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Small Ruminant Collaborative Research Support Program

Annual Report 1989-1990

Collaborating Institutions

United States

Science and Technology Bureau, United States Agency for International Development (USAID)

Board for International Food and Agricultural Development (BIFAD)

Joint Committee on Agricultural Development (JCARD)

Overseas Collaborators

Indonesia	Agency for International Research and Development (AARD)
Kenya	Kenya Agricultural Research Institute (KARI)
Morocco	Institut Agronomique et Veterinaire (IAV), Hassan II University
Peru	Instituto Nacional de Investigacion Agraria y Agroindustrial (INIAA)

Participating Institutions

University of California, Davis
Colorado State University, Ft. Collins
University of Missouri, Columbia
Montana State University, Bozeman
North Carolina State University, Raleigh
Texas A&M University, College Station
Texas Tech University, Lubbock
Utah State University, Logan
Washington State University, Pullman
Winrock International Institute for Agricultural Development, Morrilton, Arkansas

Small Ruminant Collaborative Research Support Program

Annual Report

Program Year Eleven
1989-1990

United States Agency for International Development
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Foreword

This 1989-90 Annual Report for the Small Ruminant Collaborative Research Support Program covers the activities in research, extension eduction, and formal academic training conducted by ten U.S. universities and research institutions and the four collaborating institutions overseas. It is the last year of the second five-year grant from the Agency for International Development in support of a development strategy with small ruminants. Another five-year program of work has been planned, approved, and is in progress. The objectives are to increase the production, efficiency, and sustainability of small ruminants (sheep, goats, llamas, and alpacas) in lesser developed countries and in the U.S. The collaborating organizations are listed on the inside covers of this report.

The program and the report are organized under five major broad categories or thrusts within which the work is carried out. These are called components and are identified as follows:

I. Integration of Dual Purpose Goats into Kenyan Farming Systems

II. Breeding More Prolific Strains of Sheep

III. Animal Health Management

IV. Agropastoral Systems on Marginal Lands

V. Socioeconomics of Crop and Livestock Production

Reports are by projects that are planned, budgeted, and carried out by the participating U.S. institutions in collaboration with the overseas agencies. Each project report identifies the names and affiliation of collaborating personnel, and a brief summary of the results for the past year. The detailed reports for each project are as prepared by the indicated project leader or principal investigator.

Some of the highlights of the present report are detailed below.

- A considerable improvement in milk yield of Kenyan goats with the infusion of genes from the dairy breeds Toggenburg and Anglo Nubian.

- In Kenya, where feed supplies for goats are short, sweet potato vines were found as the best milk replacement for unweaned goat kids.

- Also in Kenya, the stripping and feeding of the lower maize leaves to lactating does provided maintenance and production without affecting grain yields.

- Sheep in Indonesia were a mixture of ewes of high and low prolificacy, making it possible for farmers to chose the types suitable to their feed supplies and management practices.

- Feeding trials in Morocco clearly indicated the need for protein and energy supplementation of ewes after the first month on stubble grazing.

- Ewes given molasses with 3% urea while grazing under rubber trees in Malaysia produced a lamb crop that was 21% greater in value less the cost of the supplement than those unsupplemented.

- Producers of sheep in Peru can reduce the occurrence of ovine pulmonary carcinoma in their flocks by rapid and periodic elimination of disease affected animals.

- An inactivated vaccine has been developed for contagious caprine pleuropneumonia that protects goats in Kenya for at least a year.

- Heritability estimates under the harsh high Andean environment are similar to those observed in other parts of the world, clearly indicated a selection program within breeds should succeed.

- Detailed studies of grazing intensity of Steppe vegetation in Morocco are providing information on the possible future of a vegetation type that dominates 50 million hectares in North Africa and the Middle East.

- In a complementary grazing system in Peru, llamas and sheep offer the most efficient way of harvesting the native vegetation because of differences in their species preference.

