumption (Rurangirwa et al., 1987a:399). In response, the vaccine was modified to incorporate saponin as the adjuvant. Tests confirmed immunity from disease challenge and a shelf life of at least nine months. As the vaccine was not thermal stable, storage at 4°C was required.

Further efforts to extend the shelf life led to the development of a vaccine based on the preparation of F38 mycoplasma in a lyophilized form. Under controlled conditions, it was demonstrated that a single minimum dose (0.15 mg) of lyophilized F38 induced full immunity in goats. Additionally, it was shown (Rurangirwa et al., 1987b) that:

- Lyophilization and storage of F38 at 22°C or 4°C did not affect immunogenicity;
- Lyophilized F38 can be produced or stored at either temperature for approximately 14 months without affecting immunogenicity;
- Immunity from the vaccine lasts over 12 months.

Later controlled field trials confirmed these initial findings (Rurangirwa and McGuire, 1991b).

At present, goats in Kenya are immunized with the liquid vaccine. The freeze-dried vaccine has not been integrated into the production and delivery system. However, inputs into the two vaccines are, in principle, similar. Because of the unavailability of funds, extensive field tests have not been carried out to determine the affects of the lyophilized vaccine on goats under natural challenge.

Constraints to production and delivery of CCPP vaccine

A viable vaccine against CCPP has been available in Kenya since 1987. However, the vaccine has not been widely distributed and its impact is unclear. SR-CRSP scientists carried out a socio-economic study from March through November 1992 to identify constraints to the production and delivery of CCPP vaccine in Kenya. Informal and formal interviews were held with over 50 individuals, including farmers, scientists, veterinary service personnel, Ministry (MOLD, MORST) and KARI representatives, business men and women, and veterinarians. Information was also gathered from the Department of Veterinary Services (DVS) annual reports for 1989-1991, Ministry and consultancy reports, and associated literature. Key findings are presented below.

Severity of the problem

Over the course of the study period, Ministry personnel and administrators were generally in agreement that CCPP is not widespread in Kenya and the economic loss to households resulting from animal loss or sickness is not high. These assumptions have tended to guide the level of vaccine production and the general lack of emphasis placed on disease eradication. Yet in fact, preliminary investigation revealed that to date,

little attention has been directed to understanding the epidemiology and control of CCPP in Kenya. Disease prevalence and distribution have not been quantified. As a result, perception, rather than hard data, has guided disease control and prevention measures in terms of CCPP.

In order to gain a more accurate profile on CCPP and its importance in Kenya, Department of Veterinary Service annual reports from all districts and provinces from 1989-1991 were examined. Information gathered included: number of cases of CCPP reported/treated per year, number of animals vaccinated, trends in livestock movement for slaughter and breeding, and disease prevalence (endemic, outbreaks, isolated cases, no incidence).

It was found that over the three-year period, CCPP was reported in all Kenyan provinces with the exception of Western and Nyanza—two provinces with relatively low goat numbers and climate that is not conducive to CCPP transmission. CCPP was recorded as endemic in Northeastern, Eastern, and most of Rift Valley provinces, as well as in Tana River District in Coast Province. In addition to areas endemic with CCPP, outbreaks were reported in parts of Coast Province (Taita Taveta District), Central Province (Kiambu District), and Nairobi.[1]

The number of CCPP cases reported almost doubled from 1989 to 1991—from 14,225 to 27,940 (DVS, 1989-1991). In general, numbers of deaths from an outbreak were not reported in annual reports, suggesting that animal loss from CCPP is much higher than that provided above. However, from personal interviews with field staff and private veterinarians, it was suggested that thousands of animals are lost on average per month from CCPP infection.

From this information, it appears that the disease is more widespread than suggested and that risk to the national goat herd is substantial. Given that over 70% of the 10.5 million (MOLD, 1990) goat population in Kenya is located in areas where CCPP is endemic, the risk of infection is high. It is true that the actual number of goats susceptible to CCPP would not reach the percentage noted above; outbreaks are affected by grazing patterns, production systems, level of animal stress, livestock movement, and other factors. (Bari, 1983). Still, these general figures would suggest that the prevalence of CCPP has been underestimated and that vaccine supply has not kept pace with actual need.

Socio-economic data

Interviews with extension administrators, Ministry personnel, and vaccine producers suggested that farmers are unwilling to pay for the vaccine and that the domestic and export market is not sufficiently large to justify expanded vaccine production. Yet, from interviews with those actually involved in the delivery and use of vaccine (veterinary field officers, farmers, and vaccine exporters), this position is not supported.

If one were to examine domestic demand in terms of actual numbers, comparing only the number of CCPP cases treated with the number of doses of vaccine provided, supply does not even begin to respond to actual demand. For instance, Kitui District would be considered a high risk zone for CCPP outbreaks. If all goats in the District were vaccinated against CCPP, approximately 700,000 animals would be reached rather than the 37,500 vaccinated in 1991. In Baringo District, the Lake Baringo Basin is endemic with CCPP, where one-third of the goat population in the district is located. Yet with a total goat population of about 450,000, it is expected that at most, only 200,000 animals in 1992 will be vaccinated against CCPP. In 1989, when 41,508 vaccine doses were provided to the District, almost 10,000 goats received vaccine treatment. In Turkana District, 55,195 goats (43.7% of the goat population) were vaccinated against CCPP in 1989 compared to 4,131 in 1991. Because of the declining vaccination numbers from 1989-1991, over 38,500 animals were infected with CCPP and received treatment in the District (DVS, 1989; 1990; 1991).

Demand is established not only on the basis of numbers, but on receptivity of the user to the vaccine as well. Given that most campaigns have either been donor- or government-supported, it is still too early to draw definite conclusions from this limited data source. However, interviews conducted with farmers and field staff suggest, in fact, that demand for the vaccine at the farmer level is high. While cost was brought up as a limiting factor, interviewed farmers stated they would be willing to pay for a vaccination against CCPP if it were effective and saved the herd.

At present, KEVEVAPI (Kenya Veterinary Vaccines Production Institute) is the only producer of CCPP vaccine on the African continent. Cost of the vaccine per dose for export is U.S. $0.15. Requests for the vaccine have come in from the Middle East—Oman, Yemen, Saudi Arabia—and Ethiopia. An ODA (Overseas Development and Administration) report (1989) suggests that a good export market for the vaccine does exist. As one informant suggested, there is a market for CCPP overseas and the vaccine could be promoted when and if supply consistently met demand. Because of problems with availability of supply, export numbers for the vaccine are currently very small.

As one informant stated, assessing actual export demand will not be undertaken until production supply can be assured. Yet, since KEVEVAPI is less than three years old, the risks of increasing production without the certainty of a market may well outweigh potential benefits. To expand production on the basis of a "potential market" may not be a viable form of action, particularly given that financial constraints external to KEVEVAPI result in limited cash flow into the parastatal and subsequent curtailment of production.

Economic demand

Comments have been made that the CCPP vaccine is not a high production (or distribution) priority because goats are not perceived as economically important to farmers. In fact, small ruminants provide approximately 30% of the meat and milk output in the country (pers. comm.). Additionally, as a number of respondents argued, small ruminants are, in places, as important, if not more important, than cattle to farmers. In the semi-arid and arid zones, for instance, small ruminants are often a more durable animal than cattle. In times of drought or where water supply is unreliable, small ruminants are key to the survival of the farm household. They are a constant form of security and cash. Based on interviews, it was reported that selling a goat may earn a farmer Ksh 300 to Ksh 500 if the animal is small or sold during drought conditions. This price can rise to Ksh 600 to Ksh 1000 for a larger animal and during a good rainy season. Money received from sales will be used to purchase food, pay for school fees, obtain health care, etc.

The issue of economic importance is clearly an area for further research. However, there is no doubt that the economic costs to farmers from a CCPP outbreak can be devastating. During an outbreak, some farmers have reported losing 50-70% of their goat herds over a two to three year period; others report that infected pregnant females abort and that there is a loss in animal performance. An infected goat that dies from CCPP may represent a full economic loss to the farmer. At such times, a slaughtered animal will often be buried, rather than its meat consumed. In general, meat from a CCPP-infected goat will be of lower quality and volume—fetching a reduced price (if any) than if the animal were healthy. If indeed goats are a form of security in times of drought and a ready form of cash, their loss could have major repercussions on the well-being of the family.

Organization of the production process

In 1990, the labs producing animal health vaccines were transferred to the newly created parastatal, KEVEVAPI. KEVEVAPI's mandate is the production and marketing of animal health vaccines in Kenya for domestic distribution and export. Additional functions of the Institute, as defined by Government order (1990), include:

- [carrying out] research, either alone or in collaboration with other research institutions into new innovations of veterinary vaccines production;
- providing information in the field on the suitability and effectiveness of veterinary vaccines.

While KEVEVAPI is expected to generate its own profits and operate on a commercial basis as a parastatal, it is provided the facilities for vaccine production and management is government-appointed. Thus, it does not operate as an independent body.

The parastatal is still a relatively new venture. Production and marketing strategies, as well as a functioning research and development unit, are still in their early stages of development. The result is that profitable enterprises within the Institute are yet to be fully defined and promoted. In terms of the CCPP vaccine, production costs have not been systematically determined, and actual need, in terms of supply, has

not been established. Without a better understanding of demand and cost, it is difficult to produce the vaccine in quantities that meet the needs of the country or the export market.

Officially, vaccine is currently sold by KEVEVAPI for Ksh 1.50/dose. The official charge of the vaccine to the farmer is also Ksh 1.50/dose. However, the vaccine has been provided free of charge (e.g., as in Kitui where DANIDA is supporting a district-wide vaccination campaign against Contagious Bovine Pleuropneumonia, rinderpest, and CCPP or in Baringo where the government pays). Private veterinarians, who may purchase the vaccine directly from KEVEVAPI, buy at cost (Ksh 1.50) and sell to traders or farmers for a slight profit (e.g., Ksh 2.00 to Ksh 7.00 per dose).

Table 1. Total CCPP Vaccinations By Province, 1989-1991[a]

Province	1989	1990	1991
Central	700	—	2,489
Eastern	8,000	20,458	63,430
Northeastern	—	—	—
Nyanza	—	—	—
Western	—	—	—
Coast	10,786	3,596	199
Rift Valley	218,760	150,969	159,004
Total	238,246	173,023	225,122

[a]Vaccine totals are based on annual veterinary reports. Information was not available from KEVEVAPI. Figures provided should be viewed with caution. Annual reporting between districts/provinces or across years is not regularized; vaccination numbers do not consistently correspond between district and provincial reports or from one year to the next. Numbers are as well not always provided, or, if present, may cover only a few divisions of a district and omit mention of the full district.

Table 1 provides a breakdown of CCPP vaccinations from 1989-1991 by province. Information was obtained from provincial and district Veterinary Service annual reports for the three years. Private purchases are not included. As can be seen from the table, CCPP vaccine was provided to all provinces during the reporting period with the exception of Nyanza, Western, and Northeastern.[2] In 1989, before KEVEVAPI came into existence, 238,246 doses were administered, compared to 173,023 and 225,122 in 1990 and 1991, respectively. Eastern and Rift Valley provinces, with the exception of 1989, have been the major beneficiaries of the vaccine.

Having said this, it is nevertheless the case that supply does not meet demand. When asked, "what is the major constraint to the delivery of CCPP vaccine," the primary response given was lack of supply. Only 60,000 doses of the CCPP vaccine can be produced by KEVEVAPI at any one time and the production process is lengthy (one month). Inoperative or inadequate equipment has limited production potential. It has been suggested that if the vaccine currently in use were replaced by the lyophilized form instead, larger quantities could be produced (more cheaply) and kept on the shelf for longer time periods (ODA, 1989).

Lack of operating funds

Lack of operating funds impacts on both production levels and delivery. In terms of production, although KEVEVAPI is expected to generate profits that will be fed back into the parastatal for facility development and vaccine improvement, its primary purchaser of vaccines is the Government. Financial constraints of the GOK (Governmental Kenya) limit KEVEVAPI's ability to access capital for its own use. Without available or sufficient operating capital, production numbers are reduced, and it becomes difficult to purchase inputs needed to prepare vaccines.

Additionally, there are not sufficient funds available for facility/equipment maintenance. Thus, breakdowns in vaccine production are likely to occur. The lack of functioning equipment has, in the past, held up delivery of vaccine because quality assurance standards were not met (pers. comm.). With limited resources, maximum production cannot be sustained. Water shortages, electricity cuts, etc. can cause a full stoppage in vaccine production.

Lack of funds also constrains delivery of vaccine. The operating budget of the Department of Veterinary Services—the primary conduit in the vaccine delivery system—is insufficient to meet the demands placed on DVS personnel. Salaries alone have been reported to comprise at least 60% of the Department's budget (pers. comm.; GOK, 1990).[3] Veterinary offices at the district and divisional levels often lack sufficient transport, fuel, refrigeration facilities, personnel, telephones, office space, etc. Given the extensive services DVS provides and the limited funds that are available, it becomes difficult to carry out effective disease control activities. In addition, outbreaks of major cattle diseases (e.g., Foot and Mouth) will take priority over scheduled CCPP control or prevention campaigns. Thus, resources targeted for disease prevention—such as a CCPP vaccination campaign—may be diverted to control major disease outbreaks instead (pers. comm.).

Additionally, DVS is often unable to effectively carry out complementary preventative activities that would help curb disease incidence. Diagnostic services, disease surveillance, and control of livestock movement require a level of funding that is simply not available within the operating budget of the Department. In terms of CCPP, the result is that cases are more often suspected rather than confirmed through laboratory analysis; data regarding mortality, morbidity, and frequency of the disease are often suspect; livestock movement, considered a major cause for the widespread nature of the disease, is not well controlled; and campaigns begin after disease outbreak. Given that CCPP is highly contagious, the disease spreads quickly and can result in major animal losses in a short time frame. The lack of these services can be devastating to farmers and goat herds.

Disease surveillance and control

As indicated above, the lack of funds impacts directly on the ability of DVS to carry out effective disease surveillance and control programs (IFAD, 1991). Without an effective tracking system, disease outbreaks are more likely to occur. A number of respondents suggested that CCPP is widespread in Kenya primarily because of livestock movement—CCPP-infected goats are either moved (illegally and otherwise) from district to district or from neighboring countries into Kenya. Cases of suspected CCPP are often not verified through laboratory analysis. Given the shortage of funds, lack of transport, inaccessibility to CCPP-infected areas because of weather or roads, etc., animal movement is difficult to restrict and control even harder to attain. Without adequate surveillance, information on animal deaths, outbreaks, patterns of outbreaks, effectiveness of vaccination, etc. are not well recorded.

It has been suggested (IFAD, 1991) that the problem is in part related to the expanded mandate that presently guides DVS activities. Charged with disease control and prevention, provision of clinical services and the sale of drugs, the Department simply does not have the resources to provide all services to all constituents. Efforts to privatize aspects of veterinary services (e.g., provision of clinical services, sale of drugs) may, in the longer term, help the DVS focus more attention on those aspects of its mandate that originally were identified as priority areas—specifically, disease prevention, control, and surveillance.

Lack of communication and information

With CCPP, there are no solid linkages in place to integrate research output, production, and delivery. For example, while there is a vaccine on the shelf that shows potential as a more viable product than that which is presently being marketed, little attempt has been made to field-test the vaccine or integrate it into the production process. Information at the farmer-level regarding the efficacy of the vaccine presently in use is not fed back into the research or production cycle for examination. Different sources stated that the length of immunity provided by the liquid form of the CCPP vaccine is either six, nine, or 12 months. One veterinary officer in the field claimed an immunity of only four months. Some have reported

that the vaccine did not provide any immunity against CCPP. Others have stated that pregnant animals aborted soon after being administered the vaccine. To date, these claims have neither been confirmed nor denied.

Further information about the disease itself would help researchers, production managers, and decision makers create policies and plans that lead to more effective disease control. Such work would, in the longer term, move activities away from disease control and more towards prevention. To attain this goal, additional data is needed to answer such questions as:

1. How does animal management help control or constrain the spread of the disease?
2. Does breed or age of animal have an effect on disease incidence or risk?
3. How large a factor is livestock movement in terms of disease transmission? Preliminary data on this last point suggests some correlation. However, further investigation is needed.
4. What are the actual number of CCPP cases and deaths on a yearly basis?
5. What are the economic costs to farmers from disease outbreaks?
6. Is the vaccine effective, or is the lack of CCPP outbreak in vaccinated areas a result of other factors (e.g. absence of CCPP-infected goats in the area)?

This undertaking would require collaboration among all parties involved in the process of vaccine development and adoption: biological and social scientists, KEVEVAPI, the Department of Veterinary Services, and farmers.

Conclusion: Recommendations for future action

If CCPP is to be effectively controlled, additional resources, time, and personnel will need to be committed by those sectors involved in disease prevention/control and delivery of animal health services. Yet, the issue is more than simply finding additional resources to carry out research. Issues that should be considered as efforts are made to combat major livestock diseases are presented below.

Linkages between technology generation, adoption and diffusion

No matter how sound a technology may appear to be in the laboratory, its usefulness is determined only when applied and, eventually, adopted. If the process of technology generation, adoption, and diffusion is not coordinated, with no linkages in place to connect research with adoption and diffusion, there is only the *potential* for application and positive impact. The CCPP vaccine is a good example of a technology that has, in a sense, become stuck in a process that is not well linked to its component parts.

Presently, efforts are underway to create stronger linkages between KARI and KEVEVAPI in terms of research and development. Once in place, this mechanism will help ensure that solutions to mutually important problems can be found. As one respondent suggested, with shared resources (e.g., personnel, equipment, etc.) a network can be built that promotes real application to farmers. Such a network could also help ensure that the best product will be developed that meets not perceived, but actual needs. For the CCPP vaccine, greater collaboration between the research (KARI) and production units (KEVEVAPI) would encourage efforts aimed at: better understanding of the disease and its importance to small ruminant production systems; screening and testing the viability of both vaccines in the field to promote the most efficient and effective product; developing an integrated approach to animal health that combines disease control and prevention.

Veterinary epidemiological studies

The data provided in this paper on disease mortality, morbidity, treatment, and frequency is based on a secondary data set—specifically, annual reports from district and provincial annual reports. While a starting point, the information was often inadequate in terms of detail. Actual numbers were often lacking or inconsistencies within reports made some of the information suspect. In order to gain a more accurate profile of CCPP, it is suggested that further epidemiological studies be carried out. Once this information is made available, better and more appropriate preventative and control measures against CCPP can be developed.

Small ruminant research

About 80% of Kenya's land mass is located in the arid/semi-arid lands (ASAL). The area supports 20% of the country's people and one half of its livestock (GOK, 1990). In addition to improving the breeding of small ruminants and developing stock routes and water supplies, controlling livestock disease is seen by the GOK as central to ASAL development (GOK, 1990). Disease control and prevention was recognized as a priority in the *National Livestock Policy* of 1980 (MOLD, 1980) and research aimed at improving animal health has been initiated. However, most attention has been directed towards the cattle industry. Small ruminant research has been guided by the perception that these animals are only of secondary importance (in relation to cattle) to the country's economy. While reports dating back to the early 1980s urge more rigorous integration of small ruminants into production and research activities, this has yet to be accomplished.

With few exceptions (e.g., the work of the UNDP, SR-CRSP, ILCA), small ruminants have remained a relatively underexamined resource (e.g., Nygaard and Amir, 1988). Evidence, for instance, on the dominant health problems of sheep and goats in Kenya is minimal. Few epidemiology studies have been carried out on a national level to examine disease prevalence or movement. The social and economic importance of small ruminants on a regional scale has not been well explored Nor is there sufficient information on the production and management patterns that characterize holdings with small ruminants.

A World Bank report (1983) suggested that the current and potential role of small ruminants in developing countries is not well recognized. As a result, money and resources placed on small ruminant research by donors, international agricultural research centers, and NARS have been limited. Yet, as intensification of production increases, human population figures continue to rise and land for raising cattle under extensive systems declines, the need to devote more resources to small ruminants will only increase. If the importance of small ruminants to the national meat and milk supply increases, it is vital that a more integrated and interdisciplinary effort be instituted that not only describes constraints to improved production (e.g., animal health, nutrition, management, etc.) but provides an agenda for action as well.

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Literature Cited

Bari, J. K. 1983. Use of Enzyme-Linked Immunosorbent Assay (ELISA) in Serodiagnosis of CCPP: Preliminary Results. In: Proceedings of the 2nd SR-CRSP Kenya Workshop, Nairobi, Kenya. SR-CRSP, Nairobi, Kenya.

GOK (Government of Kenya). 1990. Sessional Paper No. 1 on Economic Management for Renewed Growth. Nairobi, Kenya.

IFAD. 1991. Animal Health Services Project: Mid-Term Evaluation Mission August-September 1991.

MacOwan K. J. 1976. Ph.D. Thesis. Centre for Tropical Veterinary Medicine, University of Edinburgh.

MOLD (Ministry of Livestock Development). 1990. Annual Report—Animal Production Division. MOLD, Nairobi, Kenya.

MOLD (Ministry of Livestock Development). 1980. National Livestock Development Policy. MOLD, Nairobi, Kenya.

Nygaard, D. F. and P. Amir. 1988. Research Strategies for Development: Improving Sheep and Goat Production in Developing Countries. In: Thomson E. F. and F. S. Thomson (eds.), Increasing Small Ruminant Productivity in Semi-Arid Areas. ICARDA, Syria.

ODA (Overseas Development Administration). 1989. Review of the Production and Usage of Veterinary Vaccines in Kenya (July 1989).

Rurangirwa F. R. and T. C. McGuire. 1991a. Maintaining a Healthy Flock. In: Semenye P. P. and T. Hutchcroft (eds.), On-Farm Research and Technology for Dual Purpose Goats.

Rurangirwa F. R. and T. C. McGuire. 1991b. Preliminary Field Test of Lyophilized Contagious Caprine Pleuropneumonia Vaccine. Res. in Vet. Sci. 50:240-241.

Rurangirwa F. R., T. C. McGuire, A. Kibor and S. Chema. 1987a. AnInactivated Vaccine for Contagious Caprine Pleuropneumonia. Vet. Record. 121:397-402.

Rurangirwa F. R., T. C. McGuire and S. Chema. 1987b. Vaccination Against Contagious Caprine Pleuropneumonia Caused by F38. Israel J. of Med. Sci. 23:641-643.

Rurangirwa F. R., W. N. Masiga and E. K. Muthomia. 1984. Immunisation of Goats Against Contagious Caprine Pleuropneumonia using Sonicated Antigens of F-38 Strain of Mycoplasma. Res. in Vet. Sci. 36:174-176.

World Bank. 1983. Sheep and Goats in Developing Countries. World Bank, Washington DC.

Notes

[1] Information on Nairobi was omitted from the data set. Reports of CCPP outbreaks in the capitol are based on personal communications.

[2] Although estimates provided by KEVEVAPI suggested Ksh 1.00 to 1.50/dose.

[3] District reports from Northeastern suggest that CCPP campaigns should be carried out since CCPP is endemic to all three districts in the Province.

[4] The GOK (1990) reported that within the Ministry, the proportion of the budget allocated to salaries is anywhere from 60-80%.

Socioeconomic Elements For Effective Herd Health Programs In Developing Countries

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Introduction

More often than not, technological interventions tend to dwell on technical possibilities, with little consideration for the socioeconomic environment pertaining to the receiving clients. Although not always stated, this approach assumes universality of needs and aspirations on the part of the receiving clients. On close scrutiny, this assumption may not be entirely without foundation. In the last several centuries, market forces have been penetrating even the remotest corners of the globe (Wallerstein, 1980). In many ways, these forces have been universalizing realities, to the extent that we can now talk of a global market. Closely intertwined with the advances of the market forces has been technological break-through in various fields of human endeavor. In this sense, science and technology could be said to be the hallmark of modern societies. Of particular importance—perhaps in the same magnitude as the market forces—has been the impact of technological break-through in the field of communications. The latter has literally reduced the world into a 'small village.' Indeed, we are now witnessing the consolidation of a global culture. On the political front, following the collapse of the Eastern Bloc, we see the emergence of a new world order—in so many ways manifesting shared political values. With such universalizing forces in the world today, it may not be difficult to understand the inclination to assume homogeneity in the global population.

However, given differential productive capacities among countries and even regions within countries, the mode of integration (articulation) into the market has not been uniform (Kitching, 1977; Taylor, 1979). Thus, whereas this articulation process may have been universalizing not only economic relations but also the political and cultural realities of the respective societies, different patterns of integration have tended to generate peculiarities in each of these societies (Cardoso and Faletto, 1979). It may not be surprising, therefore, to find in a single country production systems that are highly automated, operating at optimal efficiencies, and making admirable profits, co-existing with the very basic subsistence production systems. Needless to say, intervention packages for such varying production systems would have to be different if they were to have any meaning to the varying clients.

How then are we to identify these varying farmer categories in order to develop meaningful intervention strategies and packages for them?

To develop a conceptual framework to guide us into identifying varying farmer circumstances, we need to make some assumptions about the nature of agricultural production in modern times. The first assumption will be that one of the most dynamic forces in the transformation process of present day agriculture is the market. The second assumption will be that when market forces penetrate agricultural production, they tend to commoditize not only the agricultural produce (purpose of production), but also the factors of production (land, labor, and capital). The third assumption will be that the extent to which these factors of produc-

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tion are commoditized will reflect the degree to which the farmer is integrated to the market. Table 1 illustrates the different conceptual farmer categories in very broad terms.

-Subsistence farmers: land-owning small-holder, relying on family labor, minimal off-farm inputs, using hand tools, and producing mainly for subsistence.

-Family farm enterprise: land-owning small-holder, relying partly on hired and partly family labor, using mainly purchased inputs but also some farm generated inputs, partly using machinery and partly hand tools, and producing mainly for the market. Note that this farmer category embodies a dual character—both commercial and subsistence.

-Commercial farmer: land-owning and or leasing large tracts of land, using hired labor and a lot of purchased inputs, relying extensively on machinery, and producing exclusively for the market.

Table 1. Conceptual Categories of the Farming Community.

Attributes	Type of Farmer			
	Commercial	Family Farm Enterprise		Subsistence
		Commercial	Subsistence	
Land Owned-Size	Large	Small	Small	Small-Agrarian Large Pastoralists
Type of Labor	Hired	Mainly hired	Partly hired	Mainly family
Capital-Inputs	Purchased	Mainly purchased	Party purchased	Mainly generated on farm
Capital-Equipment	Capital intensive machinery	Partly machinery partly hand-tools	Partly hand-tools partly machinery	Mainly hand-tools
Purpose of Production	Market	Market	Subsistence	Subsistence

Case study to illustrate potential biases in the process of technology development: dairy research in Kenya

Aware of the varying needs and aspirations of the respective farmer categories, a study was conducted recently to identify the potential users of the research activities geared towards increasing milk production in Kenya since 1945 (Mbabu et al., 1993). As the following presentation illustrates, most of the research activities were targeted to the market oriented farmers. This was notwithstanding the fact that at certain points in time government policies specifically demanded that attention be paid to the subsistence farmers. In any case, an overwhelming majority of livestock keepers, and hence milk producers, are indeed subsistence milk producers. Of the 12 million cattle in Kenya, only 25% are grade or upgraded for milk production (KARI, 1991). The rest are indigenous breeds with limited milk production capacity, but hardy enough to thrive under difficult management conditions.

The first ten-year development plan for Kenya, launched in 1946, specifically addressed the plight of subsistence agriculture in the African areas (KNA, 1951-54; Cone and Lipscomb, 1972). The same concern was re-emphasized by the East African Royal Commission Report (1953) which highlighted the prevailing poverty in the African reserves (Ochieng', 1977). This commission recommended that an agrarian revolution be launched within the African areas to alleviate the deteriorating conditions related to over-population, over-stocking and over-grazing. However, as Table 2 shows, examined records from the dairy research program between 1946 and 1960 indicate that research was predominantly inclined to serve large-scale dairy farmers (48.7%). Family farm enterprises attracted some interest in research activities (22.4%), but subsistence milk producers remained in the backyard of the research program (10.5%). This pattern of research interest is understandable given the dominance of the settler economy in Kenya's agricultural sector

at that time, but it definitely does not show responsiveness to the policy expectation. Implementation of the Swynnerton Plan, beginning 1954, may explain the substantial interest in the family farm enterprises during that time. However, if the Swynnerton plan was meant to implement the recommendations of the East African Royal Commission, then it did a partial job because its concern revolved around the family farm enterprises (so called progressive farmers). The plan did not reach out for the marginalized areas and people—the cradle of subsistence production.

At independence, populist politics were predominant in Kenya. This spirit was well manifested in the Sessional Paper No. 10 titled "African Socialism, and its Application to Planning in Kenya" (Kenya, 1965). However, by the end of that decade, populist politics were overtaken by the more commercial-oriented policies. This new thinking was reflected in subsequent development plans (1970-73; 1974-78). Resources were dedicated to strengthen commercially oriented small-holder production systems. In our classification, this category of farmers is referred to as family farm enterprises. As Table 3 shows, examined records of the dairy research program in the period between 1961 and 1978 reflected the prevailing policy environment. The program maintained a balance between large-scale commercial dairy farmers (37.3%) and family farm enterprises (35.2%). The records also show that, then as in the previous era, interest in subsistence milk production remained very low (13% of the entries).

The period between 1979 to 1992 marked a turning point in the policy environment in Kenya. Government priorities shifted from over-emphasis on commercial enterprises to a more welfare-oriented preference, seeking to alleviate the plight of marginalized regions and people. This new thinking was first manifested in the 1979-83 Development Plan and re-emphasized in all subsequent development plans (Kenya Republic, 1979, 1983, 1989). This shift in policy expectation posed a serious challenge to the scientists to innovate technological packages appropriate for the hitherto marginalized population. This called for a re-assessment of the basic assumptions underlying technology development process. However, as Table 4 shows, in the period between 1979 and 1992, examined records indicate that the dairy research program was further consolidated to address production problems pertaining to family farm enterprises (48.2%). Interest in large-scale commercial dairy production decreased, but it was still maintained at a reasonable level (25.9%). As in all other periods, and contrary to policy expectations, subsistence milk production remained least attractive to the program (17%). The question to pose is why research program activities were unable or unwilling to alter their domain assumptions in the technology development process in order to develop the desired intervention packages for an identified target group? Or is it technically impossible to develop potentially attractive technological packages for low resource farmers?

The moral behind this case study is that, consciously or otherwise, the decisions we make with respect to technology development incorporate important assumptions which consequently determine—not only the kind of product, but also the potential users of that product. It is imperative, therefore, that we strive to always be conscious of those values that influence our work and to anticipate their potential impact on our clientele.

Table 2. Targeting of dairy programs by ERA by research stations, 1946-1960: Class replacing racial differentiation.

	All Categories	Commercial Farmers	Family Farm Enterprises	Subsistence Farmers	Scientists	TOTAL	
Embu	--	35.7%	35.7%	28.6%	--	N=14	100%
Kakamega	--	50%	50%	--	--	N=4	100%
Katumani	--	33.3%	33.3%	33.3%	--	N=3	100%
Kisii	22.2%	33.3%	22.2%	22.2%	--	N=9	100%
Kitale	7.5%	57.5%	12.5%	--	22.5%	N=40	100%
Mtwapa	--	50%	33.3%	16.7%	--	N=6	100%
Total	6.6%	48.7%	22.4%	10.5%	11.8%	N=76	100%

Table 3. Targeting of dairy programs by era by research stations, 1961-1978: Entrenchment of class differentiation.

	All Categories	Commercial Farmers	Family Farm Enterprises	Subsistence Farmers	Scientists	Other	TOTAL	
Embu	--	33.3%	41.7%	25%	--	--	N=12	100%
Kakamega	--	38.5%	53.8%	7.7%	--	--	N=13	100%
Katumani	8.3%	33.3%	33.3%	25%	--	--	N=12	100%
Kisii	22.2%	22.2%	44.4%	--	--	11.1%	N=9	100%
Kitale	11.6%	32.6%	32.6%	2.3%	14%	7%	N=43	100%
Mtwapa	--	42.9%	42.9%	--	14.3%	--	N=7	100%
Muguga	--	--	100%	--	--	--	N=1	100%
Naivasha	--	38.7%	35.2%	18.2%	6.8%	1.1%	N=88	100%
Total	4.3%	35.7%	37.3%	13%	7%	2.7%	N=185	100%

Table 4. Targeting of dairy programs by era by research stations, 1979-1992: Welfare Orientation.