Maps

Maps of the countries with which the Small Ruminant CRSP collaborates are included on the following pages:

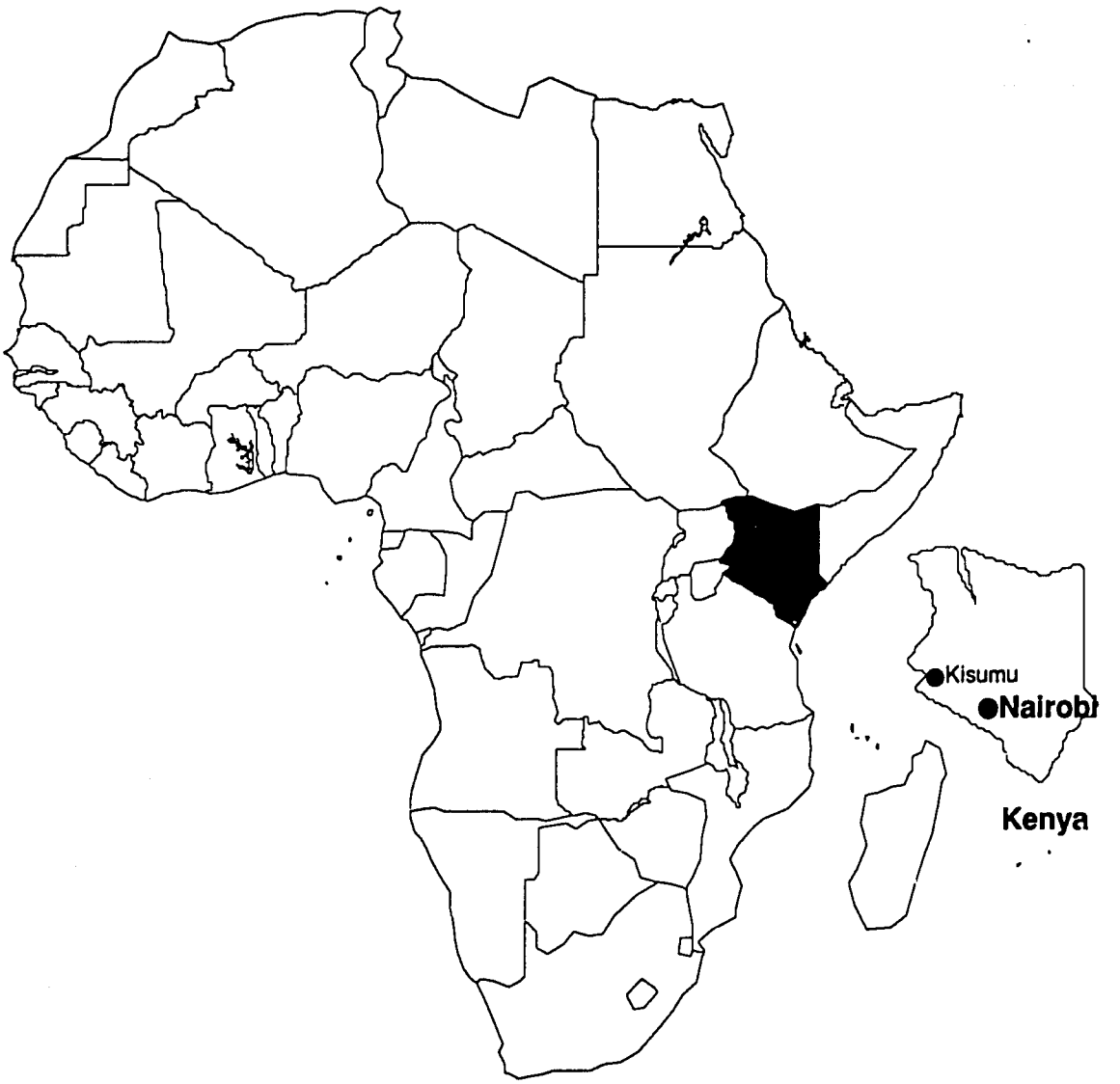
viii Indonesia

ix Kenya

x Morocco

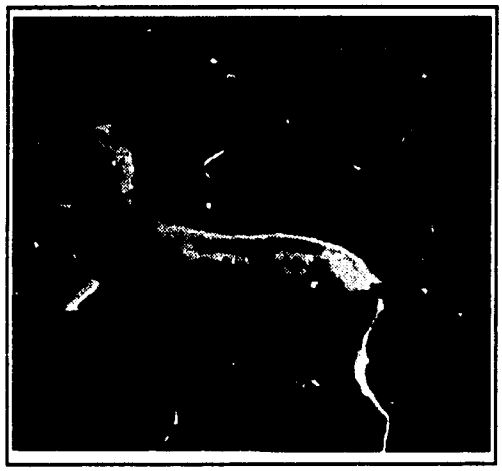
xi Peru

Indonesia


Kisumu
Nairobi
Kenya

Rabat
Tadla
Morocco

Lima
Peru



Breeding and Integration of Dual Purpose Goats into Kenyan Farming Systems

◆ Texas A&M University

Breeding a genetically improved dual purpose goat adapted for production in Kenya

◆ University of Missouri

Sociological analysis of small ruminant production systems in Kenya

◆ Winrock International – Economics

Economic analysis of small ruminant production and marketing systems in Kenya

◆ Winrock International – Production

Dual purpose goat production systems for smallholder agriculturalists in Kenya

Breeding a Genetically Improved Dual Purpose Goat Adapted For Production in Kenya

Texas A&M University
Jeremy F. Taylor

Principal Investigator

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Collaborating Institutions

Kenya Agricultural Research Institute (KARI), Kenya House, Koinange Street, P. O. Box 57811, Nairobi, Kenya

University of Nairobi, Nairobi, Kenya

Summary

Project objectives are to breed a genetically improved dual purpose goat for Kenya and to determine the genetic mode of resistance to *Haemonchus contortus*, a parasite that is difficult and expensive to control through the use of drugs. Indigenous goats are too low in genetic potential for growth and milk yield to provide a base for developing a suitable dual purpose goat and exotic dairy breeds are not viable in western Kenya. Therefore a breeding program was designed and implemented to produce a low maintenance and high milk producing goat adapted to Kenya conditions.

A study initiated in 1989 investigated milk yields of Kenya dual purpose goats, F_1s, and indigenous East African and Galla does. The F_1s were from crosses of Toggenburg and Anglo Nubian breeds with East African and Galla breeds. The results indicate considerable

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improvement in milk yield with the infusion of genes from the dairy Toggenburg and Anglo Nubian breeds. The average milk yield of 1.1 kg/d of the dual purpose goats was consistent with the goal of 4.0 kg/d peak daily yield achieved after selection. Sufficient variation was evident in the breed-type to allow selection to ensure the breeding goal as well as to reduce the variation in yield evident in the existing first generation Kenyan dual purpose goat. Numbers of purebred indigenous goats at the Ol'Magogo Research Station are decreasing proportionally to F_1's and the Kenyan dual purpose goats as the emphasis in the breeding program moves toward producing the 4-way synthetic cross from F_1's and inter se mating of the dual purpose goats.

A computer model was used that simulates small ruminant performance to predict how sheep in northern Kenya would respond to selection pressure for mature size and milk production. Flock performance as determined by protein efficiency indicated that in this arid environment, culling ewes at eight years of age was the most beneficial practice. A high level of selection intensity should be used to compensate for modest ewe replacement rates. The computer simulation studies provide insight into changes of flock performance as different selection programs were imposed on a sheep population that had not previously been subject to selection. It was clear that care must be taken as to the speed with which programs are implemented in harsh environments and where both meat and milk are important components of the sheep enterprise. The computer simulation provides an additional tool for animal breeders to make evaluations of selection strategies.

Texas A&M University, Washington State University, and the University of Nairobi are collaborating on a study of resistance in goats to the parasite *Haemonchus contortus*. Among 95 kids as well as others monitored for natural infection, 21 goats showed resistance/resilience of differing magnitudes and comprise a resistant line. One doe showed no detectable fecal egg counts in three separate artificial infections. An embryo transfer program is planned to create a halfsib family to augment existing family data. In an earlier screening trial of 134 individuals, 13 never required treatment for parasite load, and of 25 sires represented by their progeny, six produced progeny which were resistant or resilient.