	All Categories	Commercial Farmers	Family Farm Enterprises	Subsistence Farmers	Scientists	TOTAL	
Embu	--	27.3%	54.4%	18.2%	--	N=11	100%
Kakamega	12.5%	29.2%	45.8%	8.3%	4.2%	N=24	100%
Katumani	--	11.1%	44.4%	44.4%	--	N=9	100%
Kisii	16.7%	--	66.7%	16.7%	--	N=6	100%
Kitale	3.4%	34.5%	48.3%	10.3%	3.4%	N=29	100%
Mtwapa	8.3%	25%	58.3%	--	8.3%	N=12	100%
Muguga	--	22.2%	38.9%	38.9%	--	N=18	100%
Naivashi	--	33.3%	33.3%	--	33.3%	N=3	100%
Total	5.4%	25.9%	48.2%	17%	3.6%	N=112	100%

Case study to illustrate potential biases in the process of technology distribution - contagious caprine pleuropneumonia (CCPP) vaccine

Elsewhere in these proceedings, Lipner and Brown report on the integration of CCPP vaccine into Kenya's animal health delivery system. While the vaccine has been available since 1987, its integration into the disease prevention and control system has been limited. Lipner and Brown's observation provides a useful case study on the potential biases in the process of technology distribution. We will summarize their key findings here and offer a few summary conclusions.

- CCPP was found to be prevalent in all Kenya provinces except Western and Nyanza. Further, the disease was found to be endemic in North Eastern, Eastern, and most of the Rift Valley provinces. Tana River District in Coast Province was also found to have endemic CCPP. Seventy percent of the 10.5 million goat population in Kenya are to be found in the CCPP endemic areas. Out-break areas included: Coast Province (Taita Taveta), Central Province (Kiambu); and Nairobi (Lipner and Brown, 1993, and Lipner, 1992). All things being equal, one would expect vaccine distribution patterns to reflect this reality on the ground.

- Of particular significance is the fact that records show no vaccinations in North Eastern Province (Lipner and Brown, 1993). This is particularly interesting given the very large number of goats in the province, and the fact that the area is endemic to CCPP. Another important observation from the Lipner/Brown and Lipner paper is the discrepancy between the number of reported and vaccinated cases. In many instances, there were vaccinations in areas where there were no records of reported cases. In endemic areas, this may be quite acceptable since vaccinations may be necessary on a regular basis to control the spread of the disease. However, this does not explain why such necessary vaccinations should be concentrated in the Rift Valley Province and not in North Eastern Province given that both provinces are endemic to the disease (CCPP). In contrast, there are instances where reported cases are not accompanied by vaccination records. This was particularly the case in Eastern Province. Note that this province is also endemic to CCPP, in which case, as in the Rift Valley Province, vaccinations could have been given on a routine basis to contain the spread of the disease.
- Note also the disproportionate allocation of the CCPP vaccine by province (Lipner and Brown, 1993). Out of the 238,246 vaccinations in 1989, 92% were given in the Rift Valley. The following year, out of the 173,023 vaccinations, 87% were given in Rift Valley Province. In 1991, out of the 225,122 vaccinations, 71% were given in the same province (Rift Valley Province). In the same year, one particular district in the Rift Valley Province received over 60% of the total vaccinations given that year. This is notwithstanding the fact that there were no records of reported cases in that district that year.

What then drives CCPP vaccination campaigns? The fact that certain endemic areas do not appear to have received any of the distributed vaccine; the fact that vaccination campaigns may have been conducted without any out-break reports while reported out-breaks remained waiting; the fact that certain areas received a lion's share of the available vaccine while other deserving cases got nothing or little; all are pointers of a value-laden process. In the case of CCPP vaccine where the distribution process is so heavily dependent on government support, the bias should be sought in the ranks of the state machinery. In such circumstances, it would appear, alternative delivery models would have to be developed to reach the less favored regions and populations. Among such alternative delivery systems would include private sector or community based organizations.

Conclusion

Although not always acknowledged by both technology producers and/or distributors, the process of technology development and distribution is highly value-laden. For example, the decision to put resources into development of drugs and or vaccines that reach farmers through the market assumes several things about farmers. The most obvious assumption would be that farmers are willing and able to purchase the drug/vaccine. The obvious implication of this assumption is that those farmers either not willing or able to purchase those items would be left out of the technology intervention option. On the other hand, an intervention that assumes there are farmers who would have no access to such purchased interventions would put more resources into developing management options which take into account available resources and management capacities of the farmer. Both options take value positions. Despite the very far-reaching implications of the values embedded in the whole process of technology development and distribution, not much thought is given to them, and hence their effect tends to pass unnoticed.

All this has potential implication for projects such as the SR-CRSP as well as for institutions like KARI which are charged with developing technologies suitable for a broad cross-section of Kenya's farmers. Given that the process of technology development, and the choices inherent in that (e.g., dairy cattle research) involves a number of choices, then it becomes critical for externally funded programs to take that into account. Substituting dairy goats for dairy cattle involves much more than a small ruminant for a large one. It also potentially involves choice regarding subsistence versus commercial production, "family" versus small farmers, and other social and political considerations. KARI's history with dairy cattle research programs, and the SR-CRSP's and KARI's more recent CCPP vaccine development effort, speaks volumes regarding the important role which social and political factors play in the development and utilization of

agricultural technologies. An introspective examination of the institutional context within which such developments take place will help biological and social science researchers alike anticipate whether their efforts will be truly sustainable.

Literature Cited

Bienen, H. 1974. Kenya Politics of Participation and Control. Princeton University Press, Princeton, New Jersey.

Cardoso, F.H. and Faletto, E. 1979. Dependency and Development in Latin America. University of California Press, Berkeley.

Cone, L.W. and Lipscomb, J.F. 1972. The History of Kenya Agriculture. University Press of Africa.

Kenya National Archives. 1951-1954. "Agriculture Department: Plan to Intensify the Development of African Agriculture." AGR./KSM./1/525, 1951-1954.

Kenya National Archives. 1953-1957. "Accelerated Development of Agriculture in Kenya." DC/KMGA/1/2/11.

Kenya, Republic. 1965. African Socialism and its Application to Planning in Kenya. Government Printers, Nairobi.

Kenya, Republic. 1970-73; 1974-78; 1979-83; 1984-88; 1989-93. Development Plans: Government Printer.

Kitching, G. 1977. "Modes of Production and Kenyan Dependency." Review of African Political Economy (ROAPE), #8: 56-74.

Lipner, M.E. 1993. "Constraints to the Integration of the CCPP Vaccine into Kenya's Animal Health Delivery System." Paper presented at the SR-CRSP Workshop, ILRAD, March.

Lipner, M.E. and Brown, R. 1993. "Constraints to the Integration of the CCPP Vaccine into Kenya's Animal Health Delivery System." Paper presented at the SR-CRSP Workshop in Puerto Rico. September.

Mbabu, A.N. 1988. The Transformation of Kenya's Agrarian Sector: the case of western Kenya, unpublished Ph.D. dissertation, University of Missouri-Columbia, 1988.

Mbabu, A.N., L. O. Otieno, L. Munyi, D. E. Ethuro. 1993. "Targeting Farmer Categories: The Case of Dairy Research Programmes in Kenya." Paper presented at the Workshop on Research-Extension-Farmer Linkage in Livestock Research and Development, 15th and 16th February, Nairobi.

Ochieng', W.R. 1977. The Second Word: More Essays on Kenyan History. East African Literature Bureau Kampala, Nairobi, Dar-es-Salaam.

Scheijtman, A. 1984. "The Peasant Economy: Internal Logic, Articulation and Persistence." The Political Economy of Development and Underdevelopment. C.K. Wilber, ed. pp. 274-298, Random House, New York.

Sinclair, P.R. 1980. "Agricultural Policy and the Decline of Commercial Family Farm: A Comparative Analysis of the U.S., Sweden, and the Netherlands." The Sociology of Advanced Societies: Critical Perspectives. F.H. Buttel and H. Newby, eds. pp. 327-349, Allenheld, Osmun, Montclair, Croom, Helm, London.

Taylor, J.G. 1979. From Modernization to Modes of Production: A Critique of the Sociologies of Development and Underdevelopment. Humanities Press, Atlantic Highlands, N.J.

Thorner, D., Kerblay, B., and Smith R.E.F, eds. 1966. A.V. Chayanov on the Theory of Peasant Economy. Richard D. Irwin, Homewood, IL.

Wallerstein, I.M. 1980. The Modern World-System Mercantilism and the Consolidation of the European World-Economy, 1600-1750. Academic Press Inc. New York London Toronto Sydney.

Wolff, R.D. 1974. Britain and Kenya, 1870-1930: The Economics of Colonialism. Transafrica Publishers Ltd. Nairobi.

Chapter 5. The Kenya Dual Purpose Goat Production System

Quantitative and Molecular Approaches to Genetic Improvement of the Kenya Dual Purpose Goat

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Abstract

Conventional animal breeding approaches have not been used to select for disease resistance in domestic livestock for three reasons. Industries have felt secure because chemotherapeutic methods appeared to provide satisfactory control; measuring eggs per gram of feces and packed cell volumes on sufficient numbers of animals to effect a selection program is not practical or cost effective; and reservations have been expressed about these traits as measures of resistance to internal parasites. However, it is now evident that eggs per gram of feces is repeatable, heritable, and correlated with actual worm burden, and the high cost of anthelmintics and increasing frequency of drug resistance provide strong impetus to develop alternative strategies for helminth control. Our approach is to identify caprine microsatellite markers for chromosomal regions associated with resistance to *Haemonchus contortus* in the Kenya Dual Purpose goat. Eight unlinked and two linked markers are broadly conserved across 12 bovid species and have application to germplasm evaluation and conservation studies in wildlife and endangered species. Eight loci conserved in cattle can be added to the bovine and caprine genetic maps and will help align these maps. Marker characteristics and their application to mapping genes associated with *Haemonchus contortus* resistance in the caprine is described.

Introduction

The basis for genetic improvement

In the simplest case, genetic improvement is effected by measuring individual animals and choosing, or "selecting," those animals that the breeder wants to be the parents of the next generation. The superiority in performance of the progeny over the entire parent generation (i.e., the difference between generation means) is called the "selection response." This form of selection is called "mass selection," and a rather simple model used by animal breeders predicts that the selection response per unit time will depend on heritability of the trait, phenotypic variation, selection intensity, and generation interval. The heritability of the trait can be interpreted as the proportion of differences among individuals that are due to genes with effects that are inherited additively. All too often, animal scientists look only at the heritability to determine whether a trait will respond to selection. However, it is the product of heritability and the phenotypic standard deviation that is important, i.e., the proportion of phenotypic differences that is due to additive gene effects. If individuals are very similar, the phenotypic standard deviation will be very small, and, even if the trait has a very high heritability, there will not be much in the way of selection response. On the other hand, a trait

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with a relatively low heritability could allow for a significant selection response if the trait was very variable.

Selection intensity is determined by the superiority of the selected parents relative to the population from which they were selected. If the best 5% of parents are selected, the selection intensity is greater than if the best 20% of parents are selected, and one would expect the progeny from the best 5% of parents to outperform the progeny of the best 20%. Finally, the generation interval is the amount of time that it takes to replace one generation with the next, which can be measured as the average age of animals at replacement. The more rapidly we replace a population, the greater we would expect the genetic progress to be. However, the average age of the population would decrease, and this may result in productivity losses that are associated with animal maturity (Blackburn and Taylor, 1990).

In practice, mass selection works very effectively for traits that are at least moderately heritable and that can be measured accurately and cost effectively in live animals. However, traits such as milk production, meat tenderness, and disease resistance either cannot be measured in both sexes in live animals or are extremely difficult and expensive to measure in a sufficiently large number of animals to enable selection to be effective. The alternatives to mass selection include progeny testing, which is the approach that is usually taken to identify elite dairy sires and beef bulls, or selecting on a correlated trait that is more easily measured than the trait that we actually want to improve. This strategy relies upon the existence of pleiotropy or linkage. Pleiotropy is when a gene product is involved in the expression of more than one trait, while linkage occurs when two, or more, genes lie sufficiently close together on a chromosome that the copies on one chromosome tend to be inherited together because recombination among the linked genes is rare. In either case, it may be possible to identify a trait that is easy and inexpensive to measure and that will respond to selection and act as a marker for the trait that the breeder actually wants to improve. This is called marker assisted selection.

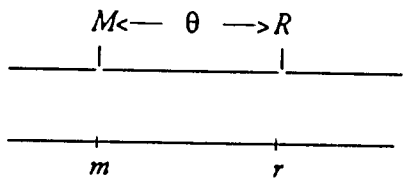
The molecular genetic approach

The concept of marker assisted selection is not a new. However, the recent resurgence of interest in the application of markers to selection problems comes from the rapid recent advances in technology for developing highly informative marker systems that are reliably and easily scored in a large number of individuals. Successful searches for quantitative trait loci (QTL) with major effects using DNA based markers have been reported in plants (Edwards et al., 1987), cattle (Rocha et al., 1992), and in humans (Morell, 1993).

Theoretically, the process of identifying and selecting for a gene of large effect would proceed as follows. First, we need to develop a series of families that are segregating for the gene of interest. Then we need to score genotypes of family members for a suite of markers that are evenly spaced throughout the genome to allow detection of the presence of the genes of interest between flanking markers. To accomplish this requires the existence of a genetic map comprising variable markers and the map distance between these markers which is determined from the rate at which the markers recombine at meiosis. It has been estimated that approximately 150 evenly spaced markers are necessary to saturate a map to 20 cM, and efforts are currently under way to develop genetic maps in a number of commercial livestock species.

Two family designs commonly used in mapping studies are backcross and F_2 designs. The term segregating means that different alleles (versions of the same gene) are inherited by sibs within the families; consequently, if there is an effect due to the locus it could be detected through comparing the performance of individuals that inherited the different alleles. For example, suppose that there were a single locus with alleles *R* and *r* that determine phenotype for resistance to the parasite *Haemonchus contortus*. Individuals that are *RR* are resistant to infection, *Rr* are resilient, and *rr* are susceptible to infection. Suppose that we mated a buck and a doe using embryo transfer that we knew were both resilient (*Rr*) to produce a large fullsib family. Mendelian segregation would lead us to expect the progeny to have genotypes in the proportions 1/4 *RR*, 1/2 *Rr*, and 1/4 *rr*, and, even though we have no idea of the location of the "resistance" locus in the goat genome, we could classify these individuals into susceptible, resilient, or resistant phenotypes by experimentally challenging the kids with infective *Haemonchus* larvae. The important thing to note is that with the exception of a small region of chromosome on each side of the "resistance" locus, all the other loci

in the genomes of these progeny segregated at random. Hence at an anonymous locus on another chromosome at which alleles *A* and *a* are segregating, we would expect to find about the same proportions of *AA*, *Aa*, and *aa* genotypes among resistant, resilient, and susceptible progeny, indicating that the "A" locus is not linked to the "resistance" locus. On the other hand, suppose that in the region adjacent to the susceptible locus, we have an identifiable marker, "M," and that both the buck and the doe were both heterozygotes as follows:



The parameter θ is called the recombination rate which measures the "genetic distance" (the frequency of crossing over between the M and R loci) which is related to the "physical distance" (the number of nucleotides) between the two loci. A map distance of 20 cM would equate to a recombination rate θ of about .26. The individual above would be expected to produce gametes in the proportions: 1/2(1-θ) *MR*, 1/2θ *Mr*, 1/2θ *mR*, and 1/2(1-θ) *mr* and the progeny produced in the mating would be distributed as follows:

Marker Genotype	*MM*			*Mm*			*mm*			Σ
"Resistance" Genotype	*RR*	*Rr*	*rr*	*RR*	*Rr*	*rr*	*RR*	*Rr*	*rr*	
Frequency	$1/4(1-\theta)^2$	$1/2\theta(1-\theta)$	$1/4\theta^2$	$1/2\theta(1-\theta)$	$1/2(1-\theta)^2+1/2\theta^2$	$1/2\theta(1-\theta)$	$1/4\theta^2$	$1/2\theta(1-\theta)$	$1/4(1-\theta)^2$	1

The recombination that has occurred between the marker and "resistance" locus causes a lack of power in detecting the presence of the "resistance" locus. For θ < .5 the marker is linked to the "resistance" locus and there will be a greater proportion of resistant progeny with the *MM* marker genotype than the other marker genotypes, providing evidence for the location of the resistance locus. However, for θ = .5, which happens when the marker is on a different chromosome or if the marker is distant from the "resistance" locus on the same chromosome, the marker is inherited independently of the "resistance" locus and is not useful for its detection. This is why a genetic map of markers separated by 20 cM is critical to this kind of mapping study, so that by systematically screening these markers in the segregating families, at least one marker should be detected that is associated with the "resistance" locus. Most of the time we cannot be certain a priori that the parents are heterozygous at the locus of interest, or that the parents are heterozygous at the marker loci. Hence the need to replicate families within the experimental design.

The case for selection for resistance to *Haemonchus*

Helminthiasis constitutes one of the major economic health constraints to ruminant production worldwide. In the U.S. alone, losses in sheep and goat production due to internal parasites were estimated at $45 million annually (Drummond et al., 1981), with *Haemonchus contortus* the most pathogenic of the gastrointestinal nematode parasites (Levine, 1968; Soulsby, 1977). The estimated costs of anthelmintic drug treatment in Australia in 1984 totaled $90 million and production loss attributable to parasites was $360 million (Baker, 1991). In the U.S., the estimate is $39 million spent annually for anthelmintic drugs. Current control methods for internal parasites focus on reducing contamination of pastures through anthelmintic treatment combined with controlled grazing. These control methods are limited by the high cost of anthelmintics and increasing frequency of drug resistance as well as the emerging awareness worldwide of environmental issues resulting in consumer demand for animal products free of chemical residues. Evidence suggests that general fitness has been decreasing in some breeds due, in part, to intensive production practices and "genetic stress" imposed by selection (Wu et al., 1989). As a result, farmers are becoming increasingly reliant on antibiotics and chemoprophylaxis for health management. These economic and environmental considerations provide a strong impetus to develop alternative or complementary strategies for the control of helminths.

One solution is to breed animals which possess a natural resistance to internal parasites. However, livestock breeding programs have not included selection for parasite resistance for three reasons. First, the

livestock industries have felt secure because chemotherapeutic methods appeared to provide satisfactory control, although anthelmintic resistance has been observed where drugs have been used frequently and for prolonged periods (Donald, 1982). Parasites resistant to one drug with a particular mode of action are usually resistant to all related compounds (Kelly and Hall, 1979a, 1979b). Many parasites are resistant to drugs with different modes of action, and a few are resistant to almost all available drugs (Kelly and Hall, 1979a, 1979b). Second, obtaining measurements of fecal eggs per gram (EPG) and (or) whole blood packed cell volume (PCV) on sufficient numbers of animals to effect a selection program for improved resistance is impractical and not cost-effective. Third, considerable reservations have been expressed by parasitologists about the use of EPG and PCV as measures of resistance to internal parasites (Dargie, 1982; Grunner, 1991).

Despite these reservations it is now clear that EPG is repeatable, heritable, and correlated with actual worm burden (Gray, 1991). Based on measures of EPG, additive genetic variance for nematode resistance exists (Cabaret and Grunner, 1988; Baker et al., 1990; Baker, 1991) and heritability estimates are in the range of .2 to .4 (Albers et al., 1984; 1987; Woolaston, 1990). Baker et al. (1990) reported that the correlation between EPG and number of infective worms was sufficiently high under pasture conditions (.48) that EPG could be used as a predictor of an animal's worm burden. Resistant ewes were identified by periparturient fecal egg counts (Courtney et al., 1984), and selection has been used to produce resistant sheep (Albers et al., 1984). Woolaston (1990) showed that animals selected for resistance to one particular species of nematode also possessed a greater level of resistance to other nematode species.

There is concern that selection for host resistance may be futile if the parasite is able to adapt to the host's resistance mechanisms. Parasites are able to develop genetically based resistance to chemicals and drugs (Nicholas, 1987), and, in particular, internal parasites can develop resistance to anthelmintics (Waller, 1990). However, Adams (1988), Albers and Burgess (1988), and Barger and Sutherst (1991) did not find any adaptation of *Haemonchus contortus* to resistant hosts after up to seven parasite generations of serial passage through resistant hosts. Since it has been demonstrated that breeding for resistance to internal parasites is feasible in domestic animals (Morris, 1991) and because of the impact that this would have on ruminant production, there is an urgent need to develop strategies for accommodating disease resistance traits in breeding programs. However, the issue of measurement of the phenotypes of resistance needs to be resolved. Research is also required to provide estimates of the genetic correlations between disease traits and economically important production traits. In this context, the identification of predictive markers to screen animals for resistance would make breeding for resistance simpler and more effective. With the advent of molecular and embryo transfer techniques, the tools needed to create and propagate disease resistant livestock are at hand.

The KDPG approach

Goat population

The Small Ruminant Collaborative Research Support Program in collaboration with the Kenya Agricultural Research Institute (KARI) is developing a four-breed composite goat dual purpose goat at the Ol'Magogo research station (Figure 1). The present flock size is 1,137 goats comprised of 113 purebred indigenous East African (E) and Galla (G) breeds; 31 purebred imported Toggenburg (T) and Anglo Nubian (N) breeds; 332 first cross TxE, TxG, NxE, and NxG; and 661 four-way cross TNEG animals. In these proceedings Dr. Ruvuna reported the breeding program employed for selection towards an optimum genotype for milk and meat production. *Haemonchus contortus* was found to be the major nematode infecting goats at the Ol'Magogo research station (Shavulimo et al., 1988), and fecal and blood samples are obtained continuously on goats at two-week intervals starting at four months of age. Nematode and coccidia egg counts are estimated from fecal samples and PCV is determined from blood samples. Animals with less than 1,000 eggs per gram of feces from field sampling (Waruiru et al., 1993) are artificially challenged with infective *Haemonchus contortus* larvae, and a line of 64 animals determined to be resistant (that maintain less than 1,000 eggs per gram of feces) are being multiplied.

Identification of polymorphic markers

Over 400 goat DNAs representing 21 sire families from the population segregating for *Haemonchus contortus* resistance have been sampled. The current phase of research focuses on the identification of polymorphic microsatellite markers with at least 17 dinucleotide repeats that may be associated with QTLs for resistance to *Haemonchus contortus*. Microsatellites are short, tandemly repeating elements that are randomly distributed throughout the genome and possess a relatively high degree of polymorphism (Weber and May, 1989). The procedure that we use for generating polymorphic microsatellites was reported by Aravelo et al. (1993).

Results and discussion

Our initial DNA analyses using RAPDs indicated genotypic diversity at marker loci associated with growth and packed cell volume (PCV) in the goat population screened for resistance to *Haemonchus contortus* (Rohrer et al., 1991). However, RAPDs are particularly uninformative for mapping studies in animals because they are usually dominant markers measured as band present or band absent, and the heterozygotes are not distinguishable from homozygotes for the band. However, these analyses encouraged us to pursue the marker based approach, and we decided to initiate the development of a caprine genetic map based upon polymorphic dinucleotide repeat microsatellites. To date, we have generated over 20 goat specific microsatellites, and, of these, we have developed PCR primers that amplify ten polymorphic systems which exhibit a codominant mode of inheritance (Aravelo et al., 1993; Derr et al., 1993; Bhebhe et al., 1993).

Figure 2 confirms the Mendelian inheritance of two microsatellite loci designated SR-CRSP-4 and SR-CRSP-5. In Figure 2 (A) the sire in lane 4 is homozygous for the 249 bp allele, the dam in lane 1 is heterozygous for the 249 bp and 259 bp alleles at the SR-CRSP-4 locus. The progeny in lane 2 inherited the 259 bp allele from the dam and the 249 bp allele from the sire; the progeny in lane 3 inherited one 249 bp allele from the dam and the other 249 bp allele from the sire. The dam in lane 8 is heterozygous for the 249 bp and 255 bp alleles, and the progeny in lanes 6, 7, and 8 all inherited the 255 bp allele from the dam and the 249 bp allele from the sire. In Figure 2 (B) the sire in lane 4 and dam in lane 8 are both heterozygous for the 168 bp allele and the 170 bp allele and the dam in lane 1 is heterozygous for the 170 bp and 180 bp alleles at the SR-CRSP-5 locus. This gel, and those in Figure 3, indicate the sub-banding feature that is common for most microsatellite, probably due to slippage of the *Taq* polymerase within the microsatellite repeat sequence during early PCR amplification cycles. Slippage is thought to produce DNA fragments that are sequentially shorter by 2 bp which are then amplified by the PCR. The genomic DNA containing the microsatellite is amplified exponentially according to the number of PCR cycles (N) and produces the darkest band. The shorter fragments produced by slippage are only amplified for the number of cycles remaining following the cycle in which the slippage occurred (<N) and are at a lower concentration on completion of the PCR relative to the genomic fragment and produce a fainter band. For the most useful marker loci with many alleles, such as SR-CRSP-1 in Figure 3 (A), sub-banding complicates the scoring of genotypes, particularly when a large number of animals are being scored. To remove this human source of error, radioactivity, and the rate limiting steps of electrophoretic separation of alleles, autoradiography, and genotype scoring, we plan to automate this process with an Applied Biosystems automated sequencer. Figure 3 (B) also contains a partial sequence of the cloned SR-CRSP-7 genomic fragment containing a complex microsatellite repeat. From left to right in the sequencing gel, the lanes represent the nucleotides in alphabetic order A, C, G, and T. The microsatellite repeat sequence in this fragment is of the form $(GT)_7(AT)_8ATTAC(AT)_4$.

Microsatellite alleles are scored according to the length of the fragment resolved by electrophoresis on a polyacrylamide gel when compared to fragments of known sequence length in a M13 "sequence ladder" run on the same gel. Allele variation is generally considered to be due to variation in the length of the microsatellite repeat. However, the position to which a DNA fragment migrates on a gel is influenced by both its length and structural conformation which is determined by its nucleotide sequence. We are in the process of sequencing the alleles found at several microsatellite loci, and our preliminary findings indicate that structural polymorphisms due to sequence variation other than the length of the microsatellite repeat are involved in determining microsatellite alleles. This is no doubt due to the high rate of molecular evolu-

tion in these noncoding genomic regions which gives rise to the large number of alleles present at some microsatellite loci. The existence of multiple alleles is one of the greatest advantages of microsatellites for mapping studies. On the other hand, in population genetic studies that lack pedigree information, the potential of scoring alleles as identical that vary in DNA sequence may be of concern.

Table 1. Sample size, sex ratio, allele sizes (bp) and frequencies, direct count heterozygosity (H), and polymorphism information content (PIC) for 10 SR-CRSP microsatellites.

Locus	Sample size	Sex ratio (M/F)	Alleles (bp) (Frequency)	H	PIC
SR-CRSP-1	228	114/114	150 (.042); 148 (.066); 146 (.048); 144 (.101); 142 (.136); 140 (.143); 138 (.151); 136 (.162); 134 (.132); 130 (.020)	.868	.863
SR-CRSP-2	212	106/106	157 (.066); 155 (.047); 153 (.021); 151 (.866)	.255	.233
SR-CRSP-3	249	123/126	123 (.060); 121 (.538); 119 (.233); 113 (.163)	.743	.574
SR-CRSP-4	246	120/126	263 (.091); 259 (.079); 257 (.037); 249 (.793)	.317	.335
SR-CRSP-5	233	119/114	180 (.049); 174 (.107); 172 (.099); 170 (.397); 168 (.090); 166 (.062); 164 (.077); 160 (.088); 158 (.030)	.893	.774
SR-CRSP-6	213	109/104	150 (.014); 148 (.087); 146 (.275); 144 (.141); 142 (.143); 140 (.315); 136 (.026)	.869	.743
SR-CRSP-7	229	113/116	128 (.002); 126 (.068); 124 (.284); 122 (.201); 120 (.445)	.411	.619
SR-CRSP-8	224	110/114	235 (.228); 231 (.025); 227 (.096); 225 (.027); 223 (.036); 221 (.002); 219 (.484); 217 (.038); 215 (.009); 213 (.002); 209 (.054)	.688	.664
SR-CRSP-9	223	105/118	143 (.038); 141 (.054); 139 (.016); 137 (.117); 135 (.108); 133 (.112); 131 (.016); 129 (.105); 127 (.325); 125 (.092); 123 (.009); 119 (.009)	.866	.816
SR-CRSP-10	248	121/127	121 (.317); 119 (.206); 117 (.244); 115 (.234)	.835	.696

Sources: Aravelo et al. (1993); Derr et al. (1993); Bhebhe et al. (1993).

Table 1 summarizes the allele frequencies and polymorphism information content (PIC) for ten polymorphic caprine microsatellites scored in at least 212 KDPG. Seven of the markers have PIC values greater than .6 which measures the expected proportion of heterozygous animals in a random mating population. For seven of these loci, more than 70% of the KDPG assayed were polymorphic. These statistics indicate that microsatellites are an ideal marker system for gene mapping and also that the KDPG population is ideal for mapping genes associated with quantitative traits. The linkage analysis program CRI-MAP was used to test for two point linkage of these markers, and all loci are unlinked with the exception of SR-

CRSP-2 and SR-CRSP-7 which are separated by 20 cM with a LOD score of 2.7 (Gary Rohrer, USDA MARC, personal communication). The LOD score indicates that there is a $10^{2.7}$ = 501.2 greater likelihood that these loci are linked than that they are unlinked.

To determine the extent to which these microsatellite loci are conserved within bovid species, we assayed the first ten microsatellites in SR-CRSP series in individuals of twelve bovid species. In general, the degree to which these loci are conserved across the bovids is quite remarkable. Table 2 indicates that nine of the ten caprine loci are conserved in domestic cattle and that at least eight of these loci are polymorphic and can be immediately added to the bovine gene map. Mapping the SR-CRSP loci in cattle will add to the number of mapped bovine markers and will allow the alignment of both the bovine and caprine genetic maps. Table 2 also indicates the ancillary importance of gene mapping in domesticated livestock to conservation biology studies for germplasm evaluation involving wildlife and endangered species.

Table 2. Number of alleles observed and animals sampled in twelve bovid species or their crosses.

Species	Locus (SR-CRSP-#)									
	1	2	3	4	5	6	7	8	9	10
Bos taurus x Bos indicus[1]	186 (5)[2]	186 (5)	186 (2)	12 (1)	186 (3)	186 (3)	--	186 (6)	186 (3)	186 (7)
Bison bison	--[3]	7 (2)	7 (2)	--	12 (1)	12 (1)	12 (2)	--	--	12 (2)
Bos grunniens	--	10 (2)	10 (2)	--	7 (2)	7 (1)	--	--	--	7 (2)
Bos gaurus	--	12 (4)	12 (1)	--	--	8 (1)	10 (2)	--	--	10 (1)
Odocoileus virginianus	--	--	12 (2)	--	10 (2)	10 (6)	--	--	--	10 (3)
Ovis aries	--	--	8 (1)	--	12 (2)	12 (5)	--	--	--	12 (2)
Cervis canadensis	--	--	5 (1)	--	--	5 (2)	--	--	--	5 (1)
Cervis elaphus	--	10 (2)	10 (2)	--	--	5 (2)	--	--	--	5 (2)
Gazella spekei	--	5 (1)	--	--	--	6 (2)	6 (2)	--	--	6 (1)
Neotragus moschatus	--	5 (1)	--	--	--	--	24 (3)	--	--	24 (2)
Odocoileus hemionus	--	6 (1)	--	--	5 (1)	5 (1)	--	x	x	x
Ovibos moschatus	x[4]	x	x	x	8 (1)	8 (1)	--	x	x	x

[1]Angus x Brahman
[2]Number of animals (number of alleles)
[3]No PCR product
[4]Not screened
Sources: Aravelo et al. (1993); Derr et al. (1993); Bhebhe et al. (1993).

Analyses to detect associations between the first ten microsatellites in SR-CRSP series and loci influencing growth and *Haemonchus* resistance traits are currently in progress and results will be reported at the Workshop.

Our rationale for a molecular genetic approach for the detection of genes associated with resistance to *Haemonchus contortus* is that incorporation of resistance to nematode infections into ruminant hosts will eliminate, or at least reduce, the need for anthelmintics in smallholder and extensive production systems. If genetic markers were available which could detect the desirable allele(s) at the major locus (loci), then significant genetic progress for improved nematode resistance and hence ruminant productivity could be made in a few generations of selection. In addition, this research could lead to the identification and analysis of the genes responsible for parasite resistance in other species which would have worldwide application, as internal parasites are endemic wherever ruminants are produced.

Literature Cited

Adams, D.B. 1988. Infection with Haemonchus contortus in sheep and the role of adaptive immunity in selection of the parasite. Int. J. Parasitol. 18:1071.

Albers, G. A. A., S. E. Burgess, D. B. Adams, J. S. F. Barker, L. F. Le Jambre and L. R. Piper. 1984. Breeding Haemonchus contortus resistant sheep - Problems and prospects. In: Immunogenetic Approaches to the Control of Endoparasites with Particular Reference to Parasites of Sheep. pp 41-52. Ed. J. K. Dineen and P. M. Outteridge. CSIRO and Australian Wool Corp., Melbourne.

Albers, G. A. A., G. D. Gray, L. R. Piper, J. S. F. Barker, L. F. Le Jambre and I. A. Barger. 1987. The genetics of resistance and resilience to Haemonchus contortus infection in young Merino sheep. Int. J. Parasitol. 17: 1355.