Preliminary results indicate resistance is not controlled by a single gene but by two or more genes, perhaps with several modifying genes. Resistant kids grew more rapidly than the average of all tested goats, indicating that selection for resistance is without negative effects on growth. To search for Quantitative Trait Loci controlling resistance, blood samples were taken and DNA isolated for Restriction Fragment Length Polymorphisms (RFLP) analysis. Although a number of problems exist with the collection of data at this time, initial results from these experiments are promising. As more data are collected on these animals, it will be possible to assess the potential for using molecular genetics techniques along with other animal breeding practices.

The Randomly Amplified Polymorphic DNA marker technique was used with blood samples from 105 goats of various breeds and crosses among them. Use of this technique appears to be a powerful tool for detecting polymorphic DNA markers which can be used in marker assisted selection. With more data it is possible that this technique will be useful in selection to reduce fecal egg count.

Research Results

Objectives

1. Research on the Kenya Dual Purpose Goat (KDPG) has three objectives, namely:

- To propagate a nucleus flock of KDPG and to establish on-station and on-farm testing, stabilization, breed selection, and registration criteria required for the widespread utilization of the KDPG as a genetic resource.

- To effect breed improvement and stabilization through individual and progeny testing programs for the new synthetic breed (1/4

Toggenburg x 1/4 Anglo Nubian x 1/4 East African x 1/4 Galla).

- Milk and meat production and adaptability (especially resistance to internal parasites) are the major selection criteria. The target KDPG for the smallholder has a milk potential of 4 kg/day at peak lactation and a mature weight of 40 kg.

2. Determination of the genetic mode of inheritance of resistance to *Haemonchus contortus* and development of a resistant line of KDPG.

Problem Statement and Approach

Developing a new breed is a relatively long-term process and the time investment must, therefore, be weighed against needs, benefits, and alternatives. At the initiation of the SR-CRSP project in Kenya, four key criteria for an acceptable and sustainable Kenya Dual Purpose goat (KDPG) were identified:

1. Survey results showed that a dual purpose goat was critically needed in the high potential area of Western Kenya and that, if the forage resource was developed to its potential, it would be adequate to support the nutritional requirements of such a goat.

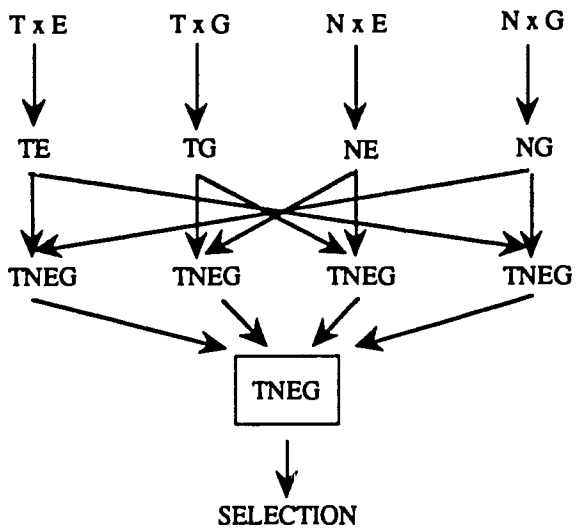
2. On-farm and on-station studies indicated that indigenous goats were too low in genetic potential for growth and milk yield to be an acceptable base for developing a suitable dual purpose goat.

3. From experience and research data, it was evident that exotic dairy breeds were not viable under the nutritional and management conditions of the smallholder farmer in Western Kenya.

4. Although early research demonstrated that the F_1 cross between the indigenous and exotic goats performed satisfactorily, a structured crossbreeding program was not feasible for recommending to smallholder farmers.

These four criteria indicated that the development of a new breed was the best strategy, because a breed:

- provides a lasting genetic resource;
- can be effectively selected to improve performance to suit existing conditions; and
- can be adapted to conditions as they change in the future.



T - Toggenburg purebred males
N - Anglo Nubian purebred males
E - East African purebred females
G - Galla purebred females

Figure 1. Formation of the Kenya Dual Purpose Goat.