Albers, G.A.A. and S.K. Burgess. 1988. Serial passage of Haemonchus contortus in resistant and susceptible sheep. Vet. Parasitol. 28 :303.

Arevalo, E., D.A. Holder, J.N. Derr, E. Bhebhe, R.A. Linn, J.F. Taylor, S.K. Davis, and F. Ruvuna. 1993 Caprine microsatellite dinucleotide repeat polymorphism at the SR-CRSP-1, SR-CRSP-2, SR-CRSP-3, and SR-CRSP-4 loci. Animal Genetics (submitted).

Baker, R. L., T. G. Watson, S. A. Bisset and A. Vlassoff. 1990. Breeding Romney sheep which are resistant to gastro-intestinal parasites. Proc. Aust. Assoc. Anim. Breed. Genet. 8:173.

Baker, R.L. 1991. Breeding for disease resistance in sheep. Eds. G.D. Gray and R.R. Woolaston, Australian Wool Corporation, Melbourne.

Barger, I.A. and R.W. Sutherst. 1991. Population biology of host and parasite. In: Breeding for Disease Resistance in Sheep. Eds. G.D. Gray and R.R. Woolaston, Australian Wool Corporation, Melbourne.

Bhebhe, E., J.K. Kogi, D.A. Holder, E. Arevalo, J.N. Derr, R.A. Linn, F. Ruvuna, J.F. Taylor and S.K. Davis. 1993. Caprine microsatellite dinucleotide repeat polymorphism at the SR-CRSP-8, SR-CRSP-9, and SR-CRSP-10 loci. Animal Genetics (submitted).

Blackburn, H.D., and J.F. Taylor. 1990. Simulation of flock performance when different intensities of selection are practised. Third World Congress on Genetics Applied to Livestock Production. Edinburgh. July, 1990.

Cabaret, J. and L. Gruner. 1988. Genetic variability of resistance to parasites. pp 577-592 3rd World Congress on Sheep and Beef Cattle Breeding, Paris. 1:577.

Courtney, C.H., C.F. Parker, K.E. McLure and R.P. Herd. 1984. A comparison of the periparturient rise in fecal egg counts of exotic and domestic ewes. Int. J. Parasitol. 15:101.

Dargie, J.D. 1982. The influence of genetic factors on the resistance of ruminants to gastrointestinal resistance nematodes and trypanosome infections. In: Animal Models in Parasitology Ed. Owen, G.D. McMillan Press Ltd, London, U.K.

Derr, J.N., D.A. Holder, E. Arevalo, R.A. Linn, E. Bhebhe, S.K. Davis, F. Ruvuna and J.F. Taylor. 1993. Caprine microsatellite dinucleotide repeat polymorphism at the SR-CRSP-5, SR-CRSP-6, and SR-CRSP-7 loci. Animal Genetics (submitted).

Donald, A.D. 1982. The development of anthelmintic resistance in nematodes of grazing animals. In: Facts and Reflections IV. Resistance of Parasites to Anthelmintics, Commission of European Communities, Cent. Vet. Inst., Lelystad, Netherlands. p.15.

Drummond, R.O., G. Lambert, H.E. Smalley and C.E. Terrill. 1981. Estimated losses of livestock to pests. In: Handbook of Pest Management in Agriculture. 1:111.

Edwards, M.D., C.W. Stuber and J.F. Wendel. 1987. Molecular marker facilitated investigations of quantitative-trait loci in maize. I. Numbers, genomic distribution and types of gene action. Genetics. 116:113.

Gray, G.D. 1991. Breeding for resistance to Trichostrongyle nematodes in sheep. In: Breeding for Disease Resistance in Farm Animals. J.B. Owen and R.F.E. Axford Eds. C.A.B. International, Wallingford U.K. p. 139.

Grunner, L. 1991. Breeding for helminth resistance in sheep and goats. In: Breeding for Disease Resistance in Farm Animals. J.B. Owen and R.F.E. Axford Eds. C.A.B. International, Wallingford U.K. p. 187.

Kelly, J.D. and C.A. Hall. 1979a. Anthelmintic resistance in nematodes. I. History, present status in Australia, genetic background and methods for field diagnosis. New South Wales Vet. Proc. p. 1.

Kelly, J.D. and C.A. Hall. 1979b. Anthelmintic resistance in nematodes. II. Treatment of resistant nematodes. New South Wales Vet. Proc. p. 14.

Levine, N.D. 1968. Nematode Parasites of Domestic Animals and Man. Burgess Publishing Co., Minneapolis. p. 218-220.

Morell, V. 1993. Huntington's gene finally found. Science. 260:28-30.

Morris, C.A. 1991. Screening and selection for disease resistance - Repercussions for genetic improvement. In: Breeding for Disease Resistance in Farm Animals. J.B. Owen and R.F.E. Axford Eds. C.A.B. International, Wallingford U.K. p. 123.

Nicholas, F. W. 1987. Veterinary Genetics. Clarendon Press, Oxford, 580 pp.

Rocha, J.L., J.F. Baker, J.E. Womack, J.O. Sanders and J.F. Taylor. 1992. Statistical associations between restriction fragment length polymorphisms and quantitative traits in beef cattle. J. Anim. Sci. 70:3360-3370.

Rohrer, G. A., J. F. Taylor, S. K. Davis, J. O. Sanders, J. W. Turner and J. E. Womack. 1991. Randomly amplified polymorphic DNA markers (RAPD) between Angus and Brahman cattle in a study to identify genes controlling carcass merit. J. Anim. Sci. 69 (Suppl. 1): 201 (Abstr.).

Shavulimo, R. S., F. Rurangirwa, F. Ruvuna, A. D. James, P. R. Ellis and T. McGuire. 1988. Genetic resistance to gastrointestinal nematodes, with special reference to Haemonchus contortus, in three breeds of goats in Kenya. Bull. Anim. Hlth. Prod. Afr. 36: 233.

Soulsby, E.J.L. 1977. Helminths, Arthropods and Protozoa of Domesticated Animals, 6th ed. Lea and Febiger, Philadelphia. p. 787.

Waller, P.J. 1990. Resistance in nematode parasites of livestock to the benzimidazole anthelmintics. Parasit. 6:127.

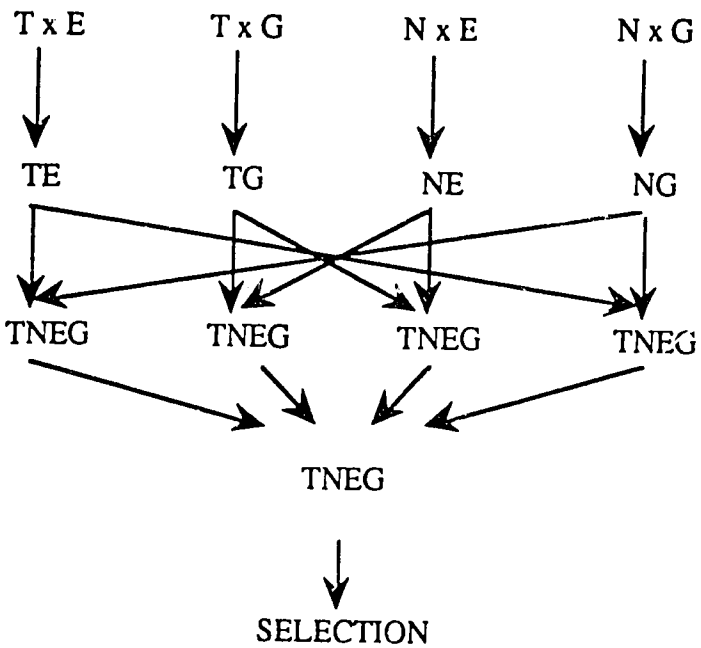
Waruiru, R.M., F.N. Karanu, B.A.J. Mwandotto, F.Ruvuna, E.J. Gichanga, J.F. Taylor, D. Jasmer, F. Rurangirwa and T.C. McGuire. 1993. Evidence of resistance to Haemonchus contortus in goats on artificial challenge Vet. Parasit. (submitted).

Weber, J.L. and P.E. May. 1989. Abundant class of human DNA polymorphisms which can be typed using the polymerase chain reaction. Am. J. Hum. Gen. 44:388.

Woolaston, R. R. 1990. Genetic improvement of resistance to internal parasites in sheep. Proc. Aust. Assoc. Anim. Breed. Genet. 8:163.

Wu, M.C., R.D. Shanks and H.A. Lewin. 1989. Milk and fat production in dairy cattle influenced by advanced subclinical progression of bovine leukemia virus infection. Proc. Natl. Acad. Sci. U.S.A. 86:993.

Figure 1. Formation of the Kenya dual purpose goat.



T - Toggenburg purebred males
N - Anglo Nubian purebred males
E - East African purebred females
G - Galla purebred females

Figure 2. Mendelian inheritance of three of the four alleles at the SR-CRSP-4 locus (A) and three of the nine alleles at the SR-CRSP-5 locus (B) in two KDPG fullsib families.

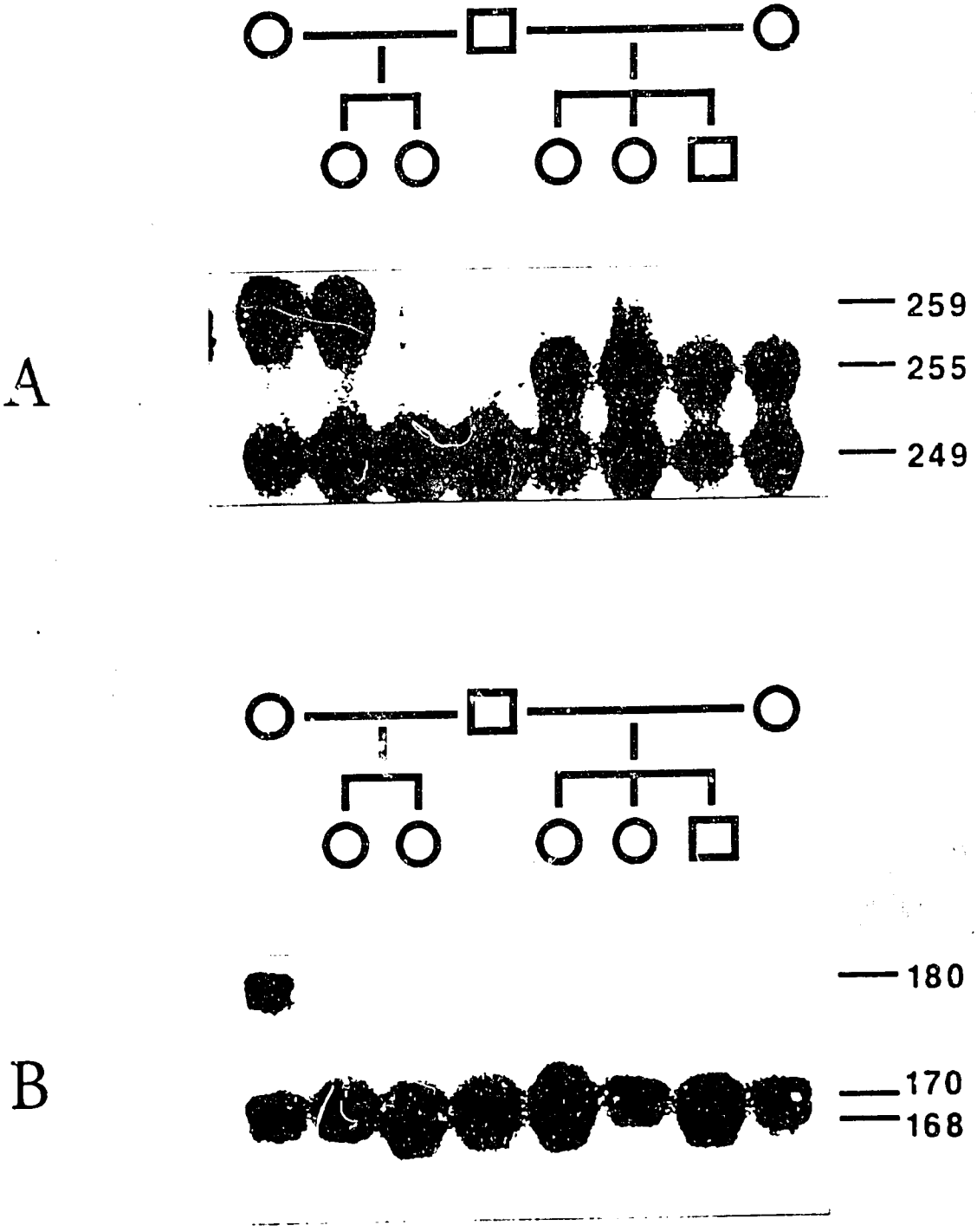
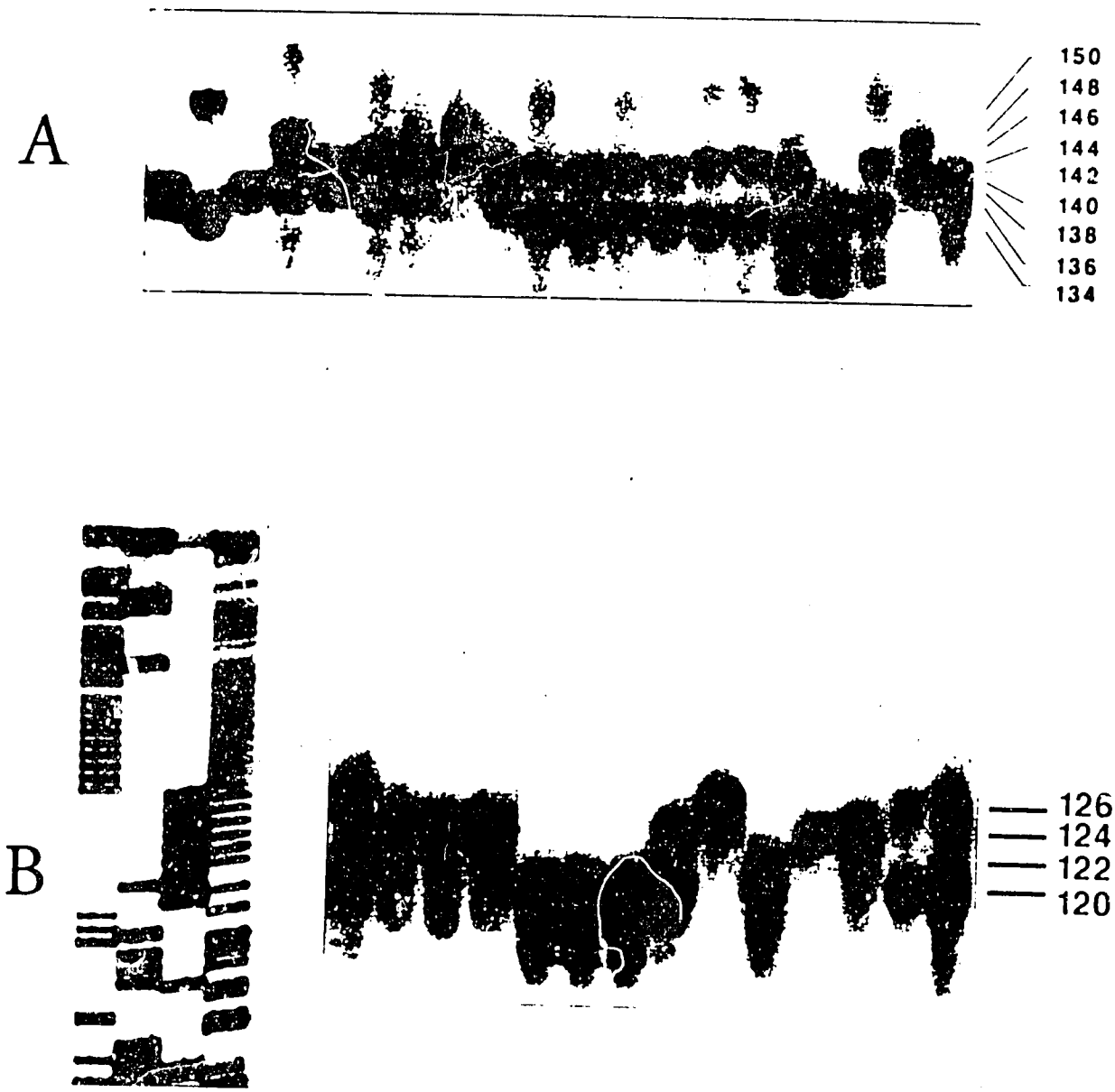


Figure 3. Nine of the ten alleles at the SR-CRSP-1 locus (A) and sequence indicating a complex microsatellite and four of the five alleles at the SR-CRSP-7 locus (B).



Creation of the Kenya Dual Purpose Goat

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Abstract

The formation of the Kenya dual purpose goat (KDPG) breed has been unique in that it was designed according to scientific principles, computer tested to be optimal for the environment, and field and experiment station tested at all stages. The breeding plan involved crossing two indigenous breeds, East African (E) and Galla (G) does, with two temperate breeds, Anglo Nubian (N) and Toggenburg (T) bucks, to form a four-way composite (1/4E, 1/4G, 1/4T, 1/4N). Growth and asymptotic mature size of 38 kg for females are near optimal for the environment. The average milk yield surplus to kid requirements is over 1.0 kg/d for a 120 d lactation length. The involvement of selected private breeders in the current impact assessment phase of breed development ensures use of the breed in many different production systems in Kenya. Recognition of the KDPG as a breed by the Kenya stud book and subsequent privatization of KDPG ownership will ensure the sustainability of the SR-CRSP/KARI KDPG research.

Introduction

The western Kenya SR-CRSP work-site provides a production environment typical of many high potential smallholder farms in the tropics. Attributes include high population density and population growth rates, limited physical and financial resources, and family diets that often do not meet minimal nutrient requirements. For a dual purpose goat production system to be viable for these smallholders, it must produce a sufficient quantity of milk in the presence of environmental constraints on a consistent basis in order to alleviate nutritional deficiencies.

Using baseline survey results of the smallholder farms in western Kenya it was identified that a dual purpose goat was critically needed for the smallholder farm families, and four key criteria for an acceptable and sustainable goat breed were identified: 1) if the forage resource was developed to its potential, it would be adequate to support the nutritional requirements of such a goat; 2) on-farm and on-station studies indicated that indigenous goats were too low in genetic potential for growth and milk yield to be an acceptable base for developing a suitable dual purpose goat; 3) from experience and research data, the exotic dairy breeds were not viable under the nutritional and management conditions of the smallholder farmer; and 4) although early research demonstrated that the F1 between the indigenous and exotic goats performed satisfactorily, a structured crossbreeding program to continuously produce F1s was not feasible for smallholder farmers. These criteria indicated that a practical breeding program must include environmental adaptability and synchronize the goat's genetic potential for production characters with the available feed supply and the prevailing production conditions. Therefore, the breeding program was designed to produce a low maintenance, hardy, meat and milk producing goat breed, which could be easily adapted to other production environments. This paper presents the genetic improvement strategy employed which was

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designed to blend traits of indigenous and exotic breeds, exploit heterosis that would be retained at a relatively high level, and create a wide genetic base responsive to selection.

Breeding goals and production objectives

There are four fundamental production functions to be considered in breeding a meat and milk goat breed appropriate for smallholders: growth, reproduction, lactation, and survival. Growth and lactation require nutrient inputs above maintenance. If available nutrients are only marginally above maintenance requirements, and at times of the year are below maintenance requirements, stresses on the animal are created. If genetic potential for growth and milk production are high, additional stress is created rendering the high-potential animal genetically less adapted and with a reduced survival. Therefore, genetic potentials for growth and lactation must be balanced against the available nutrition and other stressing conditions. For example, the seasonality of production and quality of forage is a primary limiting factor. Although supplementation, dipping, vaccination, and treatments against infection and parasites may be applied, the expense and availability of medications, and limited skills of the smallholder, restrict these practices. The development of a genotype optimally matched with the nutritional and management constraints is a systems analysis problem.

Applying the Texas A&M sheep and goat simulation model (Blackburn et al.,1987), we were able to examine the total performance of alternative genotypes and define the breeding goals to produce an optimum genotype. Simulations were performed for a western Kenya production system using different genetic potentials for mature size (GSIZE) and peak lactation milk production (GMILK) of a mature doe. Genetic potentials, expressed as GSIZE/GMILK, for the breeds were: East African 30/2.5, Galla 35/3.0 and Toggenburg 55/6.0. The crossbreds would be expected to average above the midparent averages due to the expression of heterosis. Genotypes simulated were 50/6.0, 45/4.5, 40/4.0, 35/3.0, 30/2.0, which represented expectations regarding the size and milk production of indigenous goats selected from the Kenya population, imported, and crossbred goats. Four criteria examined were: number of kids born, average weaning weight, average daily milk production per lactation, and minimum doe body condition (Table 1).

Table 1. Simulated average lifetime production of 5-year-old does of 5genotypes raised on smallholder forage in western Kenya.

	Mature size/ Milk potential			
Item	50/6.0	45/4.5	40/4.0	35/3.0
No. of Kids	6.0	6.0	7.0	6.5
Avg. Wean wt., Kg.	17.2	17.1	13.8	12.0
Avg. Milk/Lact., Kg.	157.0	149.0	115.0	98.0
Doe condition Minimum, %	67.0	68.0	77.0	63.0

Source: Blackburn et al., 1986

The 30/2.0 genotype was not suitable as a DPG because the doe was not able to produce milk, grow and reproduce in the environment. The 50/6.0, 45/4.5 and 35/3.0 genotypes were considered to be unsuitable as a DPG due to low levels of doe body condition which decreased to precarious levels at certain times of the year. Low body condition was an indication that these does were producing at a level which subjected them to excessive stress. These stressed does were susceptible to disease and parasite infection and could not reproduce regularly. Does of the 40/4.0 genotype maintained a relatively high minimum body condition and had more kids over five years than the other genotypes tested. The higher number of kiddings implied that there would be a more continuous supply of milk during the doe's during her lifetime. In terms of quantity of milk and weight of kids weaned, the 40/4.0 genotype was not maximal; the 50/6.0 and 45/4.5 genotypes were more productive in these respects. However, the combination of performance characters made the 40/4.0 genotype the most appealing choice, since it had an acceptable production level and retained robustness. The extra body reserves indicated that, if the smallholder production conditions periodically deteriorated, the 40/4.0 genotype would possess sufficient resilience to allow continuous produc-

tion, while the 45/4.5 and 50/6.0 genotypes did not have as much buffering capacity. Consequently, the 40/4.0 genotype was selected by the SR-CRSP Breeding project as the target genotype with acceptable production while maintaining resilience under the production environment.

Simulated lactation curves in Figure 1 showed that under ideal conditions of no stresses (e.g., no worm or external parasite burden, lucerne hay fed ad libitum with a dairy meal supplement), the average daily mature equivalent milk yield potential for a young doe with genetic potential of 4.0 kg of milk at peak lactation was 1.8 kg, and a mature doe would average 2.2 kg/d over a 150 d lactation. These values represent genetic potentials, but these potentials are decreased under usual farm conditions by any stresses described above.

Breeding tactics

A well designed breeding program combines facets of management, nutrition and breeding considering inputs and outputs that meet the needs of producers possessing varying resources and abilities. The strategies adopted in the development of the KDPG were based on retaining indigenous breeding for adaptability while increasing productivity traits by incorporating exotic germplasm. Figure 2 shows the mating plan used to develop the breed and the genotypic constitution. A composite breed known as Kenya Dual Purpose Goat (KDPG) synthesized from two native breeds, East African (E) and Galla (G), and two high yielding imported breeds, Toggenburg (T) and Anglo Nubian (N) (1/4T,1/4N,1/4E,1/4G) was determined to be the most suitable breeding approach. The combination of four breeds assured that during breed stabilization, less heterosis would be lost due to recombination. The 50% exotic inheritance would be superior to the productive potential (meat and milk) of the indigenous adapted breeds. The potential of crossing imported European and indigenous Kenyan breeds has long been recognized in Kenya, but the development of a well-defined, highly integrated framework for a crossbreeding program had hitherto not eventuated. The adherence to one breed and its crosses is preferable to mixed crossing involving several breeds which prevents within-breed selection for improvement. Where crossbreeding systems involving indigenous and exotic breeds have been emphasized, rapid benefits have been realized, but this is a short-term strategy that requires increased supervision and management input for sustainability and this is not viable under most smallholder production systems. Stable industries based on crossbreeding programs that require the maintenance of purebred lines have not fared well in many developing countries because parental purebreds often possess reduced viability and crossing systems cannot be maintained. Synthetics have proved especially valuable as a means of incorporating improved productivity with along adaptability. The four-breed composite synthetic possesses essentially all of the desirable traits of the F1, but also creates a population which is responsive to selection to improve or maintain production (milk and growth) while simultaneously selecting for enhanced adaptability, such as resistance to internal parasites.

Productivity characteristics of the KDPG

Performance evaluation of F1s, the indigenous breeds and the KDPG have yielded very encouraging results for growth rates, milk yield and carcass traits (Ruvuna et al., 1988a,b; 1991; 1992). Tables 2 and 3 summarize realized growth, mature size, and milk yield potential of the KDPG relative to F1 and indigenous breeds.

Table 2. Lactation parameters of straightbred and crossbred goats.

Breed group	Number of does	Number of daily records	Wood's equation parameter estimates (g)			Peak yield (g)	Peak week	120 d yield (g)
			a	b	c			
E & G	7	109	391	-.03	.062	—	—	57.6
TxE	14	1088	721	.23	.030	908	6	214.2
TxG	34	2992	819	.26	.009	1005	6	238.7
NxE	13	421	813	.22	.044	1019	8	248.9
NxG	14	1080	732	.06	.009	750	4	186.1
KDPG	12	1232	710	.48	.061	1130	7	259.7

E=East African; G=Galla; T=Toggenburg; N=Anglo Nubian
Source: Unpublished data.

Table 3. Growth parameters of straightbred and crossbred goats.

Breed Group	Mean body weights				Estimated body growth curve parameters[a]				
	No.	Bwt (kg)	Wwt (kg)	12 mo (kg)	No. does	No. monthly	A (kg)	B	k
E	208	2.0	8.6	15.7	38	2191	33.27	.914	.049
G	64	2.6	9.0	20.4	11	631	41.08	.956	.050
TxE	268	2.4	9.9	18.5	34	1732	39.13	.907	.043
TxG	258	2.9	10.6	19.2	74	3550	42.72	.895	.039
NxE	144	2.5	10.1	19.0	9	502	37.90	.907	.050
NxG	167	3.0	10.9	19.1	25	1338	43.59	.912	.048
KDPG	96	2.4	10.9	19.6	57	2806	38.67	.903	.048

E=East African; G=Galla; T=Toggenburg; N=Anglo Nubian
[a]For females.
Source: Ruvuna et al., 1988a; Unpublished data

The KDPG averaged more milk yield than all the other crosses. Because the data were for morning milk only, the results underestimate the potential average daily yield in comparison to the expected yield from 2X milking without overnight suckling. However, these results can be interpreted as the amount of milk produced surplus to kid requirement that can be harvested for human requirement. The KDPG and F1 weights are comparable and are within the ranges of values for the most promising breeds raised under similar production systems (Devendra and Burns, 1983).

Figures 3 and 4 show estimated lactation and growth curves. Wood's equation: $Y_t=at^be^{-ct}$ was used to fit lactation curves (Wood, 1967). The Y_t represents the average morning milk yield (gms) in week t of lactation, a, b, and c are parameters which determine the shape of lactation curve, and e is exponential. Brody's equation: $Y_t=A(1-Be^{-kt})$ was used to estimate growth curves for does (Brody, 1945). The Y_t is weight at t months of age, A is the asymptotic mature size, B is a scaling factor, and k is the rate of maturing. Growth and mature size of KDPG does are near optimal values predicted from simulations. Milk production is estimated to currently average 3.5 kg/d potential at peak day of lactation for a mature doe, although in the presence of environmental constraints the realized production is 2.2 kg/d (Table 1).

Stabilization, multiplication, and distribution of the KDPG

Breed stabilization, multiplication, and distribution is an important phase of the KDPG breeding program since it will provide farmer confidence and promote widespread utilization of the KDPG genetic resource. Selection to stabilize the breed was initially based on individual performance records, with some attention to progeny and parental information. The criteria used for selection are optimal growth (weight/age through lifetime) and lactation (milk production/lactation) established as optimal by the systems analyses for western Kenya. Sufficient data have now been accumulated that selection is based on estimated genetic merit using information from all relatives. A computer program (MTDFREML) suitable for use in Kenya has been adapted to personal computers (PC) 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 allow for more efficient selection. The program can handle data with any kind of pedigree structure and employs an individual animal model. The statistical basis for MTDFREML was provided by Meyer (1985, 1986, 1987), and Smith and Graser (1986).

Presently and in the future, the breeding plan is shifting from being primarily research oriented to multiplication and distribution oriented. In order to enhance this transition and to assess the acceptability of the KDPG and its adaptability to Kenya smallholder production environment, an impact assessment study has been initiated to work with 20 smallholder farm families. The study involves two sites: at Katumani, representing a semiarid environment and at Matuga, representing a tropical humid environment. The process involves the transfer of the KDPG technical packages developed by SR-CRSP and of 40 KDPG does and 6 KSPG bucks to 20 smallholder farmers at both locations. This is a cooperative effort between Kenya Agricultural Research Institute (KARI), a private voluntary organization , Heifer Project International, SR-CRSP and the 20 collaborating farmers. The Ministry of Agriculture, Livestock Development and Marketing extension officers are fully involved in the distribution process at each site to ensure that no impediments will exist to the sustainability of the distribution process beyond the involvement of the SR-CRSP. It is anticipated that the collaborating farmers will assist in establishment of the KDPG as a breed and maintain records suitable for animal registration including conformation, pedigree, and performance data. Distribution of the KDPG to other smallholders within each of the farming communities at Matuga and Katumani will be facilitated by the farmers who first receive KDPG does and who hold an economic interest in the establishment of the breed. Although the KDPG was developed utilizing scientific principles, it is important the breed establishment is maintained along traditional lines. The Kenya Goat Breeder's Society is in the process of reviewing our application to register the KDPG as a breed with the Kenya Stud Book. Once approved, all collaborating breeders at Matuga and Katumani will be registered as KDPG breeders. Any doe or buck with appropriate breeding may be nominated for registration as a purebred. Registration may be granted and recorded by the Kenya Stud Book under the recommendation by the Kenya Goat Breeders Society after inspection according to the criteria set for the breed. A written set of inspection and performance criteria are in the process of being developed.

Goats are relatively small genetic units of production, and, although this may have advantages for farmers, it tends to be uneconomic from the standpoint of individual animal record keeping which is necessary for continued development and progress of the breed. A national dairy goat recording program is not feasible for Kenya. The principal role of the flock at Ol'Magogo during the multiplication and distribution phase is to be responsible for the genetic improvement of the Kenya DPG to the point that it is truly 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 as an elite flock where detailed production records will be collected, and an intense genetic improvement plan followed with selection emphasis based on performance records and advanced reproductive technologies such as embryo transfer and artificial insemination can be used to maximize genetic progress.

Literature Cited

Blackburn, H.B., T.C. Carwright, P.J. Howard and F. Ruvuna. 1986. Development of Dual Purpose Goat Production for Smallholders in Western Kenya Using Computer Simulation and Systems Analysis. SR-CRSP Technical Report Number 89.

Blackburn, H. D., T. C. Cartwright, G. M. Smith, N. McC. Graham and F. Ruvuna. 1987. The Texas A&M Sheep and Goat Simulation Model. Texas Agr. Exp. Sta. Bul. no. 1559. p. 136.

Brody, S. 1945. Bioenergetics and Growth. Hafner Publishing, New York.

Devendra C. and M. Burns. 1983. Goat Production in the Tropics. Commonwealth Agric. Bureaux, Farnham House, UK.

Meyer K. 1985. Maximum likelihood estimates of variance components for a multivariate mixed model with equal design matrices. Biometrics. 41:153.

Meyer K. 1986. Restricted maximum likelihood to estimate genetic parameters - in practice. 3rd World Congr. On Gen. Appl. to Liv. Prod. XII: 454.

Meyer K. 1987. A note on the use of an equivalent model to account for relationships between animals in estimating variance components. J. Anim. Breed. Genet. 104:163.

Smith S.P. and Graser, H.U. 1986. Estimating variance components in a class of mixed models by restricted maximum likelihood. J. Dairy Sci. 69: 1156.

Ruvuna, F., T.C. Cartwright, H. Blackburn, M. Okeyo and S. Chema. 1988a. Lactation performance of goats and growth rates of kids under different milking and rearing methods in Kenya. Anim. Prod. 46:237.

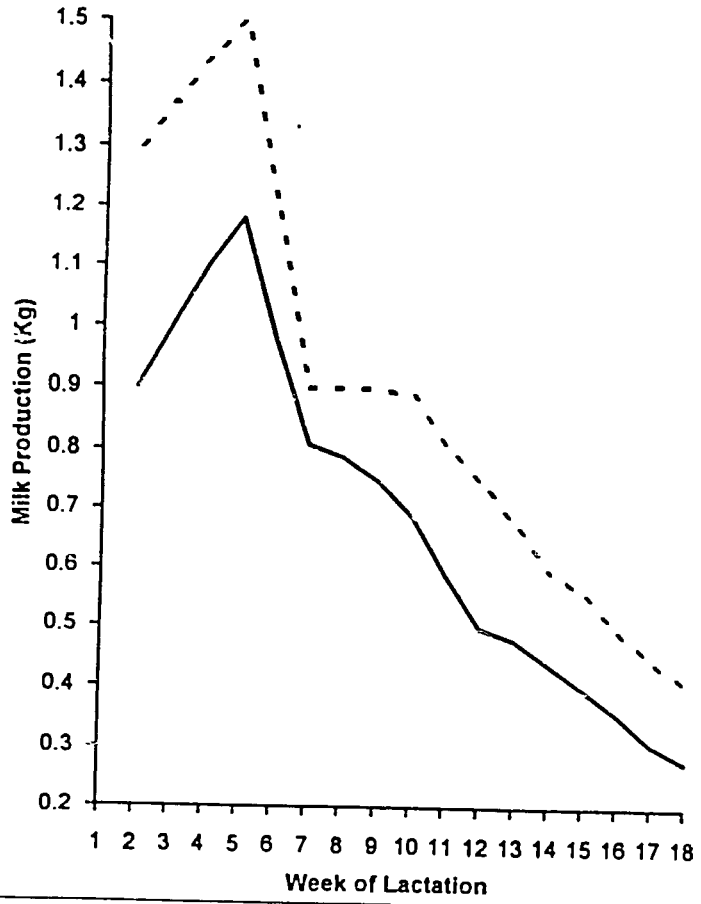
Ruvuna, F., T.C. Cartwright, H. Blackburn, M. Okeyo and S. Chema. 1988b. Gestation length, birth weight and growth rates of pure- bred indigenous goats and their crosses in Kenya. J. Agric. Sci., Camb. 111:363.

Ruvuna, F., T.C. Cartwright, J.F. Taylor, C. Ahuya and S. Chema. 1991. Factors affecting body weight of East African and Galla. Small Ruminant Res. 4:339.

Ruvuna, F., J.F. Taylor, M. Okeyo, M. Wanyoike and C. Ahuya. 1992. Effects of breed and castration on slaughter weight and carcass composition of goats. Small Ruminant Res. 7:175.

Wood P.D.P. 1967. Algebraic model of the lactation curve in cattle. Nature 216:164.

Figure 1. Simulated lactation curve of mature does taken from a flock of 6 does for different genetic potentials for mature size (35 kg, left side vs. 40 kg, right side) and milk production (3.0 kg, solid line vs. 4.5 kg, dashed line).



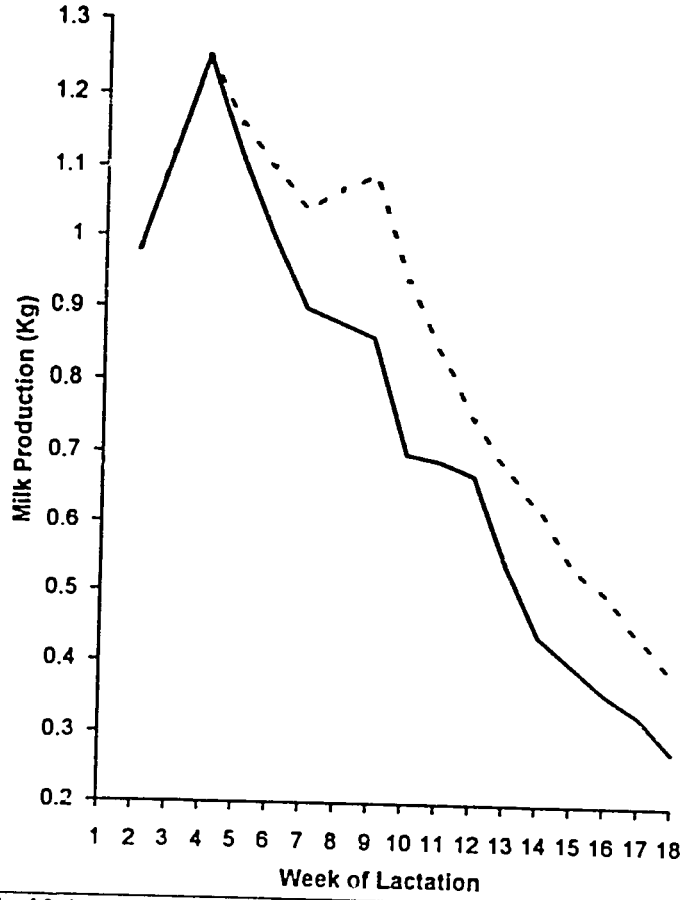
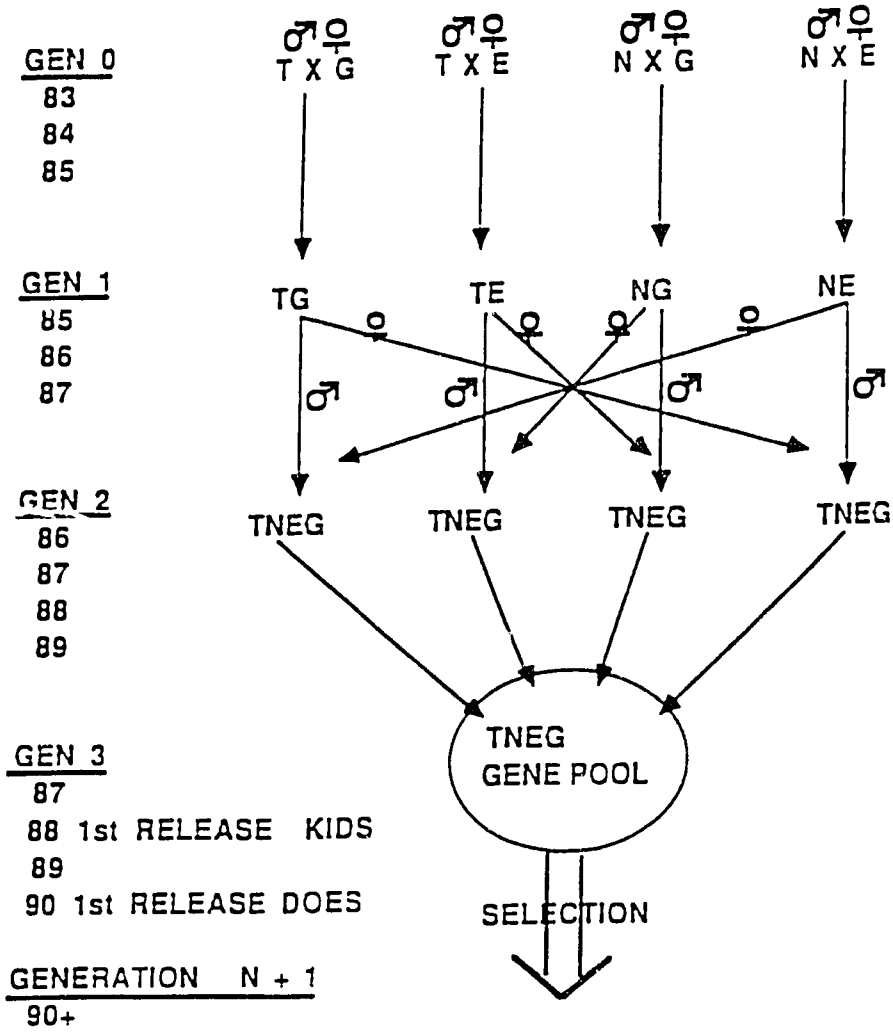


Figure 1. Simulated lactation curves of mature does each taken from a flock of 6 does for different genetic potentials for mature size (35 kg, left side vs. 40 kg, right side) and milk production (3.0 kg, solid line vs. 4.5 kg, dashed line).
Source: Blackburn et al., 1987.

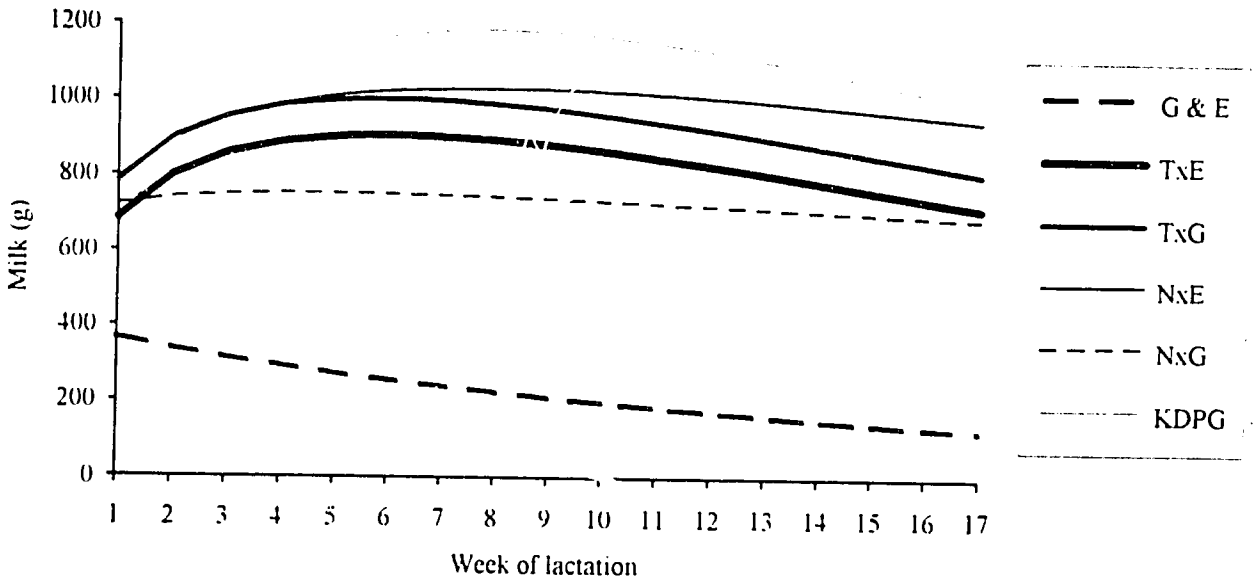
Source: Blackburn et al., 1987.

Figure 2. Kenya SR-CRSP breeding project, breeding plan for a dual purpose breed.



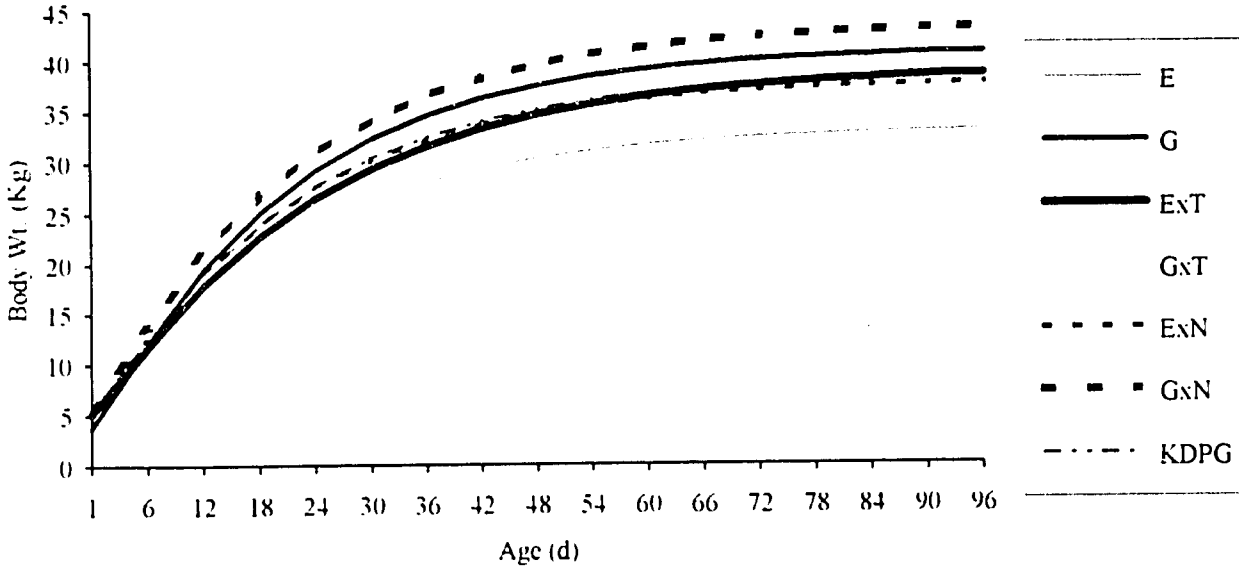
KENYA DUAL PURPOSE GOAT BREED

Figure 3. Lactation curves of straightbred and crossbred does.



Source: Unpublished data.

Figure 4. Growth curves of straightbred and crossbred does.



Source: Unpublished data.

How Farm-Oriented Research With Dual Purpose Goats Evolved in Western Kenya

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Introduction

In 1980, a Memorandum of Understanding (MOU) was signed between the Ministry of Agriculture and Livestock Development (MALD) and the Small Ruminant Collaborative Research Support Program (SR-CRSP) Management Entity, the University of California, Davis. The signing signaled the initiation of goat collaborative research in Kenya based at Kabete, Ol'Magogo, and Maseno. The work at Maseno in western Kenya represented a departure in the kind of physical environment usually targeted for goat research. It came into existence for a combination of programmatic and geopolitical reasons.

Before the SR-CRSP initiative was established, modest and useful goat research had been carried out at various government stations through the UNDP/FAO Sheep and Goat Project. However, this previous goat research did not focus on Kenya dual purpose goats (KDPG) designed for production of meat and milk. The KDPG research program was viewed as beneficial to creating a dynamic Kenya research program; in creating a cadre of scientists familiar with new research methodologies; and to resource poor smallholders engaged in mixed farming. It was anticipated that benefits would be passed on to farmers who had experience only with meat goats, giving them the opportunity to benefit from enhanced milk production potential. As things developed, manure became yet another major product of the goat to have an impact in mixed crop-livestock agricultural systems.

The activities in western Kenya were funded, for the most part, by USAID. They reflected the objectives stated in Title XII of the 1975 U.S. Famine Prevention and Freedom from Hunger Act.

1. Strengthen capacities of U.S. universities as opposed to conducting research exclusively overseas.
2. Conduct institutional development and research as opposed to direct handouts in the form of commodity transfer.
3. Provide increased and long-term support as opposed to small, short-term, stop-and-go research projects that have characterized so much of the past technical assistance to developing countries.

Currently the Kenya Agricultural Research Institute (KARI) is the national collaborating institution. The host institution in Kenya has changed over the years as necessitated by government structural changes. It started with the Ministry of Agriculture and Livestock Development (MALD), then Ministry of Livestock Development (MOLD), and currently it is under KARI which is part of the Ministry of Research, Technical Training, and Technology. Changes of host institution have adversely affected local collaborating scientists and support staff and, to a lesser extent, the research itself. For example, some of the staff are still employees of either MALD or MOLD, rather than KARI. This creates uncertainty in regard to supervision, administration of salary and benefits, and responsibilities. In another example, when MALD was the host institution, the question of placement of SR-CRSP under the veterinary or animal production research division created departmental animosity that was detrimental to research activities and allocation of stations. Since KARI took over these problems have tended to diminish in importance.

The U.S. collaborating institutions include Texas A&M University, Washington State University, University of Missouri-Columbia, Colorado State University, and Winrock International Institute for Agricultural Development. Each institution has principal responsibility for one or more components of the overall project.

Impact of technical staffing

When the program started in western Kenya, most U.S. institutions posted graduate students as resident scientists (RS). This action was prompted in part because of relatively restricted budgets for research personnel. The arrangement, however, appeared to benefit the RS more than the research program. The students conducted research which met the needs of their graduate degree program and therefore lacked continuity on the ground. At the same time the host institutions posted fresh graduates with general science degrees as collaborating scientists (CS). In both cases relatively inexperienced research staff, under less than rigorous supervision, were responsible for day-to-day implementation of the research program. This is now recognized as having been an error in staffing strategy.

These shortcomings were corrected with the posting of postdoctorates from the U.S. and promoting postgraduate training of CSs. Such changes brought in badly needed confidence in the SR-CRSP program in Kenya. Nonetheless, the change in strategy was not sufficient to create meaningful interaction with local MALD extension staff nor to lay a firm foundation in farming systems research methodologies.

However, because the principal investigators (PIs) and the host country representative (HCR) were committed to achieving the goals of SR-CRSP and the host institution, a progressive change in hiring practice led to acquisition of more experienced and internationally recognized RSs. It is this group and their colleagues, the returning graduates, who delivered the goods. Ultimately, all resident scientists in Kenya were well qualified and respected East Africans. This resulted in more credibility for the program and was evidence that qualified personnel, when given the resources, can do good and useful research.

In the current phase of the dual purpose goat program in Kenya, much of the responsibility for continuing research is being transferred into the KARI structure. This has resulted in the release of several resident scientists who must move on to other challenges now. Over half of the collaborating scientists have moved to other assignments within Kenya. Because of their good training, they have been very marketable. Their departure from SR-CRSP activities must be seen positively, for they are still engaged within the country and in jobs that support propagation of SR-CRSP and KARI's general objectives in animal agriculture.

Research implementation

A farming systems research approach was chosen because it was regarded as the most relevant to the needs and resources of smallholder farmers in western Kenya. At the time there were few instances where a systems approach was being used in animal-oriented research. The approach created much interest as the methodologies evolved from a theoretical base to field experience. In retrospect it can be seen that the research program was implemented in three phases.

Phase one

The first phase was from 1980 to 1982. It involved selection of the target villages and farmers, who were subjected to surveys aimed at characterizing the social, economic, and biological activities of western Kenya farming systems. In the interim, the on-station front was engaged in the development of a research base for solving KDPG constraints in breeding, health, and nutrition. The farming systems research strategy applied in western Kenya is presented in Figure 1.

Phase two

The second phase lasted three years, from 1983 to 1985. This phase continued, to a lesser extent, with research-base development and in-depth analyses using formal diagnostic surveys. The larger part of the work involved monitoring limited numbers of KDPGs on farms under scientist management; on-farm trials

in maize and fodder agronomy, KDPG nutrition, and animal management; and conducting preliminary cost-benefit and social feasibility analyses.

Phase three

The final phase, 1986 to 1992, involved 150 farms in a technical, economic, and social evaluation of KDPG production systems under farmer management. Adaptive research, workshops, and field days for farmers and extension staff continued during this phase but were less prominent. And finally, production of a manual on on-farm research and technology for dual- purpose goats was produced, printed, and released.

Constraints identified

As the result of literature reviews, surveys conducted, and critical observations in the western Kenya production systems, several constraints to the creation, introduction, and productivity of KDPGs were identified. The four most limiting researchable constraints related to feed shortages, diseases, scientific-driven management strategies, and genotype.

Feed shortage

During the early years of the SR-CRSP in western Kenya, a solution, along classical lines, was proposed for grazing area improvement and production of forage and fodder. This focus and strategy did not go very far because feed shortages were due to the dwindling land areas reserved for livestock. Therefore there were fewer and fewer areas that could be allocated and planted to forages alone. "Pastures" and forage plots were non-starters. Land previously reserved for livestock was taken for crop production. As crop production gained importance, because of a rapidly increasing human population, research towards overcoming feed shortages had to refocus on integrated feedstuff production from crop-livestock farming. This approach was much more in tune with the on-farm situation.

Maize as a staple food crop plays a major role in western Kenya. Research with this crop paid handsome dividends, but was not without controversy since many scientists believed it had no place in animal science oriented research. The addition of a food crop agronomist to the team was also questioned by some. Nonetheless, research studies confirmed that defoliation of lower-most leaves after tasselling produced good quality feed for KDPGs without affecting grain yield. Table 1 contains information on how much green fodder is available from this practice on different land sizes. As crop residue, maize provides stover which has proven to be adequate for maintenance requirements of does.

Table 1. Production of defoliated maize leaves per plot and KDPG feeding days.

Maize plot size (ha)	Defoliated leaves production potential (number)	Dry matter yield (kg)	Potential feeding days for a 40 kg doe producing 0.7 kg milk per day	
			per season	per year
1.0	460,860	1,437	1,105	2,210
0.5	230,430	719	553	1,106
0.25	115,215	359	276	552
0.1	46,086	144	111	222

Source: Semenye et al., 1992.

As an outcome of this on-farm and on-station research, it is now recommended to tie the production cycle of KDPGs with maize production so that the last trimester of pregnancy in dual purpose does coincides with maize thinnings, lactation with defoliation, and the non-lactation period with stover availability. Other crops studied and found to contribute to the KDPG feed pool were cassava, pigeon pea, banana leaves, and mango and banana peelings.

Low kid growth and unacceptable mortality rates due to starvation created major concern among scientists and farmers alike. The problem was caused by inadequate milk production by does or excess consumption by the household. To resolve this constraint, we experimented with sweet potato vines and leaves and found them to be an appropriate milk replacer. Table 2 illustrates the benefits from using sweet potato vines and leaves as a milk replacer. An indigenous creeper (*Tylossema fassoglensis*), commonly found growing on trees and fences, also has been found to be an equally effective milk replacer.

Table 2. Comparison of kid growth and milk off-take under two management systems.

Management system	Birth wt.	Kid age (days) 30	60	90	120	Milk offtake (kg)
Total suckle (kg)	2.9	4.9	4.6	5.6	7.3	nil
SE	0.2	0.3	0.6	1.1	1.5	
Weaned on SPV[a] (kg)	2.4	6.3	6.6	8.4	7.9	87
SE	0.3	0.6	0.8	1.0	1.1	

[a]SPV=Sweet potato vines
Source: Semenye and Hutchcroft, 1992.
Notes: N = 8 in each management system. SE = standard error.

Diseases

Diseases and ailments ranked in order of economic importance were pneumonia, helminthiasis, ectoparasitas (mange and ticks), diarrhoea and scours, abscesses, trauma, and wounds. Pneumonia, which is caused by *Pasteurella*, other bacterial pneumonias, and by *Mycoplasma* is the number one killer of KDPGs. For pneumonia and other diseases no research was done except for interventions associated with the elimination of predisposing conditions, and vaccination in some cases. For *Mycoplasma* pneumonia, which causes contagious caprine pleuropneumonia (CCPP), a sister project has developed an effective vaccine.

For the second problem, which is helminthiasis, the main endoparasite was *Haemoncus contortus*. Although the universal remedy of preventive dosing is effective, research on options for reducing dosing frequency was done. Results indicated that wilting fodder in the sun before offering it to goats reduced fecal egg count in the animals and promoted dry matter intake. Lower egg counts suggest that reduction in drenching frequency would be indicated. The result for farmers is a savings on antihelmintics and higher performance in the goats. Helminthiasis also was controlled through "cut and carry" whereby KDPGs were fed indoors in a goathouse.

With regards to ticks, conventional wisdom calls for dipping whenever ticks are found, on a weekly or monthly frequency. After typing of ticks in the study area, it was determined that ticks on KDPGs did not transmit tick-borne diseases. Therefore suggestions were made that regular dipping were unnecessary. Although this resulted in a savings of acaricide purchases, it resulted in a major mange infestation problem. Resumption of dipping at weekly intervals did not contain the mange mite. It was only when ivermectin was used that mange infestations were brought under control. Today, only sporadic cases of mange occur and are effectively contained by single treatments using ivermectin. Other diseases and ailments were controlled through standard regimes.

Management

On smallholder mixed farming systems, animal and crop agriculture are complementary. Yet resource-poor smallholders are not fully conversant on how to capitalize on this complementarity. For western Kenya farmers, the situation was further complicated by the introduction of KDPGs. In recognition of this constraint in visualization, a model farm was established on station to demonstrate the usefulness of production system interventions on small crop-livestock farming holdings in sustainable agriculture. Food and feed

crops were planted for maximum output and benefit to each other. The model farm was environmentally friendly, in that no pesticides or inorganic fertilizers were used. Land fertility was sustained by manure produced from four does attached to the farm. The food and feed output of the farm is presented in Table 3. Two routine management calendars were developed; one centered on the maize crop and the other on the climate. Other managerial aspects dealt with tethering strategies, feeding order, and mode of presentation of fodder.

Table 3. Food and forage output from a model farm on-station.

Size:	1/2 ha
Food crops:	Maize, beans, and sweet potato
	Area taken 60%
Forages:	Napier grass, Leucaena, Sesbania, Calliandra
	Area taken 40%
Food production:	1,908 kg or 21 (90 kg) bags maize
	50 kg dry beans
	273 kg sweet potato tubers
Forage production:	26 kg DM fresh maize thinnings
	505 kg DM fresh maize leaves
	5,286 kg DM sundried maize stover
	53 kg DM bean haulms
	2,526 kg DM fresh Napier grass
	1,303 kg DM fresh Leucaena, Sesbania, and Calliandra
	80 kg DM fresh sweet potato vines

Source: Adapted from Onim et al., 1990.

Genotype

The indigenous goat in western Kenya is the East African Goat (EAG). The breed is very hardy and well adapted when given the opportunity to be selective in eating and serves as a suitable source of meat, cash, and barter. It does not provide a reliable source of milk for people nor is it as fast-growing as other breeds. Initial attempts in western Kenya to develop production systems utilizing dairy goats were less than well accepted. To close the production gap, the SR-CRSP has developed a synthetic breed composed of equal proportions of two selected and adapted local goats, the East African and Galla, and two exotic dairy goats, the Toggenburg and Anglo- Nubian. Prior to the availability of the composite KDPG it was necessary for the western Kenya on-station and on-farm trials to use first-cross Toggenburg and East African goats as dual purpose composite proxies.

Have the objectives been met?

The objectives of the SR-CRSP in western Kenya have to a major degree been met. Research was conducted with KDPGs in an effort to increase production of high quality food through milk and meat production and to improve household cash flow through marketable goats and goat products. Efforts in training have resulted in farmers who are more knowledgeable on dual purpose goat production systems, and a cadre of young Kenyan and American scientists have gained valuable field experience in the application of farming systems research methodologies.

In the case of meat provision, KDPGs grew faster than the local goats so that at one year of age they weighed 16.4 SD 5.0 kg as compared to local goats at 10.2 SD 1.4 kg, under field conditions. This represents a positive change of 60% in meat produced and potential sale value. For milk production there has been a total change in product availability, because previously, farmers did not regularly milk their local goats. For milk off-take from dual purpose does the basis of comparison used by farmers has been local cows.

During a lactation period of 60 days, farmers averaged 30 kg milk per KDPG doe and 90 kg per local cow. Therefore the same amount of milk would be yielded by three KDPGs as from one cow. Given the fact that maintenance requirements of a KDPG doe are approximately one-fifth those of a local cow, then an equivalent amount of milk is given for 60% of the maintenance cost. This represents a significant improvement in feed utilization.

At the point of sale KDPG does have received a premium because of their size and milk production potential. Data collected from 1984 to 1992 revealed that KDPGs fetched Kenya Shillings (KSh) 100 to 650 and local goats KSh 100 to 400 at the farm. Proceeds from sales have been used to purchase farm inputs and meet family needs such as medical expenses and school fees.

Production of manure by KDPGs, at the rate of 130 kg dry matter/head/year, has enhanced food crop production, especially on the red, acid soils in the area, and reduced expenditures on inorganic fertilizers that might otherwise be purchased.

In the process of being involved in conducting on-farm research, the 150 target farmers have adopted many of the interventions and technologies tested on their farms. The adoptive probabilities of these technologies are presented in Table 4.

Table 4. Aggregate adoptive behavior of farm households: KDPG technology in western Kenya, 1990.

Innovations	Probability of adoption (%)
Growing napier grass	11.36
Tethering	10.73
Growing sesbania	10.56
Sweet potato vines	9.37
Growing leucaena	9.29
Hanging vines	8.35
Milking KDPGs	8.26
Feed supplements	7.63
Model farm	6.44
Production records	5.52
Steaming up	4.79
Flushing	4.57
Housing	1.54
Health records	1.52

Source: Sheikh 1992.

Measurable impact

Free discussions with and among collaborating farmers during workshops and meetings resulted in the exchange of views concerning the pros and cons of KDPG production system technologies. Since 1986 major annual workshops have been held in the target districts, while many small-group meetings have been convened as needed. Farmers were encouraged to invite neighbors to these workshops and meetings. Therefore completion of the final steps in the research process set the stage for establishing more effective extensionist- to-farmer linkages and put farmer-to-farmer extension efforts in motion. This kind of local information exchange and technical support represents the essence of sustainability.

Over 465 extension specialists, teachers, researchers, and politicians were hosted at Maseno, located on the equator in western Kenya. These collaborators helped create goodwill and facilitated the promotion of KDPG production systems. SR-CRSP owes its long tenure and funding to the results that have been achieved and to the personal initiatives of some of the visitors.

Through the western Kenya program, Kenyan and U.S. citizens have obtained six M.S. and four Ph.D. degrees. Seven internships have been provided with professional guidance and suitable accommodation. Seventy workshop papers, 15 refereed papers, 7 chapters in books, 5 articles in magazines, and 1 extension manual have been completed. Late last year a book documenting on-farm research methodologies, and a technology package for dual purpose goat production systems, was printed. All resident scientists and principal investigators had a hand in writing portions of the book.

Through their radio and television facilities the Kenya Broadcasting Corporation has recorded and broadcast many programs related to the SR-CRSP initiative. The most recent one was on KDPG technology packages, which has been televised twice to an estimated audience of over 200,000 people. In conjunction with the University of Missouri and Good News Publications, International, nearly two hours of finished video tape has been produced on KDPG technology packages for local and international viewing. Copies of the video tapes are distributed on request to agricultural institutions in Kenya.

In conjunction with the government body responsible for livestock development, over 50,000 participants have benefited from agricultural show exhibitions and field day demonstrations on KDPG husbandry and technology packages. Since 1985 demonstrations have been staged at Kisumu, Kakamega, and most recently at the annual Siaya and Nandi shows.

The most telling evidence of SR-CRSP research impact in western Kenya is the extremely high demand for KDPGs. While demand is high, supply has been extremely limited. The mandate of the production systems research group in western Kenya was on identifying constraints, sharing this information with appropriate project staff, and conducting experiments on selected interventions. Dual purpose goat multiplication was not a major part of this since the breeding subproject was given that mandate.

In light of this situation, the SR-CRSP in Kenya is redirecting its efforts towards establishment of multiplication centers in western and other parts of Kenya. The centers are most often located at existing facilities and the work done through existing government or nongovernment organization programs. So far, four centers have been established in western Kenya. More will be identified country-wide during the period 1993-1995. Impact of dual purpose goat production systems is being monitored at these sites.

Literature Cited

Onim, J. F. M., K. Otieno, and H. A. Fitzhugh. 1990. Productivity of 0.5 ha model farm for small scale crop-livestock farmers in a sub-humid ecozone. Proceedings of the 8th SR-CRSP Scientific Workshop, 7-8 March, 1990, ILRAD, Nairobi, Kenya.

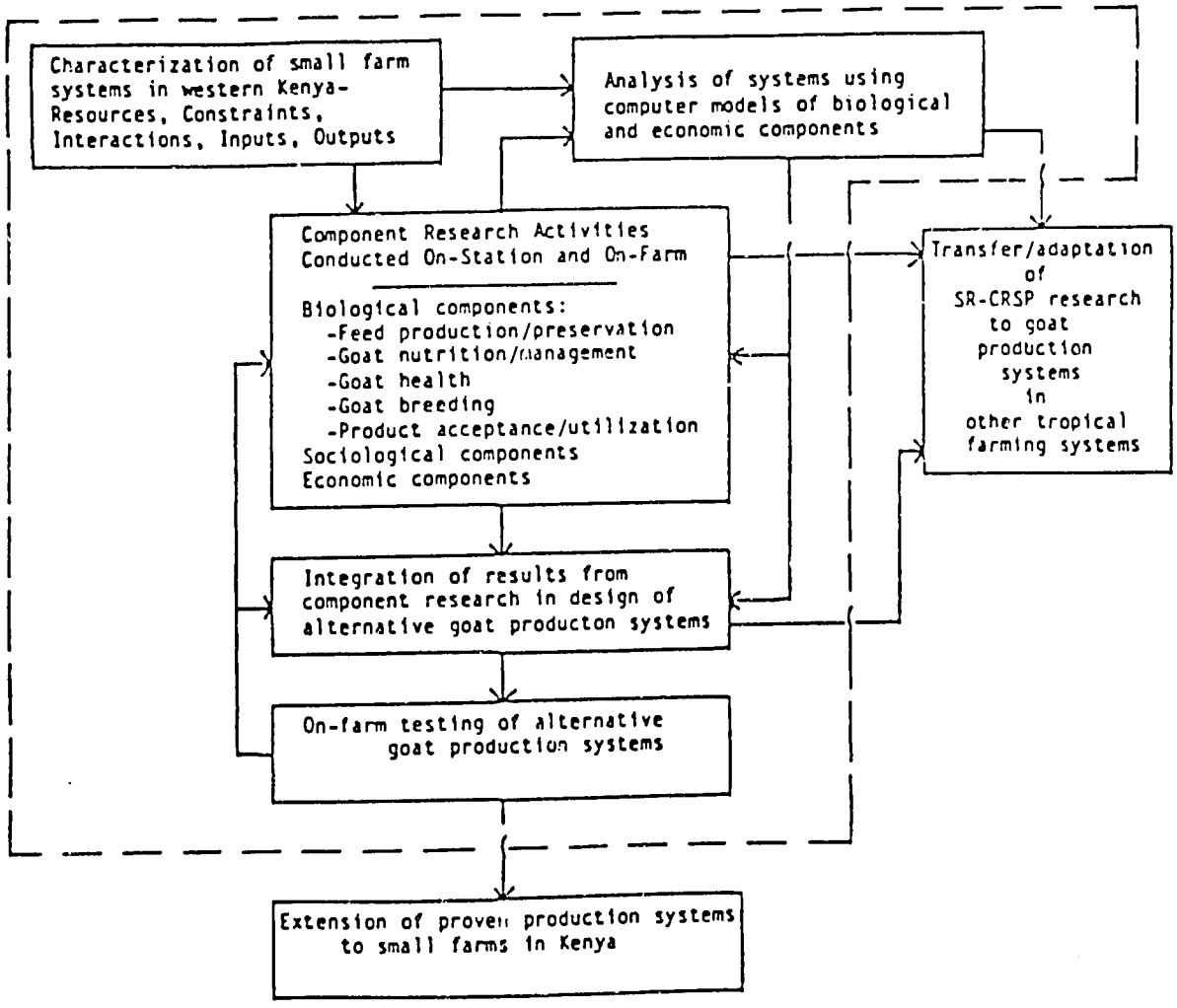
Semenye, P. P. and T. Hutchcroft (eds.). 1992. On-farm Research and Technology for Dual-Purpose Goats. Small Ruminant Collaborative Research Support Program, Kenya.

Semenye, P. P., M. Shisya, and W. R. Getz. 1992. Overcoming dual purpose goat production constraint of dry matter intake by feeding defoliated maize leaves. Paper presented at the Second Biennial Conference of the African Small Ruminant Research Network, 7-11 December, 1992, Arusha, Tanzania.

Sheikh, D. 1992. A study of the adoption of dual purpose goat technology by small-scale farmers: a case study of western Kenya. M.Sc. thesis, Clemson University, USA.

Sidahamed, A. E., J. F. M. Onim, A. W. Mukhebi, R. S. Shavulimo, A. J. De Boer, and H. A. Fitzhugh. 1985. On-farm trials with dual purpose goats on small farms in western Kenya. Proceedings of the Workshop on Research Methodology for Livestock On-farm Trials, Aleppo, Syria.

Figure 1. Implementation strategy for SR-CRSP research activities involving dual-purpose goat production systems for small farms in Kenya.



Source: Adapted from Sidahmed et al.(1985)

The SR-CRSP in Kenya, 1980-1993: Achievements and Impacts

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Abstract

The Small Ruminant CRSP's contribution to Kenya's agricultural research could be categorized into three broad areas: institution building, scientific advancement, and improved welfare of the smallholder farming community. With respect to institution building, all projects have had significant training program and important programs of development of physical facilities for research. Considering scientific advancement, research breakthroughs in the various disciplinary lines are noteworthy. Among these include: development of the Kenya Dual Purpose Goat, development of vaccines and diagnostic tools, and development of appropriate technology packages for Dual Purpose Goat production under smallholder management systems. The pioneering role of institutionalizing multidisciplinary research and on-farm trials is also an important contribution to applied agricultural research. Last, but not least, is the contribution of the program to the welfare of the smallholder farming community. Since the early 1980s, the program has worked with a total of 150 farm families in western Kenya. These farmers were allocated dual purpose goats and the supporting production technology to facilitate on-farm, farmer-managed trials.

Introduction

As Director of the Kenya Agricultural Research Institute (KARI), I am intrigued by the unity of thought between KARI's mission and that of the SR-CRSP, as embodied in the International Development and Food Assistance Act of 1975 , United States Congress (1). As many of you know, included in the Act was *Title XII: Famine Prevention and Freedom from Hunger*, aimed at engaging U.S. institutions of higher learning in scientific research and training in the area of food production in the developing countries. The rationale for this effort was to move away from food aid the in form of hand-outs to a more production oriented system, where-by aid recipients would develop their own capacity to meet food self-sufficiency. We at KARI are striving to attain this same goal–to assist Kenya in achieving food self-sufficiency by generating appropriate agricultural technologies through scientific research. Needless to say, KARI and the SR-CRSP are on the same side in this endeavor.

This paper attempts to highlight achievements and impacts of the SR-CRSP in Kenya since 1980. Those of you who have attempted to measure the impacs of agricultural research will appreciate the difficult task before me. The task is particularly complicated by the complex nature of the SR-CRSP itself. The Program activities in Kenya entail several U.S. based institutions, each responsible for project specific activities under the same management. These institutions include: Washington State University/Colorado State University (Animal Health); Winrock International (Production Systems/Economics); Texas A&M University (Breeding); and the University of Missouri-Columbia (Sociology). I will address achievements and impacts of the respective projects separately.

Breeding project

Over the years, the breeding project has been developing a synthetic breed of Kenyan dual-purpose goat (KDPG) to meet requirements of small-scale farm families. This synthetic goat is composed of equal proportions of two selected and adapted local goats, the East African and Galla, and two exotic dairy breeds, the Toggenburg and Anglo-Nubian. The objective is to build a goat that has acceptable milk yield, a fast growth rate, high fertility, and is highly adaptable to various agro-ecological zones where small-holder farming enterprises are prevalent. The KDPG can also be bred and adapted to the low-production potential areas by varying the proportions of exotic and local genes. It is hoped that a KDPG society with the Kenya Stud Book will be established to enhance community awareness of the breed.

Besides maintaining a nucleus flock for upgrading the goats to the planned synthetic KDPG, the breeding project has also provided F1 crosses for on-farm trials in western Kenya. As Table 1 illustrates, a total of 206 KDPGs (F1 proxies) have been transferred to Maseno since 1986. Some of these goats were distributed among the 150 small-holder farmers who participated in on-farm trials in western Kenya. Other goats remained on-station for controlled experiments in nutritional requirements.

As Table 1 illustrates, the breeding project has availed some KDPGs to the farmers through sales. Beginning in 1986, a total of 165 KDPGs were sold for breeding, and 374 were culled for slaughter. Follow-up studies indicate that a proportion of the culls were used as breeding materials by the farmers. The project has exhibited the KDPG technology in the Nairobi International Show on an annual basis.

Having developed and tested the KDPG techpack on farms in western Kenya, plans are underway to conduct similar on-farm trials in other ecological zones of Kenya. Towards this end, the breeding project plans to avail four-way crosses for on-farm trials in a dry-land farming area and in the humid coastal zone.

Training

The breeding project has accomplished a lot in training Kenyan research scientists. In the period under review, the project has supported KARI employees for in-service training as follows: two for B.Sc. training, four for master of science degrees, and one Ph.D., respectively. There is one more currently under MSc training.

Production systems (nutrition and management, feed resources)

Over the years, the production systems component of the project has evolved into a two-pronged program. One is geared towards development and preservation of suitable feed resources for small-holder farmers. The other, addresses nutrition and management issues of small ruminant production in small-holder production systems.

Studies conducted under feed resources sub-components include: screening forage crops from various parts of Kenya and other tropical countries to determine their suitability for western Kenya conditions; determination of production and utilization potentials of Sesbania *sesban* as a forage for small-ruminants under small-holder conditions; selection of sweet potato cultivars best suited for fodder and food production; development of appropriate silage and hay baling techniques for resource poor farmers; and evaluation of one fertilizer value of goat manure for food and feed crops under small-holder conditions.

Under the nutrition and management sub-component, studies conducted include: palatability ranking and nutritive analysis of commonly used forages in western Kenya; quantification of feed resources available for livestock throughout the year; evaluation of the effect of wilting grass on helminth larvae infestation and dry matter intake among dual purpose goats; development of appropriate nursing regimes in dual purpose goats; and refinement of tethering management (type and length of rope, tethering stations, and pattern of tethering).

Overall, the production systems project has addressed basic questions concerning small-ruminant production under small-holder management conditions. Considering how pervasive small-holder production systems are in Kenya, and in view of the widespread small-ruminant stock among this category of farmers, it is clear that the technology package emanating from this work has very far-reaching effects on the farming community in Kenya. In any case, the on-farm research activities conducted by the production systems

Table 1: DPG Distribution from Ol'Magogo (Breeding Project)

		1985			1986			1987			1988			1989			1990			1991			1992			1993			Total		
		TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC	TM	SB	SC
EA 0001	Does	-	-	-	1	-	13	-	-	21	-	-	1	-	-	5	-	-	70	-	-	8	-	-	5	-	-	-	1	-	123
	Bucks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	6	-	-	-	-	-	4	-	-	-	-	-	10
G 0002	Does	-	-	-	2	-	9	-	-	21	-	-	1	-	-	6	-	-	88	-	-	11	-	-	26	-	-	1	2	-	163
	Bucks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	1	-	-	-	-	-	-	-	-	3
F1s	Does	-	-	-	108	-	-	-	-	9	-	-	-	12	-	-	-	-	39	-	-	8	-	-	6	-	-	-	120	-	62
	Bucks	-	-	-	31	-	-	-	-	8	-	-	-	46	29	-	-	77	-	-	14	-	-	11	-	5	-	5	82	131	13
Four-ways	Does	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	1	-	-	-	-	-	1	-	-	-	-	2	-
	Bucks	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	7	-	-	3	-	-	4	-	-	-	-	-	16	-
T 0003	Does	-	-	-	1	-	-	-	-	-	-	-	-	-	-	-	-	8	-	-	1	-	-	-	-	-	-	-	1	9	-
	Bucks	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	2	-	-	-	-	-	5	-	-	-	-	-	7	-
Total		-	-	-	143	-	22	-	-	59	-	-	2	58	31	11	-	94	206	-	18	28	-	20	42	5	-	6	206	165	374

Key:

TM	=	Transfered to Maseno
SB	=	Sales for Breeding
EA	=	East Africa
T	=	Toggenburg
SC	=	Sales for Culling
G	=	Gallas

project among 150 small-holder farmers in western Kenya leave behind farmers well acquainted with the dual purpose goat technology. In collaboration with the breeding project, nucleus KDPG herds have been established at Bukura Institute of Agriculture, Lumigo Women Group, Government Prison farm at Kibos, and Siaya Livestock Multiplication Center. Furthermore, in collaboration with the Ministry of Agriculture, Livestock Development and Marketing, the program has conducted field days as well as exhibited dual purpose goats and the supporting management packages at the local agricultural shows since 1985. It is estimated that over 50,000 people have been exposed to the program activities through these channels.

Training

So far, the production systems project has supported four KARI research officers for master of science degrees and one for Ph.D. studies. In collaboration with ILCA, the project has supported one KARI officer for a short course in forage agronomy,and another for small-stock production. The project has also hosted undergraduate students from various universities for internships (four from Egerton University; two from University of Eastern Africa, Baraton; and one from Cornell University). In the last two years, primary and secondary school students have visited Maseno at the average rate of one school per month, to learn about goat production and related aspects.

Animal health project

In the period under review, several important successes in disease diagnosis, disease control, and manpower development have been achieved by the Animal Health component of SR-CRSP. In the area of disease diagnosis, development of highly sensitive and specific reagents for detection of animals infected with contagious caprine pleuropneumonia (CCPP), heartwater, and anaplasmosis, respectively, have been developed. These include: a rapid diagnostic kit for CCPP using purified antigens; a monoclonal antibody highly specific for F38, the mycoplasma that causes CCPP; a DNA probe for detecting *Cowdria ruminantium* in ticks and infected goats; and a DNA probe for detection of *Anaplasma ovis* in goats in Kenya. These highly specific and sensitive diagnostic reagents allow for the unequivocal identification and characterization of highly infectious agents of small ruminants. A number of these products have the potential for use as reference typing reagents in many parts of the world. For example, in the identification of F38 only the monoclonal antibody developed by the SR-CRSP is taxonomically relevant.

Using the animal health facilities developed in KARI in collaboration with the SR-CRSP, it has been possible to establish the presence of caprine arthritis encephalitis virus in goats imported to Kenya. Selected studies have identified potential management practices that could allow introduction of goats in areas infested with trypanosomiasis and to define areas in Kenya that require feed supplementation with selenium. All these achievements have allowed for a better management of healthy flocks of small ruminants.

In the area of animal vaccines, the Animal Health project has been in the forefront, both in conventional as well as in contemporary strategies for vaccine development. An inactivated CCPP vaccine has been developed and shown to be efficacious in on-farm trials. The shelf-life of the vaccine has been extended by lyophilization. This vaccine, when properly used at the recommended regimen, is highly effective. Other strategies being used include the development of a multivalent virus-vectored vaccine for small ruminants using the sheep and goat poxvirus, as the carrier. Such vaccines will be endowed with the thermostability of the poxvirus thus eliminating the need for maintaining a highly expensive cold-chain. Towards this end, a recombinant capripox virus has been developed carrying the Rift valley fever virus (RVFV) gene that encodes for antigens important in protection against infection with RVFV. The protective efficacy of this recombinant vaccine will be tested in animals under a controlled environment. Similar work on Nairobi sheep disease virus is going on. A complemetary deoxyribonucleic acid (cDNA) library has been constructed and the project is in the process of identifying the relevant vaccine genes for incorporation into a capripox virus vector. In addition, collaborative research with U.S. universities has led to the isolation of ovine lentivirus and demonstration that it is economically important in wool sheep production in parts of Kenya.

Training

In the area of manpower development the project has made significant achievements as nine researchers have completed their M.Sc. and one researcher has obtained his Ph.D.. Currently, there are two researchers on M.Sc. and three on Ph.D. programs, respectively. All the scientists trained in this program are involved in gainful research and we are proud of this achievement.

Socio-economics (sociology and economics)

Sociology

The main responsibility of the Sociology component in the SR-CRSP, so far, has been to assess the social acceptability of the dual purpose goat package in western Kenya. To accomplish this task, the project has conducted both micro-studies focusing on the farmer in the study area and macro-studies to contextualize the place of participating farmers in the broader regional and national politico-economy.

Baseline survey

At the beginning of the project activities in western Kenya, a survey was conducted to identify the role of the goat in the farming systems of the region. In general, the study indicated that farmers were familiar with the goat, but that it was neither a preferred source of meat, as compared with sheep, nor a conspicuous source of milk. However, it was recognized that food habits are never constant. Thus, given the population pressure in the study area, it was hypothesized that the cow would slowly be phased out and that alternative sources of milk would be welcome. In this sense, the KDPG was considered an invaluable alternative for the study area.

Extension studies

In anticipation of the KDPG techpacks, the question of how best to deliver the package to farmers was raised. With this in mind, a study was conducted to assess the capacity and capability of extension officers to deliver the anticipated SR-CRSP technology. The findings indicated that livestock extension awareness in the study area was scanty and that to many of the extension staff, a dairy goat was not a familiar concept. The livestock extension service was also hampered by many logistical problems. A major recommendation emanating from this study was to caution the SR-CRSP to recognize this problem and try to develop a techpack that was as "user friendly" as possible. It was also recommended that the SR-CRSP try to involve the extension staff in the project area in their out-reach activities, such as farmers' workshops, field days and other learning fora in order to familiarize them with the emerging technology.

Diet and milk consumption survey

To assess the role the KDPG would play in the lives of the participating farmers, a study was conducted to examine dietary patterns, with a view to highlight the specific role that milk played in the nourishment of the participants. The findings indicated that in all households examined, milk was the major source of dietary protein. For example, in the Hamisi cluster, milk was found to be the only source of animal protein consumed on 50% of the survey days (24-hour dietary recall). Many households were found to purchase Kenya Creamaries Cooperative milk to meet their needs. In this context, it was envisioned that the KDPG, as a source of milk, was destined for an important role in the nutrition of communities in the project area.

Labor requirements for livestock rearing and for the KDPG in particular

Given the recommended intensive management techniques for the KDPG and considering the on-going exodus of men from the study area in pursuit of wage labor and the absence of school-going children from on-farm activities, it was considered that labor shortage could cause problems in the management of the KDPG. In this context, a study was carried out to assess the situation. The findings indicated that, in addition to an increase in the overall labor requirements for livestock, the adoption of intensive management techniques for KDPG increased the share of work that is the responsibility of women. However, women still retained some reasonable leisure time, part of which could be spared for KDPG production, depending on how much utility they attributed to the exercise.

Integration of Western Kenya into Kenya's agrarian sector

In order to understand the character of the agrarian social structure in the study area, a historical study was undertaken to highlight the circumstances under which the region was integrated into the broader national political economy. The findings indicated that little capital investment has been made in the study area over time, and thus the agrarian social structure has not consolidated itself adequately to influence agricultural policy in their favour.

Under these circumstances, the agricultural sector has not been able to retain labor in the region, hence, the historical male out-migration from the region. This explains why, as mentioned above, the SR-CRSP has had to deal predominantly with women farmers in the study area.

Techpack evaluation in the study area

Studies conducted to evaluate the viability of the SR-CRSP techpacks (KDPG and the supporting production package) in western Kenya indicate that they are particularly attractive to farmers in the higher elevation clusters. These are the areas where population pressure is very intense and rainfall is reliable. In the lower elevation clusters, where average land sizes per household are still large and rainfall much more scarce, the techpacks have been received very reluctantly. The lesson to draw from this finding is that the current SR-CRSP techpacks are most likely to be accepted in areas where intensification of agriculture is already taking place or is a viable proposition. Also, given the current production figures, the KDPG may be acceptable in areas where farmers are not particularly commoditized.

A study conducted following the withdrawal of SR-CRSP support in the study areas indicates that, whereas recommended production practices were retained more in the high altitude areas, the KDPG appears to have been retained more in the lower elevation areas. This double-edged finding supports pilot trials for the KDPG techpack in both humid and dry-land farming areas. In this spirit, KARI in collaboration with the SR-CRSP is in the process of establishing two new sites for the KDPG in Kenya: dry-land farming at Katumani and the humid coastal environment at Mtwapa centers, respectively. In both sites, the socio-economics project will assess the viability of the KDPG techpack –production systems and health intervention strategies.

Contagious Caprine Pleuropneumonia (CCPP) vaccine

CCPP vaccine has been available for use since 1987, yet its integration into the disease prevention and control system has been limited. In view of this, the SR-CRSP conducted a socio-economic study to identify constraints to production and delivery of the vaccine. The findings of the study indicated shortfalls in the production process. This was partly attributed to the relative value given to small ruminant production, as compared to cattle production in Kenya. In response to this apparent policy bias, studies are planned to assess the socio-economic value of small ruminants at both the macro and micro levels. Hopefully this will help settle the controversy.

With respect to distribution of the vaccine, the findings indicate that certain endemic areas are not receiving enough of the vaccine, even when there are reported outbreaks.

The problems in vaccine production and distribution emanate from the complex arrangement, organization, and authority of the institutions involved in vaccine research, production, and delivery. The institutions involved in all of these facets are currently working out modalities of streamlining the deficiencies in vaccine production and delivery.

Training

With respect to training, the Sociology project has supported one M.Sc. candidate, provided research funds for one KARI officer to carry out field work for M.S. thesis, and funded two Ph.D. students.

Economics

The challenge to the Economics project was to assess the economic viability of the KDPG technology. The most commonly used methodologies to accomplish this task included: partial budgeting analysis, enterprise budgets and gross margin analysis, and whole farm modeling.

Economics of forage production

Economic analysis of forage production as developed to support KDPG production in small-holder farm situations arrived at the following recommendations:

- Always inter-crop maize with forages or dual-purpose crops,
- Farmers who do not use fertilizers should inter-crop maize with leguminous forages such as sesbania or pigeon peas,
- Maize-Sudan grass and pigeon pea inter-crops should be used by farmers who apply fertilizer.

Economics of kid-feeding practices

Subjecting recommended kid-feeding practices to economic analysis, the following findings were obtained: when a forage supplement is not available, feeding only the dam's milk generates the highest economic returns. Feeding kids with one-half the doe's milk provides the second best return. When forage supplement is available, feeding one-half of the doe's milk is the superior practice.

Linear programming models for whole farm planning

The project utilized linear programming models to evaluate the economic feasibility of the KDPG and supporting technologies. The model was also utilized to assess impacts on existing farming systems. Considering small-holder farmers in western Kenya, this analysis concluded that the most profitable food-forage associations included: maize, beans, pigeon peas, and maize inter-cropped with sudan grass. The model assumed that all male kids and females not retained as flock replacements would be sold in order to maximize farm cash income. In order to sustain the high management levels required to make the KDPG enterprise profitable, credit facilities were considered necessary.

Multinomial logit model to determine adoption rates

Using a multinomial logit model, the project determined adoption rates of the various elements of the recommended KDPG technology. The results of this analysis indicated that adoption rates were higher for the elements of the techpacks requiring low capital investment and (or) low human capital. This finding corroborates the previous study which underscored the need for credit facilities if the high management levels required to make the KDPG enterprise profitable were to be attained.

Training

In keeping with the SR-CRSP objectives, the Economics project trained one Kenyan scientist at the Ph.D. level, and supported a KARI research officer in conducting field research work in Kenya for a M.Sc. The latter student is currently engaged in strengthening the socio-economics research program at KARI.

Conclusion

In summary, the SR-CRSP's contribution to Kenya's agricultural research could be categorized into three broad areas: institution building, scientific advancement, and improved welfare of the small-holder farming community.

With respect to institution building, it is noteworthy that all projects have had significant training programs. The impact of this human resource development can be identified not only within KARI, but also in other institutions of higher learning in Kenya and elsewhere. The program has also made significant contributions to the development of physical facilities for research. The current capacity in the Kabete veterinary laboratories speaks well on this point. So do the facilities at Ol'Magogo and Maseno.

With respect to scientific advancement, research break-throughs in the various disciplinary lines are well noted. Among these include: development of the KDPG, development of vaccines and diagnostic tools, and development of appropriate production packages for KDPG production under small-holder management systems. The pioneering role of institutionalizing multi-disciplinary research and on-farm trials is also an important contribution to applied agricultural research. The numerous publications under the SR-CRSP–workshop proceedings, journal articles, management handbooks, book chapters, and even video recording of the research highlights–all contribute to the wealth of knowledge in small-ruminant production.

Last, but not least, is the contribution of the program to the welfare of the small-holder farming community. Since the early 1980s, the program has worked with a total of 150 farm families in western Kenya. These farmers were allocated dual purpose goats and the supporting production technology to facilitate on-farm, farmer-managed trials. In the final analysis, besides assisting in fine-tuning the KDPG techpack, these farmers also became acquainted with, and enjoyed the benefits of, the new technology. Through various out-reach activities, the program also distributed KDPGs and the supporting production packages on a trial basis. In this vein, the program in collaboration with KARI is now in the process of establishing two new sites for more expanded trials to assess the impact of the KDPG technology.

Literature Cited

Small Ruminant CRSP Report: A Joint Venture between the United States Agency International Development and Agricultural Research Institutes in the United States and Overseas, prepared by the Management Entity Office, Davis, California, USA. p.2.

Gender Differences in the Adoption of Dual Purpose Goat Technological Practices

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Introduction

The Kenya dual purpose goat (KDPG) technology was developed for the small holder to counter high population pressure and diminishing land sizes that can no longer maintain herds of cattle. There has been male out-migration from the small scale farms to urban areas in search of jobs (Mbabu, 1988). This has led to females taking traditional male roles including heading households and managing the farms.

The objectives of this study are 1) to assess any differences in adoptive behavior of male and female farm operators with respect to specific dual purpose goat technology items, 2) to assess whether there is gender division of labor with respect to KDPG production, and 3) to find out whether gender division of labor could be one explanation of the differential adoptive behavior of male and female farm operators.

Methodology

Data for this study was gathered in form of a questionnaire survey in which sixty-six farm households in Kenya were interviewed in 1990. Data from a 1992 survey of seventy households was also used. A multinomial logit model was utilized to categorize the farmers on the basis of demographic, farm, and household characteristics and the probabilities of adopting specific KDPG technologies items estimated. The probability of adopting each of the dual purpose goat technology items was predicted using a common set of explanatory variables. All the explanatory variables were categorical and included: farm size (large, over one hectare and small, at least one hectare), farm income (farm income under half total household income, farm income at least half total household income), sex of farm decision maker (male/female), sex of household decision maker (male/female), sex of household head (male/female), and age of household head (at least 50 years and over 50 years). Frequencies in the form of percentages were worked out and presented in form of tables and bar charts for the gender-based division of labor for adult male and female members of the household. The percentage of responses (always, most of the time, rare occasions, and never) of how often specific KDPG activities are performed by male and female farm operators are presented in tables and graphs.

Results

The majority of farm households (85.7%) are headed by men (Table 1) as is expected in the Luo/Luhya communities in which the study was conducted. Half (50%) of the farms are managed by women (Table 2) which could be due to male out-migration in search of wage earning jobs or off-farm activities including trade, casual labor, etc.

Table 1. Sex of head of household.

Household Head	Frequency	Percent of Total
Male (M)	60	85.7
Female (F)	10	14.3
Total	70	100.0

Source: Own survey, 1992.

Table 2. Sex of farm manager.

Farm Manager	Frequency	Percent of Total
Male (M)	35	50.0
Female (F)	35	50.0
Total	70	100.0

Source: Own survey, 1992.

The adoptive behavior of male and female farm decision makers represents the whole sample grouped into males and females managing the small holder farms, e.g., of all the small-holder farms managed by males the probability is 10.22 percent that a random household will practice tethering (Table 3). Conversely, of all small-holder farms managed by females, the probability is 12.41 percent that a random household will grow napier grass. If all the activities were adopted equally, then the probability of adopting each of the 14 items would be equal to 7.14 percent. The probabilities of adoption add up to one in each case, as the multinomial logit model used was estimated using CATMOD procedure in SAS which has the desirable feature of giving direct and "simultaneous" estimates of the probabilities restricted to one ("simultaneous" in that all the technological items can be compared to find out which have the higher adoption rates when compared to the others).

The probabilities of adoption ranged from 10.22 percent for tethering to 0.69 percent for health records for male decision makers, and from 12.41 percent for growing napier grass to 0.74 percent for housing for female decision makers (Table 3). Female decision makers had probabilities of adoption of at least 10 percent levels for the top five techpacks concerned with feeds and nutrition. Males had probabilities of adoption of at least 10 percent in only two techpacks namely tethering (10.22) and growing napier grass (10.21).

Probabilities of adopting milking KDPGs, feed supplements, keeping production records, flushing, steaming up, and housing by male decision makers, were higher than by female decision makers. On the other hand, probabilities for growing forages (napier grass, sesbania, leucaena), tethering, hanging vines, feeding sweet potato vines, having model farms, and keeping health records were higher for female decision makers than male decision makers. It appears that female decision makers are more engaged than male decision makers in agricultural production activities that enhance productivity as indicated by the probability of adoption of model farms. The former are also engaged more in activities that require low capital and relatively lower human capital, as indicated by at least 10 percent probability levels for the top five innovations concerned with feeds and nutrition. On the other hand, innovations that require relatively high capital, including construction of housing, had higher probabilities for male decision makers.

Table 3. Adoptive behavior of male and female farm decision makers: KDPG technology Western Kenya, 1990.

Male Farm Operators		Female Farm Operators	
Innovations	Prob(%)	Innovations	Prob(%)
Tethering	10.22	Napier grass	12.41
Napier grass	10.21	Growing sesbania	11.49
Growing sesbania	9.54	Tethering	10.28
Milking KDPGs	9.02	Growing leucaena	10.08
Feed supplements	8.71	Sweet potato vines	10.04
Sweet potato vines	8.64	Hanging vines	8.56
Growing leucaena	8.42	Model farms	8.02
Hanging vines	8.13	Milking KDPGs	7.57
Production records	7.24	Feed supplements	6.65
Flushing	7.05	Steaming up	4.64
Steaming up	4.95	Production records	3.95
Model farms	4.70	Flushing	2.31
Housing	2.42	Health records	2.28
Health records	0.69	Housing	0.74

Note: The probabilities do not add up to 100 percent due to rounding errors.

Preliminary results of gender-based division of labor with respect to KDPG production activities are presented in Tables 4-13 and Graphs 1-10. Frequencies of carrying out specific KDPG activities and the percentages are presented. For forage production, the average frequencies for napier grass, sesbania, and leucaena were used. For manure use the average frequencies for the collection, piling, and spreading the manure in the fields were used.

In comparing male and female responses to how often land preparation for forage crops was performed, we found out that 76% and 24% of males and females respectively carried out this activity always (Table 4 and Graph 1). On the other hand, 49% and 51% responses (male and female) indicated that it was performed most of the time; 17% and 83% on rare occasions and 46% and 54% said it was never performed. When we compared responses to how often planting of forages was carried out, we found out that 78% and 23% of male and female, respectively, always participated in this activity (Table 5 and Graph 2). The same trend is showed in weeding of the forages, cutting the forages for feed and feeding the forages to the KDPGs (Tables 6, 7, and 8; and Graphs 3, 4, and 5), in that the male responses were more for always participating in these activities compared to female responses. The absence of the males from the farms implies that women have to carry out most of the work that the men would have done traditionally.

When we compared male and female responses as to how often sweet potatoes were cropped, it was indicated that 16% and 84% male and female respectively were engaged in this activity all the time (Table 9 and Graph 6). Comparatively more responses (63%) for females indicated that women cropped sweet potatoes most of the time as compared to 37% for male. A possible reason is that the women may be more involved than the men in food crop production. Sweet potatoes are both a food (tubers) and feed (leaves and vines) crop.

In comparing male and female responses to how often activities related to manure use (collection, piling, and spreading on the fields) were performed, we found out that 38% and 62% of males and females respectively always participated (Table 10 and Graph 7). We also found out that 30% and 70% of males and females participated most of the time and 83% and 17% of males and females never participated. Women perform the vital household duties including cooking, which takes place in the kitchen. This implies that the

use of manure may have become an extension of these duties.

Hay making (Table 11 and Graph 8) is mainly performed by the males (80% for always, almost 50% for most of the time). Females participate to some extent (80% responses for rare occasions and 50% for most of the time).

Responses indicate that males always keep records (Table 12 and Graph 9) and over 80% of females never keep them. Women keep records to a less extent than the males probably due to their having less formal education. The contradiction with respect to keeping health records (Table 3 indicates that adoption rate for this item was higher for females than for males) comes about because the records were physically kept by farmers but the actual recording was done by the field assistants or veterinarians. On the other hand, the actual recording in the case of production records was done by the farmers.

Male and female responses as to how often milking of the KDPGs was performed showed that this activity seems to be a shared task (Table 13 and Graph 10). Any person around (male or female) could perform this task.

The majority of KDPG production activities are performed by both male and females, but due to men absenteeism in search of formal employment or wage labor, this has increased the burden on women. Women may be even more involved in KDPG production activities than indicated above. This is because there could have been a bias since, of the 70 farmers interviewed, only 26 (37%) were women. The roles played by women in the KDPG production systems is also reported by Conelly and Nolan (1986), Conelly et al. (1987), and Mbabu et al. (1990).

Conclusions

A high proportion (50%) of the farms are managed by females. Due to the absence of males, females have to perform reproductive roles as well as duties traditionally performed by the men. In many farming systems in Kenya and the rest of Africa, labor is a limiting factor in agricultural activities. The farm household unit then rationally allocates scarce resources (including labor) to achieve the greater benefit, but the choices are affected by a gender-based division of labor (specific activities performed by a specific member of the household) and the work-load of the different members. The results suggest a need to reach out more to the female decision makers and increase awareness in the transfer of innovations that require human capital and also make resources more available to them. Adoption rates by female farm operators could be increased if agricultural training, information service, and education programs were reoriented to include female farm operators. The adoption rates of technological items that require higher initial capital outlays could also be increased by making credit more accessible to female farm operators.

The roles played by different members of the household in other activities (reproduction, crop, and livestock production) and the access and control of resources need to be addressed to have more understanding of gender differences.

Table 4. Land preparation of forages (Napier, Sesbania, and Leucaena).

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	6.67	23.82	21.33	76.18	28.00
Mostly	11.33	50.74	11.00	49.26	22.33
Rarely	13.33	83.31	2.67	16.69	16.00
Never	14.67	53.66	12.67	46.34	27.34

Table 5. Planting of forages (Napier, Sesbania, and Leucaena).

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	6.00	22.50	20.67	77.50	26.67
Mostly	7.67	44.23	9.67	55.77	17.34
Rarely	3.00	56.29	2.33	43.71	5.33
Never	29.33	69.83	12.67	30.17	42.00

Table 6. Weeding of forages (Napier, Sesbania, and Leucaena).

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	5.33	26.65	14.67	73.35	20.00
Mostly	24.00	62.06	14.67	37.94	38.67
Rarely	5.67	54.84	4.67	45.16	10.34
Never	18.33	50.45	18.00	49.55	36.33

Table 7. Cutting of forages (Napier, Sesbania, and Leucaena) for feed.

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	2.00	13.96	12.33	86.04	14.33
Mostly	19.67	50.44	19.33	49.56	39.00
Rarely	9.67	67.43	4.67	32.57	14.34
Never	18.00	55.68	14.33	44.32	32.33

Table 8. Feeding forages (Napier, Sesbania, and Leucaena) to KDPGs.

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	1.33	19.97	5.33	80.03	6.66
Mostly	13.67	55.41	11.00	44.59	24.67
Rarely	7.33	54.99	6.00	45.01	13.33
Never	9.33	47.46	10.33	52.54	19.66

Table 9. Sweet potato cropping.

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	32.25	83.88	6.20	16.12	38.45
Mostly	15.40	62.60	9.20	37.40	24.60
Rarely	3.40	47.22	3.80	52.7o	7.20
Never	11.40	23.85	36.40	76.15	47.80

Table 10. Manure use (collection, piling, and spreading).

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	5.33	61.55	3.33	38.45	8.66
Mostly	20.00	69.76	8.67	30.24	28.67
Rarely	3.00	60.00	2.00	40.00	5.00
Never	4.67	17.30	22.33	82.70	27.00

Table 11. Forage and feed conservation (hay making).

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	2.75	20.37	10.75	79.63	13.50
Mostly	14.00	52.83	12.50	47.17	26.50
Rarely	5.50	78.57	1.50	21.43	7.00
Never	14.00	53.85	12.00	46.15	26.00

Table 12. Keeping of records.

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	0.00	00.00	4.00	100.00	4.00
Mostly	3.00	60.00	2.00	40.00	5.00
Rarely	2.00	40.00	3.00	60.00	5.00
Never	5.00	83.33	1.00	16.67	6.00

Table 13. Milking of KDPGs.

Responses	Females		Males		Total
	Frequency	%	Frequency	%	
Always	2.00	40.00	3.00	60.00	5.00
Most Of The Time	3.00	50.00	3.00	50.00	6.00
Rare Occasions	3.00	60.00	2.00	40.00	5.00
Never	9.00	50.00	9.00	50.00	18.00

Literature Cited

Conelly, W. T., Mukhebi, A. W., Oyugi, L. and Knipscheer, H. C. 1987. "Household Labor Allocation in an Intensive Crop/Livestock Farming System in Western Kenya." In Proceedings of the Sixth Small Ruminant CRSP Workshop, Kenya.

Conelly, W. T. and Nolan, M. F. 1986. "Time Allocation and the Organization of Household Labor in Smallholder Farming Systems in Western Kenya." In Proceedings of the Fifth Small Ruminant CRSP Workshop, 4, 5 and 6, November, Kabete, Kenya.

Mbabu, A. N., Nolan, M. F. and Gilles, J. 1990. "Participating Farmers' Production Strategies for Dual purpose Goats in Western Kenya's (SR-CRSP) New and Old Clusters." In Proceedings of the Eighth Small Ruminant CRSP Workshop, 7 and 8 March, ILRAD, Nairobi, Kenya.

Sheikh, D. 1992. "A Study of the Adoption of Dual Purpose Technology by Small-scale Farmers: A Case Study of Western Kenya". Unpublished Masters Thesis, Clemson University, Clemson, South Carolina. May 1992.

GRAPH 1: FORAGES
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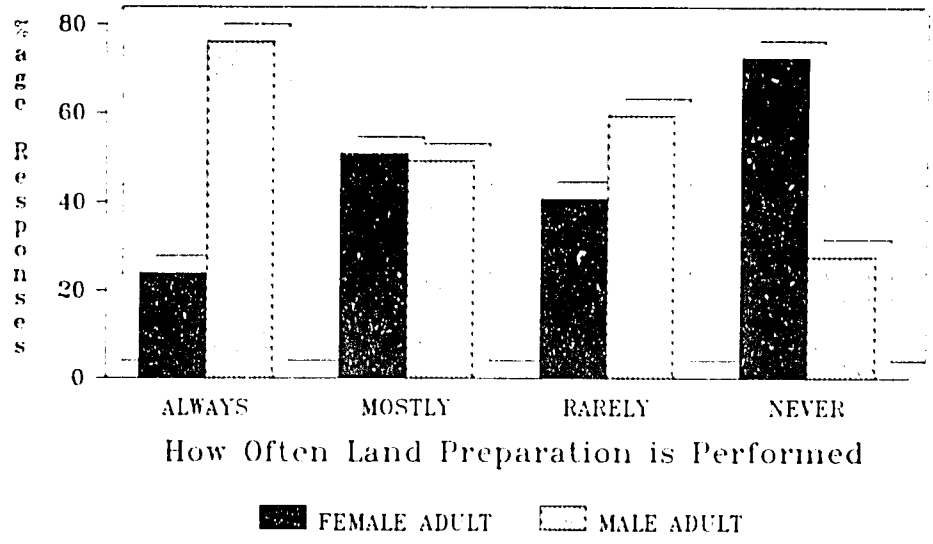
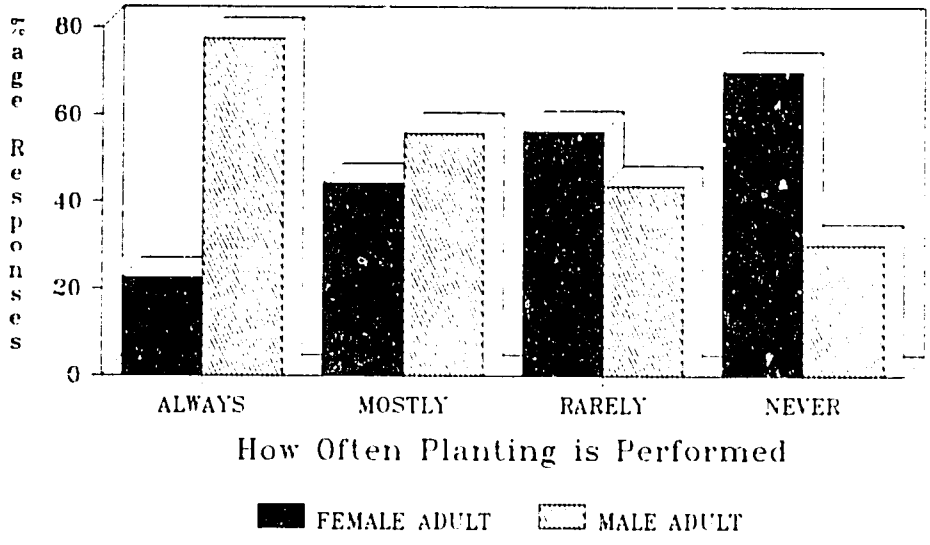


GRAPH 2: FORAGES
Planting



GRAPH 3: FORAGES
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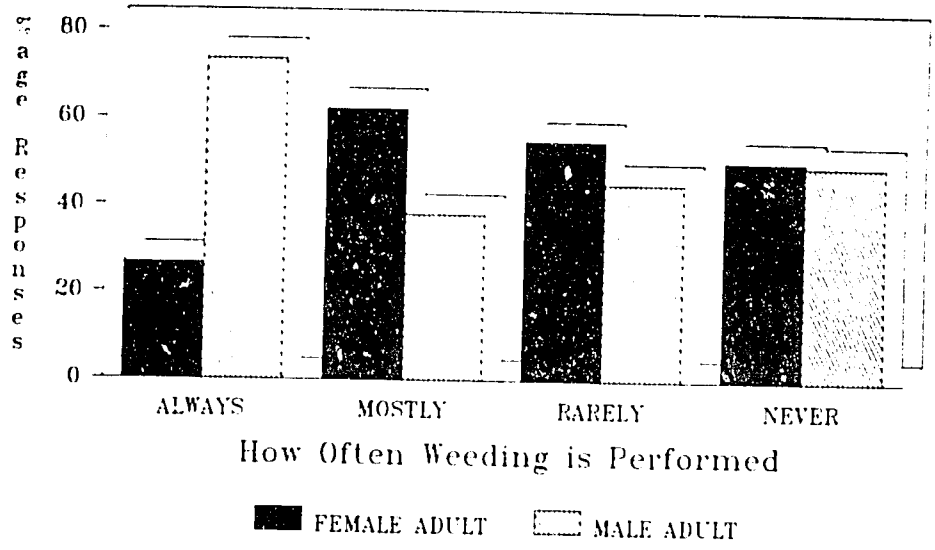

GRAPH 4: FORAGES
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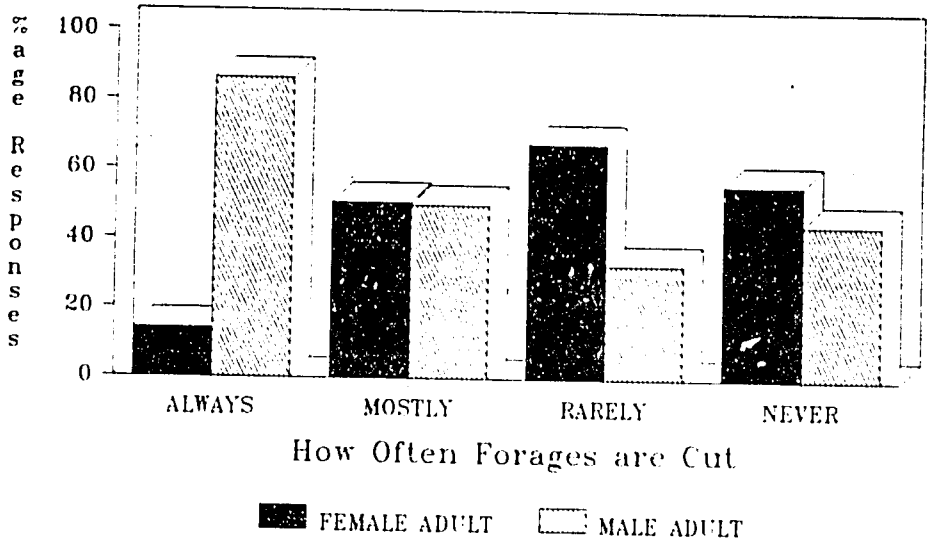
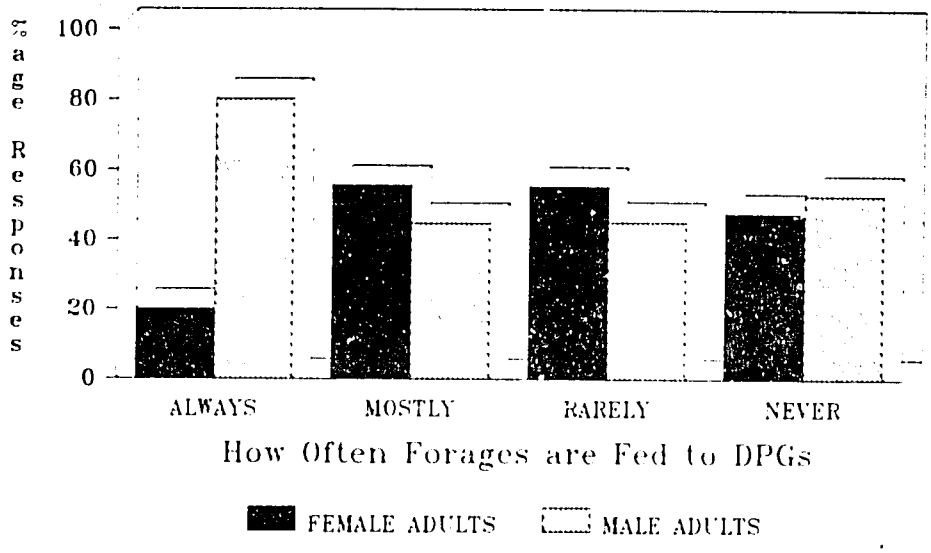
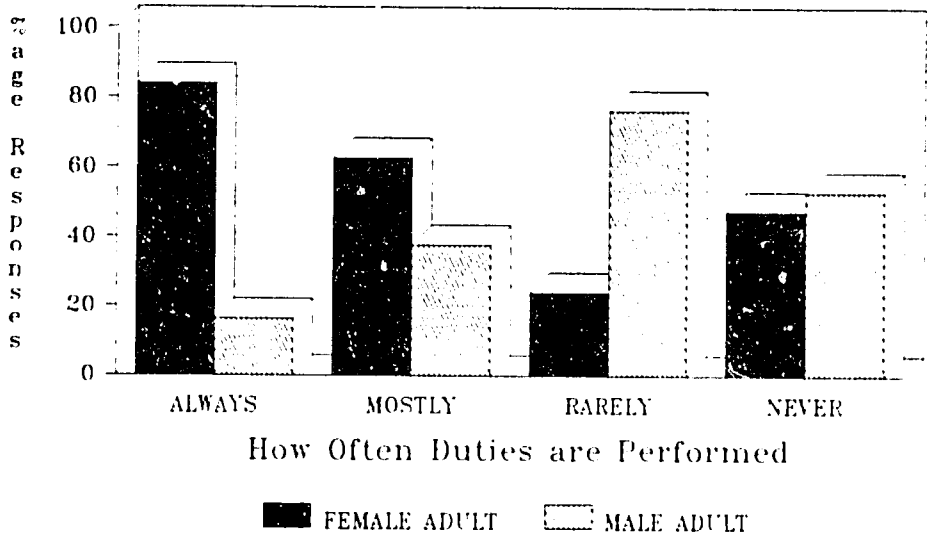


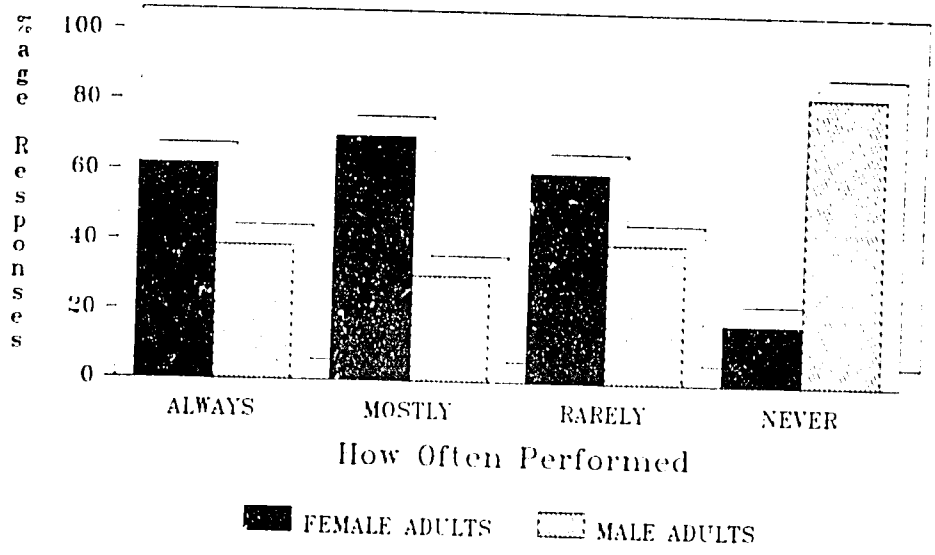
GRAPH 5: FORAGES
Feeding forages to DPGs



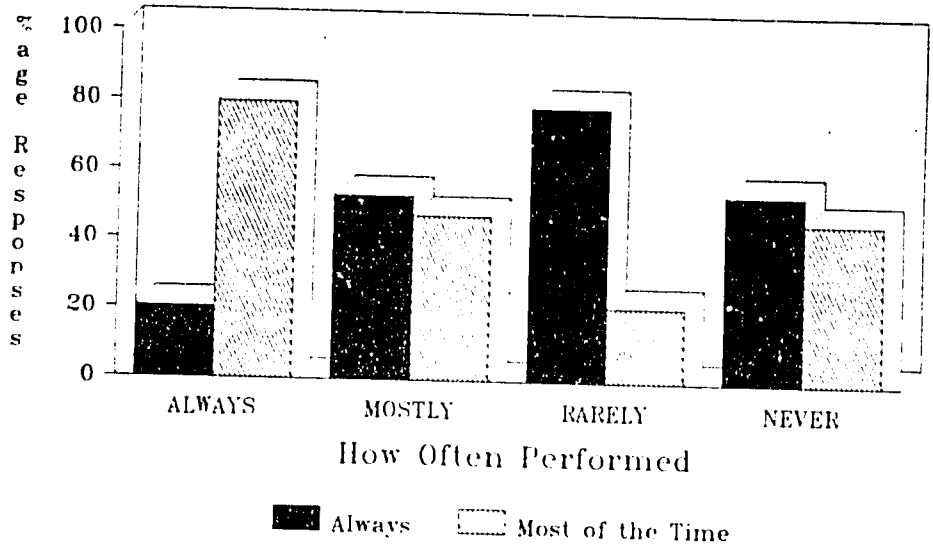
GRSPH 6: SWEET POTATOES
Food and Feed Resource Base



GRAPH 7: MANURE USE
Collection, Piling, and Spreading



GRAPH 8: CONSERVATION
Hay Making



GRAPH 9: RECORDS
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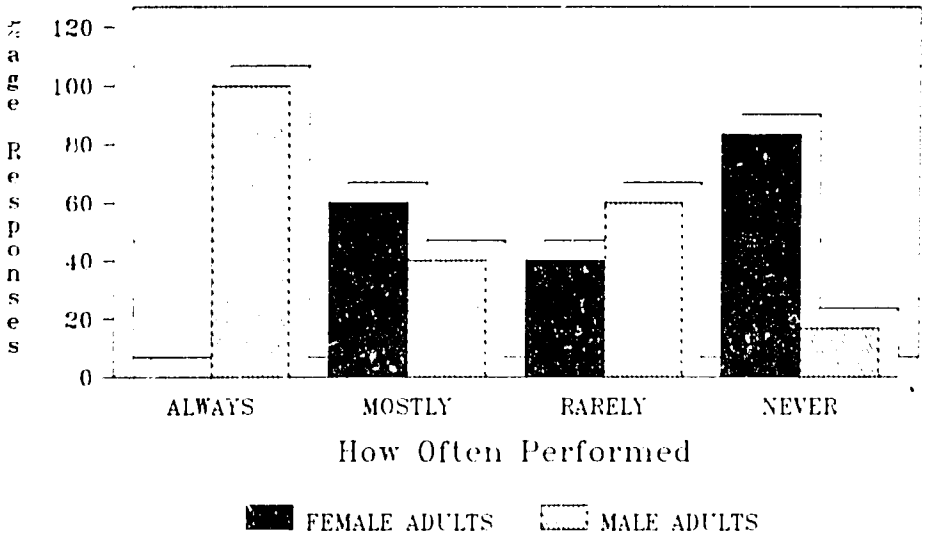
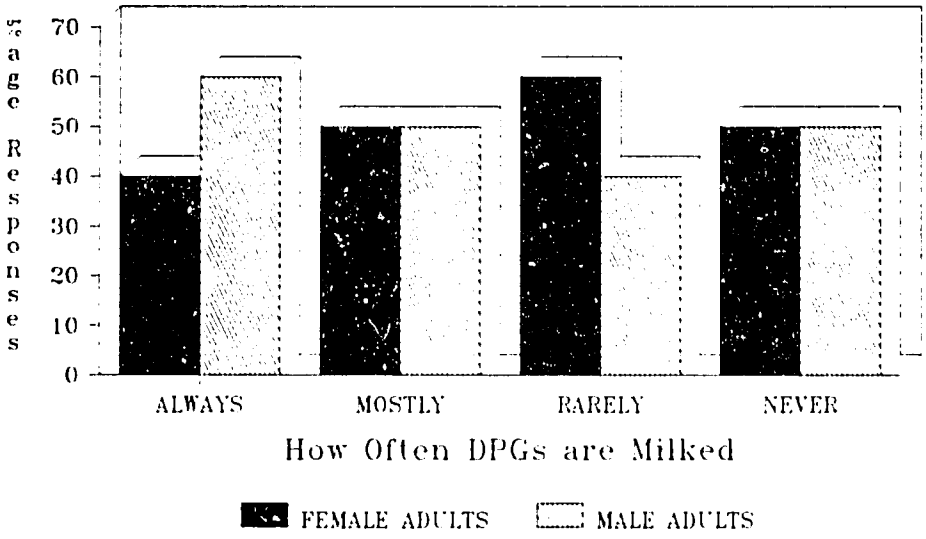


GRAPH 10: MILKING
Milking of DPGs



An Overview of Dual Purpose Goat Technology Development and Economic Returns on Small Farms in Western Kenya

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Introduction

Since the early 1980s, the Small Ruminant Collaborative Research Support Program (SR-CRSP) has conducted on-station and on-farm research on the Kenya dual purpose goat (KDPG) using 147 small farms in the Kakamega, Siaya, and Kisumu districts of Kenya. Research activities on KDPG nutrition and management, feed resources, economics, and sociology comprise the on-farm component of the SR-CRSP located at Maseno veterinary farm in western Kenya, about 425 km northwest of the capital city of Nairobi. Animal health and vaccine development research activities are conducted at the veterinary research laboratory at Kabete in the outskirts of Nairobi, and breeding and systems analysis in Naivasha about 100 km northwest of Nairobi.

The three main objectives of the SR-CRSP in Kenya include developing dual purpose (milk and meat) goat production systems suitable for the densely populated medium to high potential zones of western Kenya as a means of improving the welfare of resource-poor farmers in the region; increasing local research capacity through on-the-job training and formal training at the postgraduate level; and strengthening the capacity of local research institutions.

Development of the KDPG has been based on the concept of a composite breed with equal proportions of the East African, Galla, Toggenburg, and Anglo Nubian goat breeds. The KDPG is expected to weigh 40 kg, produce 2 kg of milk per day at peak lactation with one kid, and have a lactation period of at least 120 days (Mwandotto and Taylor, 1991). This paper presents an overview of on-farm research methodology used by the SR-CRSP in Kenya and some results from a study of potential farm-level impacts of project technologies. Data used in this analysis come from a survey of 147 participant farmers conducted in June, July, and December of 1991, and production data collected by other project activities over the years. A linear programming model was developed to simulate anticipated technology impacts as well as effects of policy and institutional support systems on adoption of these technologies.

Project study sites and farmers' resources

In western Kenya, cattle numbers have declined and the human population has continued to increase rapidly. With diminishing land/labor ratios, it was hypothesized that the KDPG might be a good alternative to a dairy cow. These goats have a high reproductive rate, require a low initial investment as well as low maintenance costs, provide high quality food protein for home consumption, and the surplus can be sold to augment farm income.

On-farm testing of the KDPG was carried out in six villages: Hamisi, Kaimosi, Masumbi, Muhanda, Rabuor, and Lela. Masumbi, Lela, and Rabuor lie in the lowlands of the Lake Victoria basin at an average altitude of 1300 m above sea level and with annual average rainfall of 1600 mm. Kaimosi, Hamisi, and Muhanda are located in the highlands west of the Rift Valley at an altitude of about 1600 m and with a

mean annual rainfall of 1850 mm. The rainfall has a bimodal distribution with long rains (about two-thirds of annual precipitation) lasting from late February to late July, and short rains falling between September and November.

The soils in the study region have low to variable fertility (Jaetzold and Schmidt, 1982; Onim et al., 1990). Of 38 farms sampled in the region, 92% indicated deficiency in soil phosphorus (P). Other limiting nutrients were sodium (Na), potassium (K), magnesium (Mg), nitrogen (N), and organic carbon (C). The dominant soil type is deep red loam with good drainage and levels of pH ranging from 4.0 to 6.5. Other edaphic limitations include steep slopes with shallow soils not suitable for cultivation, particularly in Hamisi and Muhanda.

The overall mean farm size for participant farmers is 1.68 ha and average household size ranges between seven and eight persons. Land/labor ratios are between 0.37 and 0.16. Mean total labor per household is 35.27 labor months per year and is abundant for most of the year, with high labor demand periods experienced in April, June, and August when field crop operations such as land preparation, weeding, and harvesting are at their peak. Labor supply and demand studies (Nyaribo et al., 1984; Conelly et al., 1987) have determined that currently labor does not pose a major problem.

Over two-thirds of farm cash receipts come from external sources such as off- farm employment, remittances, personal businesses, and loans (Mukhebi et al., 1986). On average, 59% of households' expenditures are on food items, indicating that western Kenya smallholders are not pure subsistence farmers. With the high level of remittances as well as food expenditures there is little cash savings for any significant investment by the household. Furthermore, farmers in the sample have reported no use of institutional credit.

Crop and livestock production

Maize is the main staple food crop and is normally intercropped with beans; other important food crops are beans, cassava, sweet potatoes, sorghum, and finger millet (Nyaribo-Roberts and Ospina, 1993). Cash crops grown are tea, coffee, sugarcane, cotton, eucalyptus trees, and French beans. The last of these is a relatively new enterprise in parts of Kakamega district and is rapidly being adopted by farmers, primarily for export and the domestic hotel industry.

Livestock play an important role in the household economy, and zebu cattle are the most valued and predominant species. About 84% of the farmers own some type of livestock. In a 1986-88 project survey conducted before the distribution of KDPGs to the new participant farmers, there were an average of 2.90 head of cattle, 0.77 sheep, and 0.74 East African (local) goats per household (Table 1). Livestock are mostly kept as a store of wealth and are rarely they slaughtered for home consumption. A few farmers in the lowland area of Masumbi keep oxen for draught power.

Table 1. Mean livestock (Tropical Livestock Units) per farm by species.

Village	N	Cattle	Local goats	Sheep	Total TLU
		head			
Hamisi	24	2.70	0.30	0.30	2.20
Kaimosi	24	2.30	0.10	0.80	2.10
Masumbi	24	4.30	1.40	0.90	4.18
Lela	11	4.09	2.27	1.46	3.81
Rabuor	35	1.46	0.34	0.71	1.41
Muhanda	28	2.57	0.21	0.29	2.58

Source: Rapid Rural Appraisal Survey data, 1986 and 1988.

Because of the high male outmigration, day-to-day running of the farm is the responsibility of female household members (Table 2). Previous studies in the area have noted this (Noble and Nolan, 1983;

Lihanda, 1978). Male family members and educated youth moved away to urban centers and may visit their rural homes only once a year, which partially accounts for the high off-farm income from remittances reported by farmers. Intensification of livestock production particularly in the highland areas, involves cutting and carrying forage, feeding and watering livestock; labor input in livestock rearing by female family members is as high as 40% of the total required time (Conelly et al., 1987).

Table 2. Proportion of farms managed by women or men among participant farmers.

Village	Male (%)	Female (%)
Hamisi	46	54
Kaimosi	42	58
Masumbi	79	21
Lela	82	18
Rabuor	29	71
Muhanda	14	86
All	49	51

Source: Rapid Rural Appraisal Survey data, 1986 and 1988.

Materials and methods

KDPG research follows the farming systems research (FSR) framework. Having selected a research domain, an initial sample of 80 farmers drawn from Hamisi, Kaimosi, and Masumbi villages were randomly selected using a stratified sampling technique. The sample was drawn from a nationwide smallholder farmers frame used by the Central Bureau of Statistics of the Ministry of Finance and Planning (1979). A detailed description of sampling procedures is presented in Sands (1983).

From November 1980 to October 1981, a team of project scientists conducted a baseline small farm systems survey. A cyclical monitoring survey was administered every 28 days to collect data on seasonal changes in farm activities, which included data on livestock inventories, household demographics, status of field crops, household consumption patterns, etc. Results from the baseline surveys were used for subsequent design and evaluation of the new KDPG technologies. Early in the program it was determined that health and nutrition would be major constraints to KDPG adoption. Other anticipated constraints included seasonal fluctuations in livestock feed supplies, small land area and limited capital or cash reserves for investment, prejudices against goat and goat products, and lack of a suitable goat genotype able to produce enough milk for kid requirements and household consumption (Sands, 1983; Noble and Nolan, 1983; Job, 1982). Following the baseline surveys, project research activities to alleviate the identified constraints were planned and implemented. The first on-station experiment involving KDPGs was initiated in 1981 (Brown and Nderitu, 1982). In 1982 a limited number of goats were placed on-farm for performance evaluation (Brown et al., 1983).

The second stage (1983-1985) was the design and screening of potential technologies, continued constraint analyses and diagnosis, and studies on social acceptability of dairy goats and goat milk (Boor et al., 1984; Nyaribo, et al., 1984; Reynolds, et al., 1984) and the beginning of evaluation of KDPG economic competitiveness under farmer production conditions (Mukhebi et. al, 1984). Researcher-managed biological trials were also expanded both on- station and on-farm as more research KDPGs became available (Shavulimo, et al., 1984; Onim et al., 1985). In this period the range of technology alternatives was narrowed with more on-farm testing of forage production, goat nutrition, and management strategies and increased distribution of research goats to participant farmers. By March 1984, a total of 112 research KDPG does and bucks had been allocated to collaborating farmers in the three original villages (Khainga et al., 1984). Farmers were offered a one-day course in KDPG management and were encouraged to build low cost sheds, milk lactating does twice a day, control suckling by kids, cut and carry locally available feeds, and cultivate forages introduced by the project. In some instances, animals placed on farms that showed poor

performance or were critically ill were withdrawn and replaced.

The third phase of the project's research (1986-1990) was dedicated to testing and verifying the emerging technology package (techpack). Three new villages (Muhanda, Rabuor, and Lela) containing a random sample of 75 farmers were added to the on-farm trial population. These farmers were treated differently in a number of ways. Experience from the baseline surveys indicated that it was not necessary to administer long-term surveys to gather data on basic features of existing farming systems. It was then decided that these data be collected using a rapid appraisal survey technique. Each farmer was interviewed by a subteam of at least two scientists and enumerators who used a simple 12- point questionnaire which included drawing a sketch map of the farmer's land holding(s). The survey took about one-half hour while sketch maps took an additional half hour. Return visits were made in cases where a farmer had multiple land holdings or large and/or complex parcels of land.

Unlike the arrangement with the original 80 farmers, goat distribution to the second group of farmers not only entailed farmer willingness to cooperate with project scientists but also required an explicit contractual agreement. The contract expiration date was determined by expected termination of donor funds. Previously, collaboration with farmers had entailed both verbal and cash contract agreements (Sidahmed et al., 1985). For example the feed resources team leased trial plots on farmers' land for cash and after the data had been collected all forages and grain were given to the farm family. Maintenance operations such as fencing, cultivation, and weeding were usually contracted with the farmer's family and cash payments were made. This type of agreement was particularly useful for researcher-managed trials. Farmers were required to plant a fodder bank prior to placement of the does, to be willing to participate in farmer-researcher meetings organized by the project, and to follow health, nutrition, breeding, and feed resource management recommendations from the project. To accelerate the breeding program and have a continued supply of animals for multiplication, the first female kids born on-farm were to be purchased by the project at a price established in advance. Farmers were also to allow project scientists to collect data and any information needed for evaluation and monitoring of the techpack.

In turn, the project would provide technical, assistance, and veterinary care. Farmers would pay for any veterinary medicines required by the goats. Sufficient bucks for on-farm mating with the does were provided and a fee could be charged by farmers who agreed to keep the bucks. Alternatively farmers could make payment arrangements based on cultural practices for breeding livestock in their area. The farmer claimed full ownership of the buck after 15 successful matings. Each household would be provided with a minimum of two does and at least one would be in-kid. A number of KDPG bucks distributed to farmers contained at least 50% of a dairy genotype (Toggenburg or Anglo Nubian). Others had a slightly higher dairy genotype to avoid a decline in milk production over time. Animals distributed to farmers were treated and vaccinated before placement. Farmers were trained on milking and milk hygiene, including how to handle and prepare milk for human consumption, but were not provided with free inputs such as veterinary medicines.

Economic analysis of experimental data

Data analyses have ranged from descriptive to fairly quantitative. Biological experiments, particularly agronomic data, have initially been analyzed using techniques such as partial and enterprise budgeting, gross margin analysis, and cost-benefit analysis. More quantitative analyses which take longer periods of time and require large data sets have been done periodically. Linear programming models were constructed at the beginning of the project (Iob, 1982) for which KDPG production data and other farm level data came from secondary sources. The variables included changed from model to model as the technology package evolved. Half-way through the project's lifespan, linear programming was done using actual on-farm trial data (Oyugi, 186; Nyaribo, 1989).

Results and discussion

Survey Results

Figure 1 shows a comparison of mean tropical livestock units (TLU) per farm during two survey periods. (1 TLU =250 kgs. Conversion factors used were: mature zebu cattle = 1 TLU; immature zebu = 0.30; mature sheep and goats = 0.12; and immature sheep and goats = 0.04 TLUs. The 1986-1988 period shows livestock data collected before distribution of the KDPG to participant farmers (SR-CRSP Rapid Rural Appraisal Surveys 1986 and 1988). The major categories of livestock are local goats, sheep, and zebu cattle. These 1986-88 data are compared to data from the survey conducted in July and August of 1991 (Table 3). In addition to the three common species, the latter survey includes KDPGs owned by participant farmers.

Table 3. Mean livestock (TLU) per household, July 1991.

Village	N	KDPGs	L. goats	Sheep	Cattle	TLU
Hamisi	27	1.85	none	0.48	.59	1.84
Kaimosi	20	2.95	none	0.40	.35	1.56
Masumbi	19	1.30	.45	1.40	.15	4.09
Lela	9	4.00	.50	0.67	.89	3.02
Rabuor	22	2.05	.09	0.23	.18	2.03
Muhanda	34	1.71	.12	0.29	.06	1.65

A comparison of the two data sets suggests declining livestock inventory per farm in all villages except for Rabuor. The villages of Masumbi and Lela with the most livestock per household are located in the low-to-medium agricultural potential zones, with mean land size for participant farmers of 2.56 ha and 1.85 ha, respectively. Farmers in these two villages practice free grazing on available fallow land or communal grounds. This is in contrast to the other villages, particularly Hamisi, where livestock are managed more intensively and are confined to limited space by tethering and "cut and carry" of feeds.

In several interviews, farmers reported declining livestock numbers as principally the result the increasing population and land demarcation, among other factors. If these data trends, currently under more rigorous statistical analysis, are significant, the project's rationale for introducing the KDPG in western Kenya would be validated and a strong case could be made for introducing them to similar regions of the country.

Changes in KDPG inventory

Between 1989 and 1990, total KDPG numbers increased from 335 to 359 (Table 4) for a net increase of 7%. By contrast, from 1990 to July 1991 there was a 29% decline in total KDPG numbers across all villages.

Table 4. KDPG inventory over three survey periods.

Village	1989	1990	1991a
		head	
Hamisi	65 (80%)	69 (69%)	49 (71%)
Kaimosi	63 (70%)	68 (62%)	59 (90%)
Masumbi	33 (55%)	26 (73%)	26 (85%)
Lela	26 (65%)	25 (64%)	22 (57%)
Rabuor	67 (84%)	96 (68%)	45 (76%)
Muhanda	81 (88%)	75 (77%)	55 (75%)
All	335 (77%)	359 (69%)	256 (76%)

[a]Up to July 1991.

Out of 109 animals sold over the three-year period in Hamisi and Masumbi, 69 were KDPGs compared to 11 sheep and local goats, and 29 cattle (Table 5). The number of KDPGs sold each year was more or less maintained in these two villages. Revenue from KDPGs contributed to about one-fourth the total value of livestock sales (Table 6).

Table 5. Number of livestock sold by species and year in five villages.

	Hamisi and Masumbi			Muhanda, Rabuor, and Lela		
Year	KDPGs	Sheep & local goats	Cattle	KDPGs	Sheep & local goats	Cattle
1989	26	8	8	60	7	22
1990	26	2	13	38	6	34
1991a	17	1	8	51	7	10
Total	69	11	29	149	20	66

Source: July 1991 survey data.
[a]Up to July 1991.

Table 6. Value in Kenyan shillings (Ksh) of livestock sold by species in Hamisi and Masumbi villages.

Year	KDPGs	Sheep & local goats	Cattle	% rev. KDPG
1989	6265	2040	21025	30
1990	6325	750	26105	24
1991a	4045	160	15005	27
Total (Ksh)	16635	2950	42550	27

Source: July 1991 survey data.
[a]Up to July 1991.

In the villages of Rabuor, Muhanda, and Lela, KDPG sales showed a more erratic pattern. Of 235 animals sold during the 3-year period, 149 were KDPGs, 14 sheep and local goats, and 66 were cattle. The share of KDPG sales fluctuated from one-half to three-quarters of the total, while its share of value changed between 14% and 40% (Table 7). These fluctuations may be attributed primarily to two factors. First, goats were distributed with the understanding that the first crop of female kids born on-farm would be purchased back by the project. Also, farmers provided with bucks for breeding purposes could sell their bucks after 15 successful services. In September of 1990 farmers were reminded that they had full ownership of the goats (with the consent of farmers, project scientists continue monitoring and evaluating the technology and collecting other necessary data). Additional analysis of sales since September 1990 is being undertaken to determine farmer sale patterns and decisions with full ownership of the KDPG.

Table 7. Value (Ksh) of livestock sold by species in Muhanda, Rabuor, and Lela villages.

Year	KDPGs	Sheep & local goats	Cattle	% rev. KDPG
1989	12000	1360	33800	25
1990	8560	1520	51700	14
1991a	10790	1690	14450	40
Total (Ksh)	31350	4570	99950	31

Source: July 1991 survey data.
[a]Up to July 1991.

Impact of the KDPG on family nutrition

In order to have a continuous supply of milk for the farm household, the project set a target of six lactating does as an adequate number based on household composition in the study villages. Simulations by the systems analysis component of the project (Blackburn et al., 1986) indicated that six mature does with staggered breeding could provide a minimum of 200 ml of milk per day per person based on a family of eight. Other data suggested that about 243 ml/person/day would be required by a family of eight members based on recommended daily allowances of calories, protein, and seven other leader human nutrients (Nyaribo, 1989). Actual milk consumption figures of 93 and 145 ml/person/day have been reported for two of the study sites (Conelly et al., 1986). (With the consent of farmers, project scientists continue monitoring technology and evaluating and collecting other necessary data.)

Anticipated numbers of KDPGs per farm and the resulting higher milk consumption by households has not been achieved so far for a number of reasons. There have not been sufficient numbers of research animals to distribute to collaborating farmers beyond the initial two does given to each participating household. On the other hand, farmers were expected to multiply the original two-doe herd to obtain a bigger flock. Farmers have reported problems in sharing one buck among several households and difficulty in detecting estrus in female does which contribute to low conception rates and kidding rates (Mbabu and Gilles, 1990).

Linear programming analysis

To handle a wide range of production and economic relationships simultaneously, a linear programming (LP) model was designed. The LP model enabled the project to determine the combined effects of component technologies. The model's objective function was to maximize total gross margin from the farm's production activities subject to available resources. In recognizing the farm household needs in the project study sites, family subsistence food requirements were included in the model specifications as a food security measure. In addition to calories and protein requirements, an additional seven leader nutrients were included. Thus the net farm income predicted is net of the variable costs of production as well as household food consumption.

The model is based on a one-year production period and assumes a steady state equilibrium. It contains seasonal specification for arable and grazing land, family and hired labor, capital availability, as well as livestock and human nutrient requirements based on farm family size and composition. Crop production activities relate to the long and short rains growing seasons. Two KDPG rearing activities are included with the first doe kidding in April and the second doe in November. A zebu cattle production activity is also specified.

The model was used to test various technology alternatives developed by the project. For the purpose of this paper, the following alternatives are considered:

I = the base model reflecting farm production conditions before the introduction of project technologies.
II = the introduction of the KDPG without the new forages introduced by the project.
III = the introduction of grown forages intercropped with food crops and grown in fence rows.
IV = the full technology package which includes storage of surplus forages and locally available mixed grasses using a simple hay baling technique developed by the project (Onim et al., 1985).

Two other considerations included in the model were improved goat management and availability of working capital through seasonal credit.

Production coefficients, resource constraints, and results

Goat production data for two levels of management for Hamisi village are displayed in Table 8. Under the first management level, milk off-take is 101 kg (mean daily off-take of 561 ml), the doe weighs 32 kg and has one kidding per year with a 66% weaning rate; the kid weighs 8 kg at weaning. Under a higher management regime (level II), milk off-take was assumed to increase by 50% to 152 kg with a doe weight of 35 kg and an annual doe mortality of 10% rather than 15% (under average management). The kid weaning rate was increased to 90%, and it is weaned at 10 kg. Table 9 compares some production parameters of the DPG with dairy goats in temperate countries and when introduced into the tropics. Forage production data (Table 10) were compiled from various sources (Sands, 1983; Hart et al., 1984; Ministry of Agriculture, 1987). In cases where inconsistent estimates were given, the lower estimates were used. For example, estimates of 9.2, 5.7, and 4.4 t DM/ha of natural productivity have been given for the Hamisi area; the lowest figure was used.

Table 8. Hamisi dual purpose goat production coefficients.

Item	Units	Management level Ia	II[b]
Weaning rate	%	66	90
Doe mortality/yr	%	15	10
Cull rate/yr	%	10	10
Doe replacement/yr	%	25	20
Doe mature lvwght	kg	32	35
Lvwght at weaning	kg	8	10
Age at weaning	mth	5	5
Lact. length	days	180	180
Milk yld/doe/lact.	kg	151	227
Kid milk req.	kg	50	75
Milk off-take	kg	101	152

[a]Nutrition and Management data bank, 1987.
[b]Assumed annual kid/doe mortality are 10%/yr; annual milk yield/doe increased by 50%.

Table 9. Production coefficients of goats in temperate regions and when introduced to the topics as compared to the KDPG.

	Europe and USA	Tropics	Western Kenya Queensland	KDPG
Milk yield/yr (kg)	808	290	829	151
Fat (%)	3.56	-	3.60	4.9
Lactation length (days)	280	254	272	180
Kidding interval (days)	336	354	360	365

Note: Adapted from Roy-Smith (1981)

Table 10. Forage production by quarter in kg DM/ha.

Item	Q1	Q2	Q3	Q4	Total
Maize stover	-	-	3469	1995	5464
Grazing	841	1593	973	1017	4424
Pigeon pea (1)a	400	1700	1500	700	4300
Pigeon pea (2)b	2000	-	-	-	2000
Sudan grass	1000	3000	1800	2000	7800
Pigeon pea hay	-	-	750	350	1100
Mixed grass hay	-	-	487	509	996
Sudan grass hay	-	-	900	1000	1900
Total kg DM	4241	6293	9879	7571	27984

Note: Q1-Q4 denote the first to the last quarter of the year.
[a]Pigeon pea from maize-pigeon pea intercrop.
[b]Pigeon pea planted in fence rows.

In the Hamisi village representative farms, farmers cultivate an average of 0.98 ha of land leaving 0.32 ha fallow (Table 11). The fallow area used for on-farm grazing includes the compound around the homestead, fence rows, and patches of land with outcrops of rock that are not cultivable. Off-farm grazing is composed of unimproved pastures along road sides and around school yards and is estimated to be about 0.40 ha (Hart et al., 1984). The bulk of the labor used in farm production is supplied by the families with an allowance for casual hired labor of seven person-days in each of the second and third quarters. These differences in family labor supply are due to the fact that in the second and fourth quarters children are at home on school holidays. Household personal capital was estimated based on previous results (Mukhebi et al., 1986).

Table 11. Resource constraints for a 1.30 ha representative farm in Hamisi.

Item		Q1	Q2	Q3	Q4
Cultivated land[a]	ha	0.98	0.98		
on farm fallow land	ha	0.32	0.32	0.32	0.32
off farm graz. lnd.	ha	0.40	0.40	0.40	0.40
Family labor	pd[b]	354	377	354	377
Hired labor	Ksh	-	7	7	-
Own capital/yr[c]	Ksh	821	910	1029	391

[a]Cultivated land is used in two growing periods determined by the long (March-July) and short (September-November) rains.
[b]pd denotes person days in adult equivalents.
[c]Main source of own capital is remittances.

The base model (I) was run with only existing sources of available feed, namely maize stover and on and off-farm grazing of unimproved pastures. The livestock production activity included in the model was zebu cattle rearing. This scenario simulates conditions before the introduction of the KDPG package. The results indicate that 0.44 cow-calf units were reared and all available land (0.98 ha) in both growing seasons was cultivated (Table 12). Farm income net of variable costs of production and household food consumption was Ksh 7442. In the technology combination II, the KDPG was added to the model without any of the new grown forages. KDPGs did not enter the solution and the predicted farm plan remained the same.

Table 12. Impact of KDPG and supporting technologies on stocking rates, cultivated land, and net farm income.

Tech. alternatives	Stocking rate KDPG units	Stocking rate Cow-calf units	Cultivated land % Long rains	Cultivated land % Short rains	Net income Ksh
I	n.a	0.44	100	100	7442
II	none	0.44	100	100	7442
III	none	2.41	100	47	11489
IV	none	2.87	100	60	11847

I = Existing condition without KDPG
II = Introduction of KDPG without supporting technologies
III = Same as II with introduction of grown forages fed fresh
IV = Full technology package which includes hay storage

Technology combination III reflects the introduction growing of forages. The grown forages made an important impact on stocking rates with 2.41 cow- calf units in the solution. In the long rains all cultivable land was used while in the short rains only 47% of the land was cultivated due to a capital shortage. The higher stocking rate brought about by increased feed raised predicted net farm income to Ksh 11489, a 54% increment over base model income.

Technology alternative IV includes the KDPG, grown forages, and hay storage. Under this scenario 2.87 cow-calf units were included in the solution. In the short rains, 40% of cultivable land was left fallow and net farm income increased by 59% over base model conditions to Ksh. 11847.

Improved goat management and capital availability

Given the above results, the models were used to determine what production levels are needed to improve KDPG economic competitiveness. The KDPG production parameters were modified to reflect management level II corresponding to a more intensive and higher quality management regime. These would also serve as minimum target off-take levels necessary for the KDPGs economic competitiveness.

As shown in Table 13, both improved goat management and credit availability substantially changed the livestock mix predicted by the model. The KDPG became the preferred livestock enterprise. The model predicted that 12.84 doe-kid units could be potentially reared yiel ling a net farm income of Ksh 13870.

Table 13. Impact of improved goat management and credit availability with full technology package on stocking rate, cultivated land, and net farm income.

	Stocking rate		Cultivated land (%)		Amount	
Technological alternatives[a]	KDPG units	Cow-calf units	Long rains	Short rains	borrowed Ksh	Net income Ksh
Imp. mgt.	12.84	none	56	94	n.a.	13870
Credit I	9.26	none	100	100	2053	24350
Credit II	9.26	none	100	100	2053	24350

[a]Credit limit is Ksh. 3359 per ha set by the Agricultural Finance Corporation for seasonal loans for credit alternative I. No credit limit was set for credit alternative II.

The two credit levels considered represent a land-size-based credit limit (Credit I) and no credit limit where it was assumed that farmers could borrow as much cash as they wanted (Credit II). It is interesting to note that, with no credit, 56% and 94% of land was left to fallow. However, with the availability of credit all arable land was used. Introduction of credit increased net farm income to Ksh. 24350 and 9.26 KDPGs units were reared. This is a 227% increase over base model conditions and a 76% increase over income from improved goat management alone. The differences in predicted income with and without credit indicates the extent of capital limitations and their stunting effects on overall farm productivity.

While it is not expected that the KDPG will completely replace the zebu cattle, there is ample room for improvement of the goat's biological performance. The breeding project is striving towards this end. Even without inclusion of the KDPG in the farm plan, the supporting forage technologies were made available to the zebu cattle, which increased net farm income by 54% over base model conditions. This shows the positive interaction effects of the new technologies with other farm enterprises and is an indication that they need to be taken into account in impact and adoption assessment.

One important way of achieving improved management is via farmer training with regular visits by technical livestock assistants. This includes having access to essential veterinary services, access to institutional or other forms of credit markets, and an efficient marketing infrastructure because ultimately surplus milk and meat must find their way to local and regional markets. The results suggest that these policy and institutional support systems are crucial for increased and sustained adoption of the KDPG, particularly to the target group of resource-poor farmers.

Factors limiting KDPG economic competitiveness

Constraints identified in this paper fall into two broad categories, technical (biological) and institutional and policy support. Other economic and sociocultural constraints are addressed in various project publications (see Nyaribo and Young, 1992; and Noble and Nolan, 1983).

The first limitation is a result of various factors. The low level of enterprise management is not only due to lack of farmer know-how but also due to lack of cash to purchase inputs such as veterinary medicines

and services. Farmers have had difficulty in paying for the subsidized veterinary supplies provided by the project. The default rate by farmers when animals are treated on credit is high. Technologies requiring a minimal investment such as the simple forage conservation techniques introduced by the project have not been adopted due to capital shortages. Sociocultural factors such as the high value placed on zebu cattle and the use of goats and other livestock for cultural practices lead farmers to farm management decisions not necessarily consistent with the profit maximization assumed in the models. Additionally, risk aversion plays a significant role and farmers wish to rear a mix of species for diversification purposes.

Conclusions

Participant farmers have had significant income gains from the KDPG enterprise as indicated by KDPG sales. For the years under observation the revenue contribution of KDPGs ranged between 24% and 30% of total livestock revenues in the six villages where the project operates. Farmers have used the enterprise mainly for cash income to meet day-to-day financial needs, to pay school fees and for emergency purposes such as medical expenses. Declining livestock numbers in the last decade makes a strong case for promotion of small ruminants such as the KDPG as suitable replacements of larger stock in these small-scale farming systems.

LP results show that farm incomes increased by over 50% with the project innovations. The lack of institutional and policy support systems was shown to reduce both project income benefits and overall farm productivity. The results also point to the need for continued breed improvement in order to enhance the KDPG's economic competitiveness over zebu cattle, particularly if the KDPG is going to be an important source of milk.

As the program phases out, there is a great need to increase KDPG extension work in western Kenya and other areas. Predicted levels of adoption will greatly depend on continued availability of extension and other support services similar to those rendered by the project.

Literature Cited

Blackburn, H.D., T.C. Cartwright, P.J. Howard, F. Ruvuna. Development of Dual Purpose Goat Production for Smallholders in Western Kenya Using Computer Simulation and Systems Analysis. SR-CRSP Tech. Rep. 89. Texas Agricultural Experiment Station, College Station, TX. 1986.

Boor, K.J., E. Ochieng, and H.A. Fitzhugh. Comparison of goat and cow milk for human consumption in western Kenya. Proceedings of the Third Small Ruminant CRSP Kenya Workshop, 5-6 March 1984, Kabete, Kenya.

Brown, D.L., Fitzhugh, H.A., Chavulimu, E., Kiguhi, H., Otieno, E., and Amuhinda, P., Evaluation of lactating Toggenburg x East African does on small farms in western Kenya: Year 1. Proceedings of the Second Small Ruminant CRSP Kenya Workshop, 22 February, 1983, Naivasha, Kenya. University of California, Davis 95616, USA.

Brown D.L., and M. Nderitu, Nutritional strategies for dual purpose goats. Proceedings of the Second Small Ruminant CRSP Kenya Workshop, 15 march, 1982, Kabete, Kenya.

Conelly, W.T., Mukhebi, A.W., Oyugi, L. and H.C. Knipscheer. Household labor allocation in an intensive crop/livestock farming system in western Kenya. Proceeding of the Farming Systems Symposium, October 18-21 1987, University of Arkansas, Fayetteville, AR, USA.

Conelly, W.T., A.W. Mukhebi and M. Nolan. Preliminary assessmentof household dietary patterns and utilization of milk products in western Kenya. Proceedings of the Fifth Small Ruminant CRSP Workshop, ILRAD, Kabete, Kenya, Nov 4-5, 1986.

Gov. of Kenya, per Hectare Gross Margins, Ministry of Agriculture. Nairobi, Kenya, 1987.

Hart, R., M.Onim, S. Russo, M.Mathuva, K.Otieno, and H. Fitzhugh. An Analytical Framework for Feed Resources Research on Mixed Farms in Western Kenya. Small Ruminant CRSP Technical Report Series No. 46. Winrock International, Morrilton, Arkansas, 72110, USA, June 1984.

Jaetzold, R. and H. Schmidt. Farm management handbook of Kenya vol. II, natural conditions and farm management information, part A. West Kenya, Nyanza and Western provinces. Kenya Ministry of Agriculture and the German Agricultural Team of GTZ, Nairobi, Kenya, 1982.

Job, Morgan O. A Study of Technology Adoption by Subsistence Farmers with a Case Study Involving Dairy Goats in Kenya. Phd Dissertation, Purdue University, Lafayette, Indiana, USA, December 1982.

Khainga, M.S., H.A. Fitzhugh, W.O. Ochieng, A.E. Sidahmed, D. Brown, and M. Sands. SR-CRSP Dual-Purpose Goats in Western Kenya: History and Record. Proceedings of the Third Small Ruminant CRSP Kenya Workshop, 5-6 March, 1984, Kabete, Kenya.

Lihanda, F.C.L.M. Adaptive research planning: A CIMMYT case study of Vihiga division in Kakamega district, CIMMYT Eastern African Economics Programme, nairobi, Kenya, 1978.

Mbabu, A.N., and J. Gilles. An Evaluation of SR-CRSP's Techpacks in Western Kenya: A Year Long Study. Proceedings of the Ninth SR-CRSP Scientific Workshop, 27-28 February, 1990, KETRI Muguga, Kenya.

Ministry of Finance and Planning, Republic of Kenya. Population census volume II - Analytical Report, Central Bureau of Statistics, Nairobi, Kenya, 1979.

Mukhebi, A.W., F.B. Nyaribo, R.H. Bernsten, J.E. Reynolds, and A.N. Mbabu. A Socio-economic Evaluation of the Dual Purpose Goat Enterprise in Small- Scale Farming Systems in Western Kenya. Proceedings of the Third Small Ruminant CRSP Kenya Workshop, 5-6 March, 1984, Kabete, Kenya.

Mukhebi, A.W., Nyaribo, F., Oyugi, L. and H. Knipscheer. Cash flow patterns of small scale farm households in western Kenya. Proceedings of the Fifth Small Ruminant CRSP Kenya Workshop, ILRAD, Nairobi, Nov 4-5, 1986.

Mwandotto, B.A.J. and J.F. Taylor. The Kenya dual purpose goat. Brief on progress of the SR-CRSP breeding project, SR-CRSP, Kabete, 1991.

Noble, Amanda L. and Michael F. Nolan. Sociological Constraints and Social Possibilities for Production of Goats in Western Kenya. Small Ruminant CRSP Technical Report Series No. 18, Department of Rural Sociology, University of Missouri-Columbia, Columbia, MO 65211, U.S.A., March 1983.

Nyaribo, F.B., A.W. Mukhebi, and R.H. Bernsten. Implications of family labor use for the adoption of the dual purpose goat enterprise on small farms in western Kenya. Proceedings of the Third Small Ruminant CRSP Kenya Workshop, Nairobi, Kenya, 1984.

Nyaribo, F. Integration of dual purpose goats in small farms of western Kenya: a linear programming analysis. Ph.D. dissertation, Washington State University, Pullman, WA, U.S.A., December 1989.

Nyaribo-Roberts, Fanny and Enrique Ospina. Developing Dual Purpose Goat Technologies in Western Kenya. Developing Studies Series Paper, Winrock International, 1993 (forthcoming).

Nyaribo, F.B. and D.L. Young. Impact of Capital and Land Constraints on the Economics of New Livestock Technology in Western Kenya. Agricultural Economics, 6 (1992): 353-364.

Onim, J.F.M., M. Mathuva, K. Otieno, and H.A. Fitzhugh. Simplified hay making for small scale farmers in western Kenya. Fifth proceedings of the Small Ruminant CRSP Workshop, Kabete, Kenya, 1986.

Onim, J.F.M., P.P. Semenye, and H.A. Fitzhugh. Research on feed resources for small ruminants on smallholder farms in western Kenya. Proceedings of the Second PANESA Workshop, 11-15 November, 1985, Nairobi, Kenya.

Onim, J.F.M., M. Mathuva, K. Otieno, and H.A. Fitzgugh. Soil fertility changes and response of maize and beans to green manures of leucaena, sesbania and pigeonpea. Agroforestry Systems 12(1990):197-215.

Oyugi, L.A., A.W. Mukhebi, H.K. Ogada, and H. Knipscheer. The Demand for and Supply of Milk and Small Ruminants in Western Kenya. Proceedings of the 6th Small Ruminant CRSP Workshop. Kakamega, Kenya. 1986.

Reynolds, J.E., A.N. Mbabu, and M. Nolan. Extension services and the smallholder: a report of preliminary findings. Proceedings of the Third Small Ruminant CRSP Kenya workshop, 5-6 March, 1984, Kabete, Kenya.

Roy-Smith, F. Intensive milk production from goats in developing countries. In Intensive Animal Production in Developing Countries. A.J. Smith and R.G. Gunn (eds.) Occasional publication no. 4, British Society of Animal Production, 19[illegible]1.

Sands, Michael W. The role of livestock on smallholder farms in western Kenya: Prospects for a dual purpose goat. Phd dissertation, Cornell University, Ithaca, New York, 1983.

Shavulimo, R., A.E. Sidahmed, F. Gisemba, and O. Odero. Health problems in goats in western Kenya. Proceedings of the Third Small Ruminant CRSP Kenya workshop, 5-6 March, 1984, Kabete, Kenya.

Sidahmed, A.E., Onim, J.F.M., Mukhebi, A.W., Shavulimo, R., DeBoer, A.J., and H.A. Fitzhugh. On-farm trials with dual purpose goats on small farms in western Kenya. Proceedings of a workshop held on Research methodology for Livestock On-farm Trials, Aleppo, Syria, 25-28 March, 1985.

Systems Approach in Developing Feed Resource and Feeding Strategies

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Introduction

Much of western Kenya is blessed with fertile soils and a bimodal rainfall pattern allowing two cropping seasons per year. Unfortunately, wherever agricultural potential is high, human population is likely to grow rapidly. Traditional agricultural systems become inappropriate; they produce less food than is needed even for subsistence, while often severely eroding the natural resource base. Changes in traditional systems are needed if they are to provide the necessary balance of energy and protein food and generate income to improve household standard of living (Anon, 1987).

The results of early diagnostic exercises in the high potential agricultural areas of western Kenya suggested that inadequate feed resources was an important constraint in proposed dual-purpose goat production systems. This was especially important to livestock kept on small holdings within mixed crop-livestock farming systems. Figure 1 illustrates the resource and product flows on a small-scale farm in western Kenya.

Forage research had been conducted for several decades in western Kenya, prior to the work initiated through the Small Ruminant CRSP. In 1980, a collaborative Forages Project was initiated by the Ministry of Livestock Development and Ohio State University. Subsequent events and negotiations resulted in the responsibility for the forage and feed resources component in Kenya being transferred from Ohio State to Winrock International, effective October 1981. The feed production systems subproject then became a part of the SR-CRSP Production Systems Project with a full-time resident scientist and responsibility to maintain the focus on design and testing of feed production systems appropriate for dual-purpose goat production on small farms in the high potential tropics.

The purpose of this paper is to review the conceptual framework for feed resource and feeding strategy research and to trace the evolution of thinking regarding solutions to constraints in the production systems.

Initial findings

A great deal of initial work was done to establish a forage research capability with an orientation toward pasture and feed plot establishment. Under what was initially called the Forages Project, many of the classical forage species adapted to the humid tropics were set out in plots and observed for performance. The aim was to identify and characterize improved forages available in the humid tropics so that more intensive and efficient forage/animal production systems could be developed and plant/animal responses evaluated (Van Kurien, 1981). Initial steps were also taken toward the establishment of fodder shrub observation plots, especially Leucaena *leucocephala*. Food crop plots, e.g., sweet potatoes, and bana grass (Napier grass) were established at the MOLD Veterinary Station in Maseno which had been designated as the research headquarters. At that time both sheep and goats were considered to be target animal species.

Much of the initial characterization was done by a survey conducted by the production systems, economics, and sociology projects (Sands et al., 1983). The first step in the identification of potential improvement in feed production was to identify the inputs, outputs, components, and interaction among components within the farm system. Figure 2 is a diagram of the inputs and outputs flow in the system studied. The system had four major subsystems, i.e., cut-and-carry forage crops, food and cash crops, feed storage, and animals. The feed resources subproject was given responsibility for the crop systems and the cut-and-carry forage subsystem.

The Production Systems project set about developing cropping calendars and feed budgets to help characterize "typical" farms in Siaya and Kakamega Districts (Hart et al., 1984). Figures 3 and 4 illustrate the outcome of these efforts, which then set the stage for feed resources research. While the production systems focus was initially on dairy goats, it did not take long for the SR-CRSP to realize that the need in western Kenya was for dual- purpose goats that could survive the range of husbandry practices in smallholder management and yet exceed by a significant margin the milk yield of local goats. One of the aims was to determine where the necessary feed resources could and should fit into the existing systems, both physically and functionally. A production systems survey designed to characterize the biological, economic, and sociological aspects of small farms in western Kenya was completed. Comparisons were made between goats and cattle in regard to resource requirements, health and management problems, and techniques for processing and preserving feedstuffs.

A profound result of these early studies was the finding that although nearly all farms had livestock, farmers were not willing to sacrifice land usable for crop production for growing animal forage. Further, survey data and observations indicated that ruminant livestock production levels were not high, and relatively few goat production enterprises existed. Therefore, questions related to implementing pasture establishment or discrete forage banks became academic. By 1983, it was apparent that new sources of good quality feedstuffs for an annual feeding plan would need to come from crops that could be grown for multiple purposes. The principal feed resources for livestock in existing systems were crop residues. Therefore the initial research efforts in forages alone soon became efforts in feed resources in general. The research strategy became one of attempting to increase animal feed production without causing a decrease in the output of food crops.

Integration of research was especially important in western Kenya and led to the development of a combined strategy among the Production Systems (which included feed resources and feeding strategies), Economics, and Sociology projects. During the characterization phase of Kakamega and Siaya smallholder farming systems, forage production on high potential lands was perceived as one avenue toward greater intensification. Typically animals spent most of the day being herded or tethered on unimproved lands, along road sides or in harvested fields. Therefore the contribution to intake of plants on these lands was investigated. Further studies established a ranking of palatability among the major plant species. There were breed-type differences in dry matter consumption wherein dairy x indigenous crosses consumed higher levels, but both breeds consumed sub-maintenance levels of energy during the dry seasons.

Farmers practiced cut-and-carry of forages to supplement tethering, or need a combination of tethering and grazing. Uncultivated plant species constituted about 60% of the total biomass fed. The primary plant species which goats consumed on roadsides and fallow lands are listed in Table 1. The grasses had a mean of 16.3% crude protein (CP) with star grass (Cynodon spp.) showing the highest value of 21.7% during the growth stage. Common weeds averaged 23.6% CP. Some of the higher weeds included *Amaranthus* spp. (32.5%), *Tagetes minuta* (26.8%), *Leonotis mollisima* (25.2%), *Lantana camara* (24.1%), and *Bidens pilosa* (26.0%). These values indicate that animals grazing borders and fallow fields should obtain adequate CP and digestible energy (DE) provided consumption was adequate. It was therefore determined that the major feeding constraint was inadequate quantity of dry matter intake.

Table 1. Crude protein content of some fodder shrubs and grasses consumed by goats.

Plant type	Analyzed at	% CP
Morning glory - leaves	NAHRS	17.36
Mexican thistle - leaves	"	18.31
D. Scalarum - leaves and stem tips	"	13.19
Lantana camera		
- leaves	"	16.21
- leaves and young stems	"	24.13
Commelina spp. - leaves and stem tips	"	26.34
Galinsoga parviflora - leaves and young stems	"	14.42
Black Jack - leaves	"	20.95
Amaranthus spp.		
- leaves	"	29.39
- leaves and young stalks	"	32.46
Cynodon dactylon - leaves and stem tips	"	21.69
B. brizantha - leaves and young stalks	"	16.19
Lionotis mollisima - leaves	"	25.16
Grewia trichocarpa - leaves	"	19.36
Tagetes minuta - leaves and young stalks	"	26.75
Sesbania spp.		
- leaves	"	23.02
- leaves	KARI	27.63
- leaves and young stalks	NAHRS	23.76
- leaves and young stalks	KARI	28.44
- seeds	KARI	34.80

NAHRS - National Animal Husbandry Research Station, Naivasha
KARI - Kenya Agricultural Research Institute
Information from Otieno et al. (1984).

Feed resource production and preservation objectives

During the first five years of feed resource research in Kenya the following objectives were *en force*:

- Evaluate by-products and residues from typical food crops.
- Evaluate productivity of food and forage from multiple cropping systems.
- Screen forage crops considered to have high potential.
- Evaluate means of preserving nutritive value.
- Determine fertilizer value of goat manure for specific crops.
- Evaluate potential interventions in utilization of dual-purpose food and forage crops.
- Document farmer acceptability of forage production alternatives.

As pointed out previously, the increasing pressure on land in western Kenya prevented farmers from using cropland for pastures. Therefore investigations were made into the potential of intercropping forages with the staple food crop, maize. Research suggested there was potential for intercropping maize with *Sesbania* spp., pigeon pea, and, in some districts, Sudan grass. There was a large response to compound fertilizer (N-P-K, 20-20-0). This suggested that the application of animal manure might be beneficial. A group of fence-row and pathway crops was evaluated, including were pigeon pea, Ses*bania sesban*, *Gliricidia* spp., *Leucaena*, and *Pennisetum purpureum* and its derivatives, e.g., bana grass. These crops tend to be perennial and therefore able to serve as living feed banks during periods of feed shortage.

Scientist-managed, on-farm research in agronomy and feed resources

The farming systems approach was emphasized to ensure relevance to the needs and resources of farmers in western Kenya.

Forage productivity

The results of cutting-frequency experiments with pigeon pea, sesbania, and leucaena in comparison with stover from maize indicated that sesbania was clearly superior in yield of forage dry matter (7,529 kg/ha) and crude protein (1535 kg/ha). Collaborative efforts with the University of California, Davis, verified that this species contained no nondegradable toxins. In comparison, leucaena yielded 5,224 kg/ha of dry matter and 1,152 kg/ha CP, respectively; pigeon pea produced 3,118 kg/ha and 603 kg/ha; and maize yielded 2,769 kg/ha and 266 kg/ha, respectively, when green leaves and mature stover were combined (Onim, 1987). Pigeon pea, sesbania, and leucaena leaves also provide a fine leaf hay with a crude protein content of about 26 percent. Several hay-making methods were studied. It was determined that good hay could be made and baled by using only a wooden box, a hand-held sickle, and sisal twine which can be tightened adequately by hand.

A major constraint to the use of forage was the supply of forage plants. Farmers do not have ready access to adapted grasses or fast-growing tree legumes. In collaboration with private, voluntary organizations such as CARE, ACTION AID, and others, the feed resources project established community nurseries for propagation and distribution of seedlings. Local production of seedlings ultimately became a part of the production and technology informational package.

Maize grain and forage

For several years during the implementation of the SR-CRSP program in western Kenya, the work with maize was conducted on a low profile basis. Many livestock-oriented researchers and administrators could see little need for what was perceived as a crop agronomy endeavor. Yet the outcome of that research was the characterization of several local maize cultivars, one of which had a high genetic frequency for multiple ears (cobs). This cultivar, dubbed the Maseno Double-Cobber, ultimately formed the foundation for a production system model combining food and forage crops to optimum advantage.

Experimental comparisons of locally selected prolific maize cultivars from farmer's fields with the recommended commercial varieties indicated important differences in grain yield and stover feeding value. In one series of experiments stover DM yields from the local maize exceeded by 50 to 300% that of commercial varieties recommended for the medium elevations of western Kenya (5,904 kg/ha-17,081 kg/ha versus 4,713 kg/ha). There were no significant differences in percent CP or DE. Even more striking were the results for grain where yields of the local cultivar (2,742 kg/ha-5266 kg/ha) were substantially higher than yields from the recommended commercial variety (1,159 kg/ha). These observations, which were consistent over several years of study, generated considerable discussion among maize scientists in Kenya. Adding to the tension was the fact that provincial administrators began urging that the "new" cultivar be released as soon as possible as a commercial variety. Ultimately the better local varieties were included in the national germplasm tests. Unfortunately, the comparisons during the first years of the test were inconclusive because of improper management of the middle elevation trials resulting in the loss of data. However, in 1991 KARI authorized the Maseno Double Cobber maize variety to be released to farmers. In 1992 and 1993, 9,500 kg and 10,000 kg of seed, respectively, were sold to farmers in the region.

Goat manure as a source of plant nutrients

In a series of trials over several years, the use of goat manure gave better crop yields than the application of the standard recommended commercial fertilizer, diammonium phosphate (DAP: N-P-K, 18-46-0). The manure improved crop (beans and maize) response over DAP at four on-farm sites and in one on-station trial. Since most soils in western Kenya are very acid (e.g., pH 4.5) and low in fertility, the use of DAP, which contains only N and P, tended to increase this acidity and severely reduce intercropped maize and bean yields. With no applying any fertilizer, only 417 kg/ha of beans were harvested, which the addition of

two double handfuls of goat manure increased dry bean yield increased to 750 kg/ha, an 80% increase (Table 2). All levels of DAP reduced bean yields relative to the manure treatments. The practical implications of this can be shown economically. Since 50 kg of DAP cost about U.S. $16.80, the farmer not only loses money purchasing the commercial fertilizer, but also loses 21% of the dry bean yield. Maize grain yields were increased by 200% (three-fold) compared to the no-manure control. A favorable residual effect was observed in the following year. Goat manure seems to improve crop performance not only by its multinutrient content, but also by its ability to reduce soil acidity.

Table 2. Impact of goat manure or diammonium phosphate (DAP) on bean grain and haulm weight.

Treatment	Approximate yields (kg) 14.4m2 plot
1 Tbs DAP	.98
2 Tbs DAP	.65
3 Tbs DAP	.90
2 HdFl Manure	1.90
4 HdFl Manure	2.25
6 HdFl Manure	2.20
Control	.89

Tbs = Tablespoon
HdFl = Handful
Information from Onim et. al. (1990).

Evidence from farms in the research clusters documented that mature dual- purpose goats provide approximately 360 kg of wet manure per goat per year, which converts to approximately 108 kg of dry matter. The manure is most often used on food crops. Farmers with surplus goat manure sell it to neighbors for cash after they have satisfied their own needs.

Forage Legumes

Sesbania research initiated by SR-CRSP scientists at Maseno in 1985, and supported with assistance from IDRC, attracted significant attention to this multipurpose tree. It grows naturally in many parts of Africa and is used for forage and fuel wood, and also enhances soil fertility. For several years the collection at Maseno has been the largest active *Sesbania* genebank in eastern and southern Africa. SR-CRSP researchers have collaborated with workers from ICRAF and others through the AFRENA and the then PANESA (now AFRINET) networks. They concentrated on screening the genebank of 14 species and over 200 accessions which originated from parts of eastern Africa. Because phosphorus deficiency is wide-spread in western Kenya and *Sesbania* is a P- loving plant, much of the screening was for response to the addition of phosphorus (P). Table 3 shows large differences between two major *Sesbania* species in terms of response to P. High versus low P-requiring *S. sesban var.nubica* accessions were also identified, there being considerable variation among accessions.

Table 3. Mean, standard deviation, and range for the different characters measured in the Sesbania provenances with (P1) and without (Po) phosphate fertilizer.

	Po Mean	P1 SD+	Range	Mean	SD+	Range
S. sesban var. *nubica*						
Seedling height (cm)	3.70	1.61	1.64-7.22	13.39	6.15	4.03-23.92
Shoot weight (gm)	1.91	0.63	0.98-3.21	4.07	1.75	1.91-8.69
Root weight (gm)	0.94	0.36	0.31-1.48	2.83	1.22	1.30-5.76
Nodule numbers	4.57	3.64	0.0-11.44	26.48	15.03	0.0-62.28
S. macrantha						
Seedling height (cm)	8.86	1.25	6.85-9.94	14.02	1.93	11.62-16.57
Shoot weight (gm)	2.18	1.01	0.94-3.39	4.40	0.87	3.39-5.36
Root weight (gm)	2.09	0.41	1.48-2.57	4.60	0.93	3.59-5.50
Nodule numbers	0.70	1.16	0.0-2.67	21.51	15.40	3.00-44.67

Source: Otieno et al. (1989).

Other forage legumes have also been studied. Leucaena, glyricidia, calliandra, and pigeonpea have been examined closely for their potential role as forage resources. Because of the multi-purpose nature of the tree legumes and the work initiated by the SR-CRSP feed resources group, a regional station associated with ICRAF/AFRENA was established at Maseno and serves Kenya, Uganda, Rwanda, and Burundi.

The role of calliandra in association with crops is becoming more doubtful based on research by the feed resources group. Studies undertaken in the last three years provide evidence that some kind of allelopathy inhibits growth and yield of maize grown in rows adjacent to calliandra (Onim et al., 1991). Interestingly, calliandra has been highly promoted in forestry and agroforestry circles in recent years prior to carrying out an indepth research program which looked at all potential uses and impacts. This underscores the importance of research groups working together in a production systems context and communicating effectively.

Sweet potatoes

Sweet potatoes are a useful crop for farmers who are raising dual-purpose goats. The tubers are excellent as human food, and the vines when fed to kids permit weaning as early as two to four weeks of age. This practice has the potential for adding 87 liters of milk available for household use during a single lactation, based on the amount that would otherwise be consumed by the goat kid were it not weaned early. Such results are a typical outcome where animal husbandry specialists work closely with agronomists in a research setting.

Early investigations in the area indicated that there were more than 40 cultivars of sweet potatoes made up of mixed clones; in one case a single cultivar comprised 13 clones in one farmer's field. These cultivars were grown by farmers within a 20 km radius. Differences were recorded in the yield of tubers and vines among cultivars, thus suggesting that a range of options existed in regard to the amount of feedstuffs produced from the sweet potato crop.

Model farm—a demonstration of feed resource options

Approximately five years ago the production systems group in western Kenya took steps to develop a model farm which would be illustrative of all the research results obtained. The 0.5ha farm incorporates the major elements of food security, income generation, and optimum resource use. On the farm the two preferred food crops are maize and beans. Around and among the food crops are rows of sesbania, leucaena, calliandra, and napier grass. A 10m x 10m patch of sweet potatoes was planted. Four dual-purpose does are attached to

the farm. Four is the number of does adequate to provide a constant supply of milk throughout the year for most households (Semenye et al., 1991).

The demonstration has shown that even on a small farm in an area of tropical acid soils it is possible to supply enough food for a typical household and, at the same time, produce more than enough feedstuffs for four mature lactating does and the associated immatures. The does produced an average of 0.68 kg of fecal material and 0.34 liters of urine per day. Figure 5 presents a sketch of the layout of the farm.

It is important to emphasize that the major element which makes the system attractive to farmers is use of the double cobber maize which allows total maize grain yields to be maintained at expected levels despite loss of land area allocated to maize in order to accommodate the multipurpose trees and forage crops. Experience with local farmers had previously indicated a strong reluctance to give up food-crop land for forage or fodder crops.

The total amount of feedstuffs produced on an annual basis were surplus to the needs of the goats. This means that the "surplus" feedstuffs can be used for other livestock, used to support a larger number of goats, sold for cash in local markets, or sold or bartered in the neighborhood. Based on local market value, the feedstuffs produced were worth at the time approximately U.S. $709 per annum. A farmer survey completed around the research clusters indicated that up to 80% of farmers would like to incorporate the interventions demonstrated on the model farm.

Summary

Research strategies for addressing the feed resource requirements of dual-purpose goat production evolved over years of investigation in the context of a production systems approach. The systems approach mandated that a broad view be taken of the biological and economic resource base available for dual-purpose goat production. The attitudes and views of farmers influenced scientists to focus on a particular set of interventions different from those originally proposed prior to defining the constraints were well defined in concert with the target smallholders.

The final outcome of this research has been a technical package that includes comprehensive interventions in the area of feed resources and feeding strategies for the dual-purpose goat. Current activities involve strengthening infrastructure and training in these technologies through nongovernment organizations in western Kenya. The production system, including feed resource development, is being tested for impact in two other environments in Kenya. This activity has the effect of training additional scientific staff in the on-farm, client-oriented research methodologies which were used so effectively in western Kenya.

Literature Cited

Anon. 1987. Annual Report for Kenya. Program Year Eight, 1986-87. Small Ruminant Collaborative Research Support Program. University of California, Davis. p 1.

Hart, R.C., J.F. Moses Onim, S.L. Russo, M. Mathuva, K. Otieno, and H.A. Fitzhugh. 1984. An Analytical Framework for Feed Resources Research on Mixed Farms in Western Kenya. SR-CRSP Technical Report 46.

Mukhebi, A.W., F.B. Nyaribo, R.H. Bernsten, J.E. Reynolds, and A.N. Mbabu. 1984. A socio-economic evaluation of the dual purpose goat enterprise in small-scale farming systems in western Kenya. Proceedings: Third SR-CRSP Workshop. pp 95-108.

Onim, J.F.M. 1987. Alternative Uses of Pigeon Pea (*Cajanus cajan* (L) Millsp.). Eastern and Northern African Regional Research Symposium on Grain Legumes. ICRISAT/ILCA, Addis Ababa, Ethopia.

Onim, J.F.M., P. Ochola, H.A. Fitzhugh, P. Oduor, and K. Otieno. 1990. Potential of goat manure as a valuable fertilizer for small scale farmers. Proceedings: Eighth Annual SR-CRSP Workshop. pp. 157-170.

Onim, J.F.M., K. Otieno, and W. Getz. 1991. Boarder effects on maize grain yields by *Leucaena*, *Sesbania* and *Calliandra* in an alley cropping system. Proceedings: Nineth Annual SR-CRSP Worlshop. pp 95-101.

Otieno, K., J.F.M. Onim, R. Hart, and H.A. Fitzhugh. 1984. Botanical composition and crude protein content of forage grazed, and grazing behavior of goats at Maseno Farm and SR-CRSP clusters. Proceedings: Third SR-CRSP Workshop. pp 75-80.

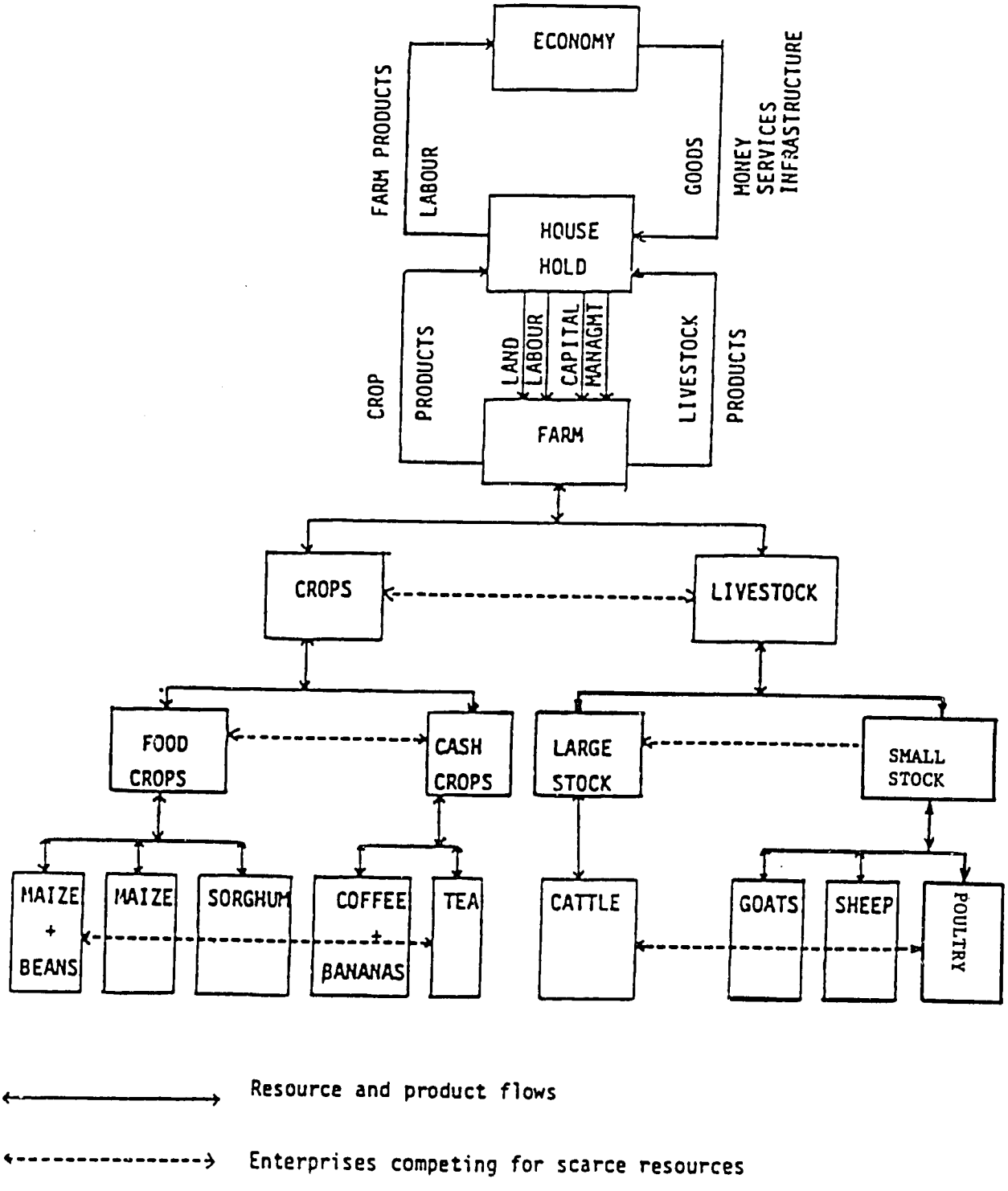
Otieno, K., J.F.M. Onim, B. Dzowela, and M.N. Mathuva. 1989. The effect of phosphorus on the germination and seedling growth of *Sesbania* provenances from Tahzania and western Kenya. Proceedings: Seventh Annual SR-CRSP Workshop. pp 73-86.

Sands, M.W., H.A. Fitzhugh, R.E. McDowell, and S. Chema. 1983. Mixed Crop- Animal Systems on Small Farms in Western Kenya. SR-CRSP Technical Report 17.

Semenye, P.P., D.N. Siamba, M. Shisya, and W. Getz. 1991. Integration of dual-purpose goats with maize production. Proceedings: Nineth Annual SR- CRSP Workshop. pp. 102-107.

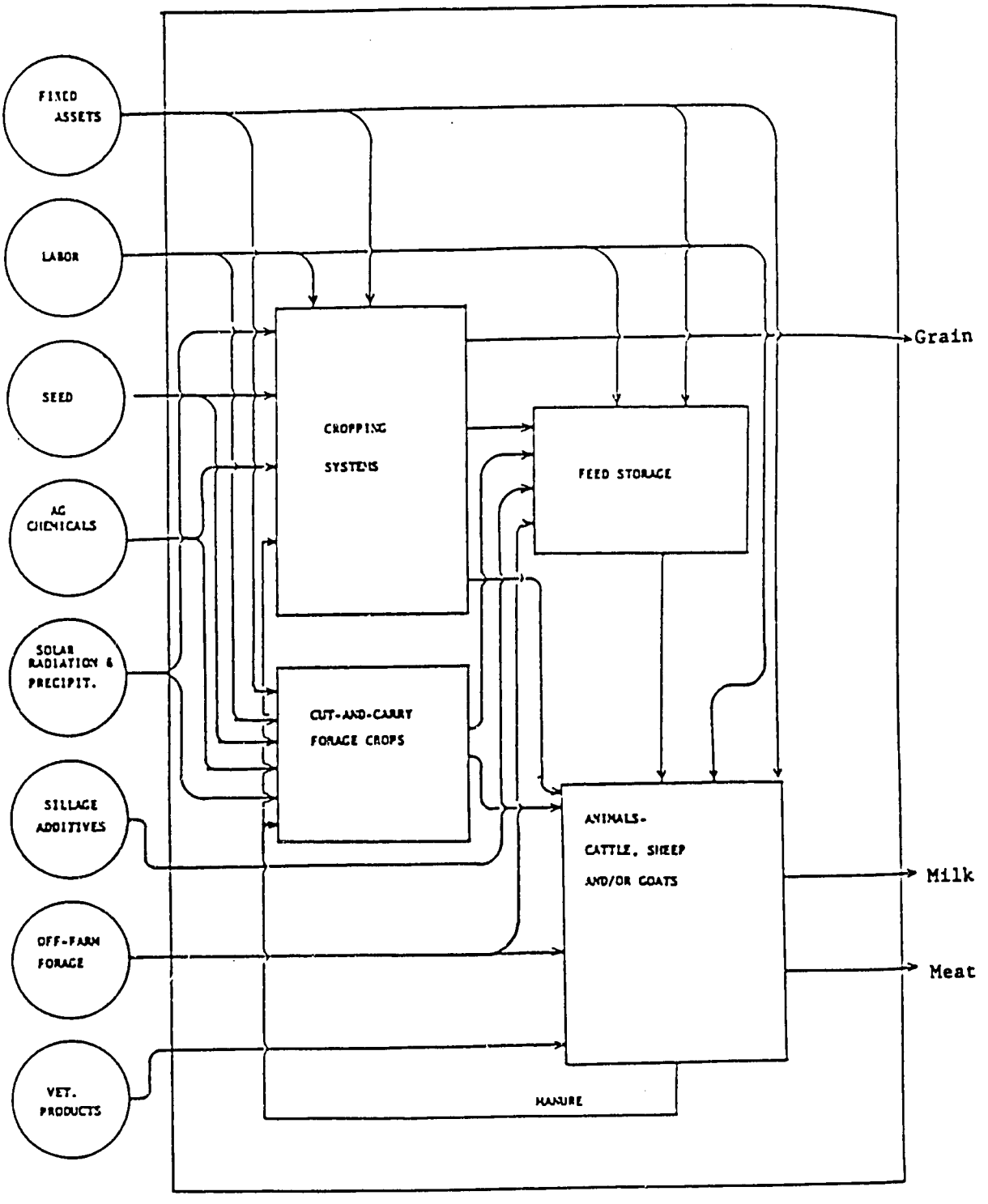
VanKeuren, Robert W. 1981. Intensive Forage Production Systems for Smallholder Sheep and Goat Producers Project Annual Report. In: Small Ruminant Collaborative Research Support Program Annual Report 1980-81. pp. 72-74.

Figure 1. Model of a small-scale farm in Western Kenya.



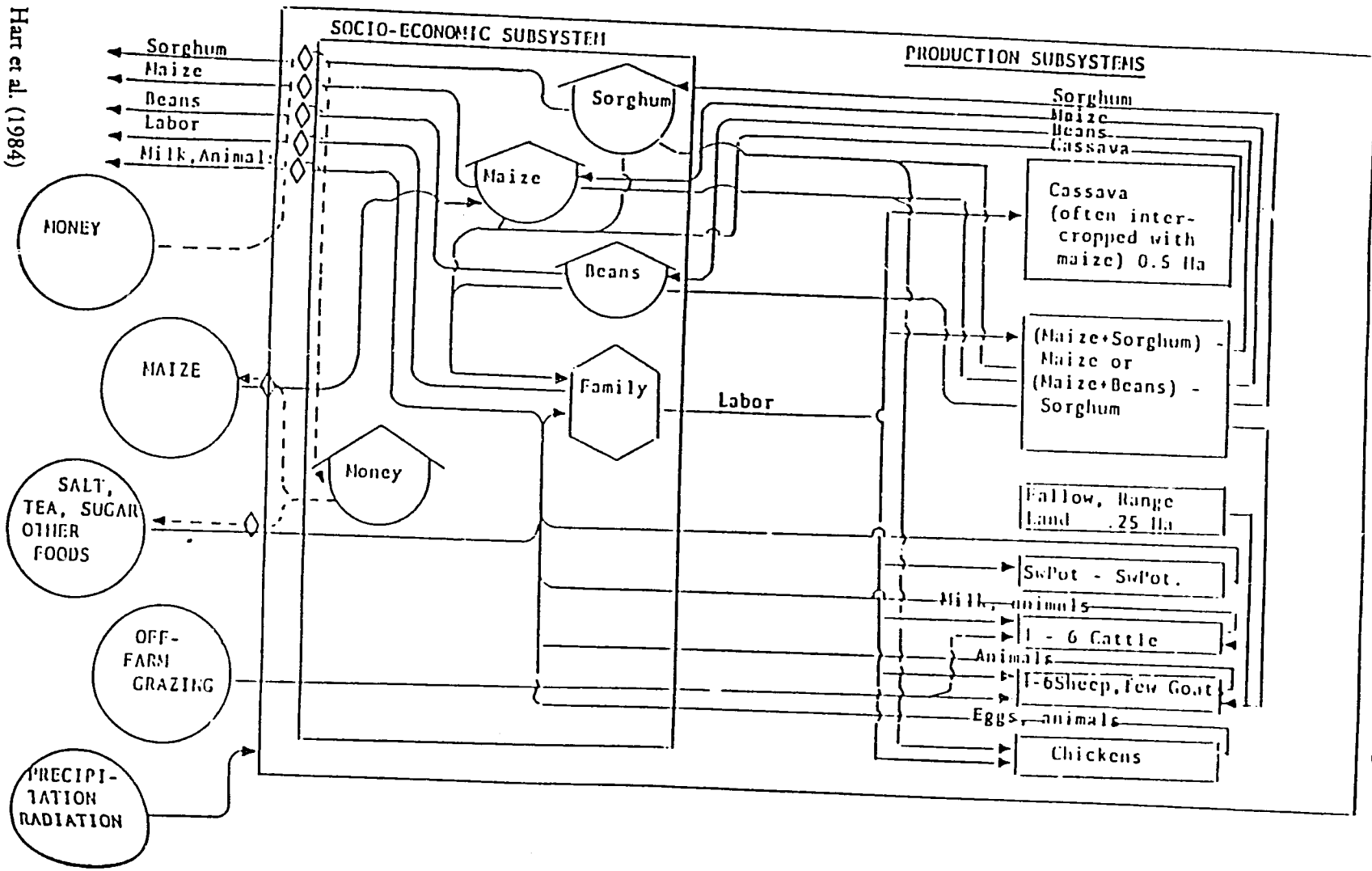
Source: Mukhebi et al. (1984)

Figure 2. A quantitative description of a crop/animal production system found on small farms in Western Kenya.



Source: Sands et al. (1983)

Figure 3. A "typical" small farm in Siaya, Kenya. Circles are inputs to the farm. Arrows are outputs. Tank symbols indicate storage. Flows of money are dotted lines; materials and energy are solid lines.



Source: Hart et al. (1984)

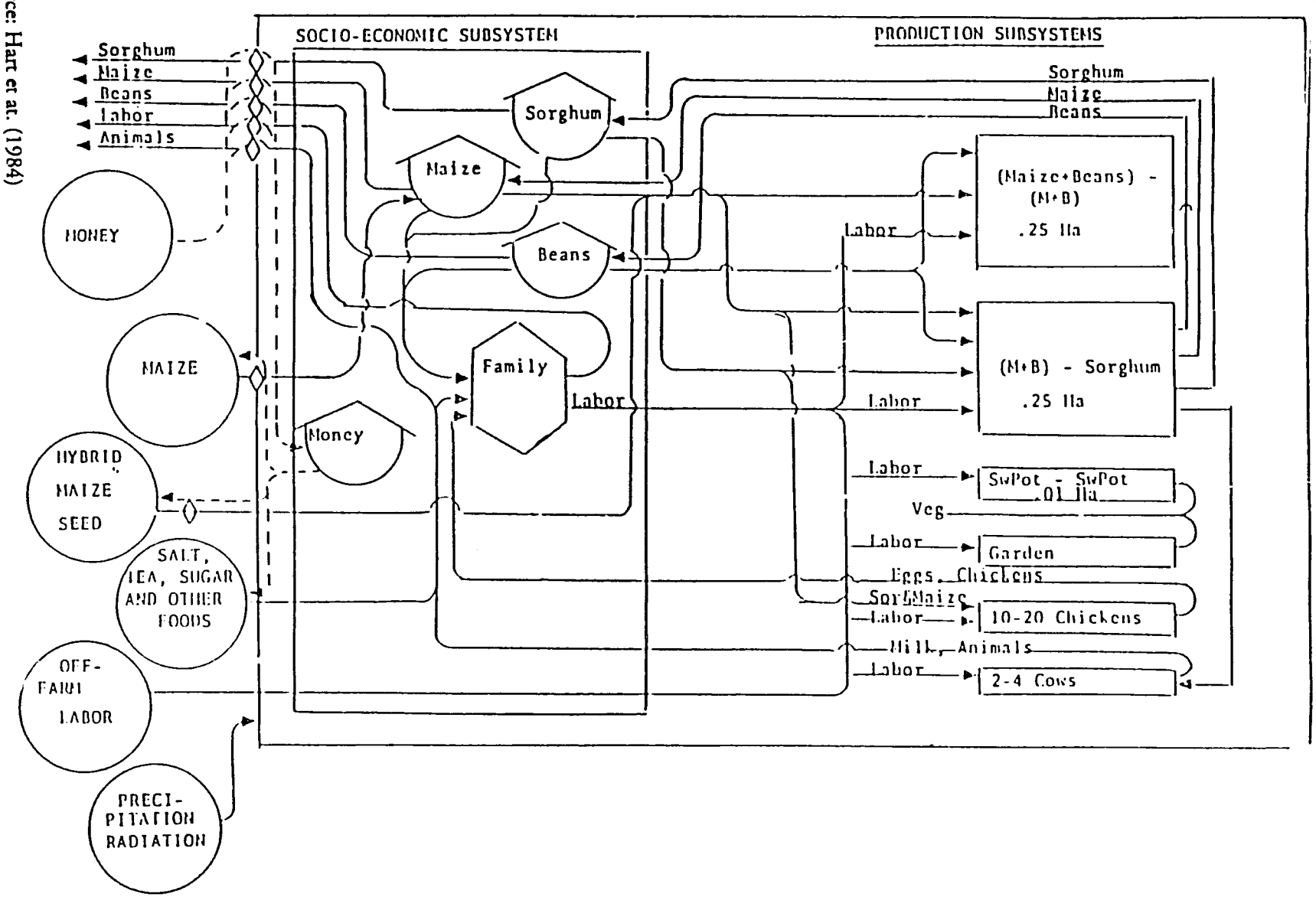
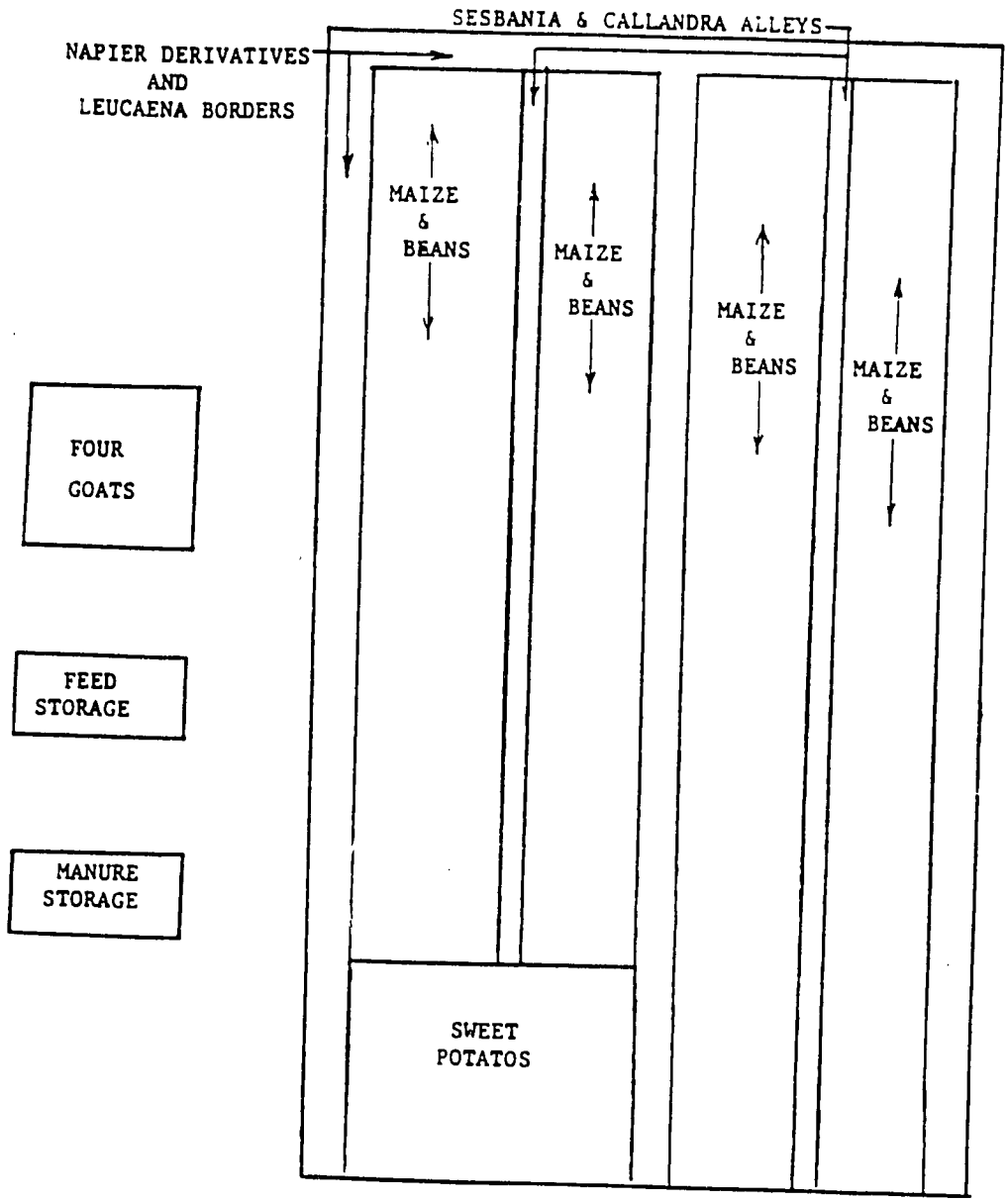


Figure 4. A "typical" small farm in Kakmega, Kenya. Circles are inputs to the farm; arrows are outputs; tank symbols indicate storage; flows of money are dotted lines; flows of materials and energy are solid lines.

Source: Hart et al. (1984)

Figure 5. Model farm (.5ha) for small scale crop-livestock farmers in sub-humid zone.



Maize and beans	60 percent
Sweet potatos	6 percent
Forages as borders	22 percent
Forages as legume alleys	12 percent