Therefore, the breeding program in Figure 1 was designed and implemented to focus on the genetic aspects of producing a low maintenance and high milk-producing KDPG for Western Kenya, which could be adapted to other areas of Kenya.

Critical to the current phase of stabilization and selection of an acceptable and sustainable breed are the numbers of four-way cross (KDPG) animals available from which a breed can be established with the required characteristics. Currently, there are approximately 329 F_1 and 155 KDPG does at Ol'Magogo. Projections are that there will be approximately 400-500 KDPG does by 1993, if the current breeding strategy is followed. Efforts to optimize husbandry practices to minimize kid losses are being implemented to maximize numbers of animals. Body weights and weight gains are measured on all kids. Reproductive perfor-

mance is measured on all females and lactation performance on samples of females is currently being monitored to facilitate selection for meat and milk productivity.

A major production constraint of cattle, sheep, and goats in tropical and subtropical areas is the detrimental effect of the stomach worm *Haemonchus contortus*. These effects include reduced productivity, cost of continuous treatment, and dangers to smallholders handling the anthelmintics. Through field testing, this project has established that there is wide ranging variability for resistance/resiliance to *Haemonchus contortus* in the genetically segregating KDPG population. Weaned kids were exposed to natural parasite infection for one year; of 134 kids sired by 25 bucks, 13 sired by six bucks did not develop a parasite load requiring treatment. These untreated yearlings performed at the same level as those that were periodically treated. A follow-up controlled experiment with both resistant and susceptible goats screened from the field tests resulted in nine goats maintaining a high level of resistance. Planned matings involving resistant and susceptible goats have been made and DNA extracted from parent animals and their progeny for analysis. Polymorphic DNA markers including Restriction Fragment Length Polymorphisms (RFLPs) and Random Amplified Polymorphic DNA (RAPDs) are being identified among goat families, and statistical analyses will be conducted to determine associations between marker loci and *Haemonchus contortus* resistance. Determination of the genetic mechanism of resistance would provide an invaluable component to the derivation of the KDPG and indeed would be a boon worldwide to reduce costs and chemical input into the food chain.

Justification

In order to establish the KDPG as a viable breed available to Kenya farmers, plans are in progress to establish nucleus breeding flocks in collaboration with three to five private and institutional breeders. These collaborating breeders will initially be supplied with bucks from the KARI foundation flock at Ol'Magogo, for progeny test evaluation on-farm. As sufficient numbers of does are produced in the KARI foundation flock, they will be released to the collaborating breeders for further selection, stabilization, and multiplication of the breed. It is expected that the major supply of KDPG goats to farmers will be through these core breeders, with the foundation flock acting as an elite nucleus breeding herd, although there will be some releases directly from the KARI foundation flock to farmers. The principal role of the foundation flock during the stabilization and multiplication phase is to be responsible for the genetic improvement of the KDPG, to the point that it is truly a superior dual-purpose breed, adapted to Kenya with the potential to produce milk and meat at an optimal level for farm families. The flock will be maintained in a long-term program as an elite flock where detailed production records will be collected and an intense genetic improvement plan followed. Selection emphasis will shift from the individual to genetic evaluation based on information on relatives as well as individual performance. Milk samples of lactating females will continue to be recorded on a daily basis and their records analyzed using mixed model procedures to predict breeding values of their sires for selection.

Goats which will form the initial flocks of collaborating breeders (core breeders) are not anticipated to have the genetic potential for milk yield that is the ultimate goal of 4.0 kg/day at peak lactation. The initial release of does should have a potential of about 3.5 kg/day. It is estimated that the foundation flock will require about six to eight years of selection to increase potential to 4.0 kg/day, while simultaneously holding mature size constant. Data collection by the collaborating breeders will be supervised by the SR-CRSP breeding project resident scientist, and will be used for progeny testing sires in the environments in which their daughters are expected to produce. The proposed program would be a joint venture between the SR-CRSP, KARI, and the core private breeders, each providing incentives as well as checks and balances to the others, all to the betterment of the KDPG and farm families who will use this new breed. This strategy will not only provide the opportunity to examine the performance of

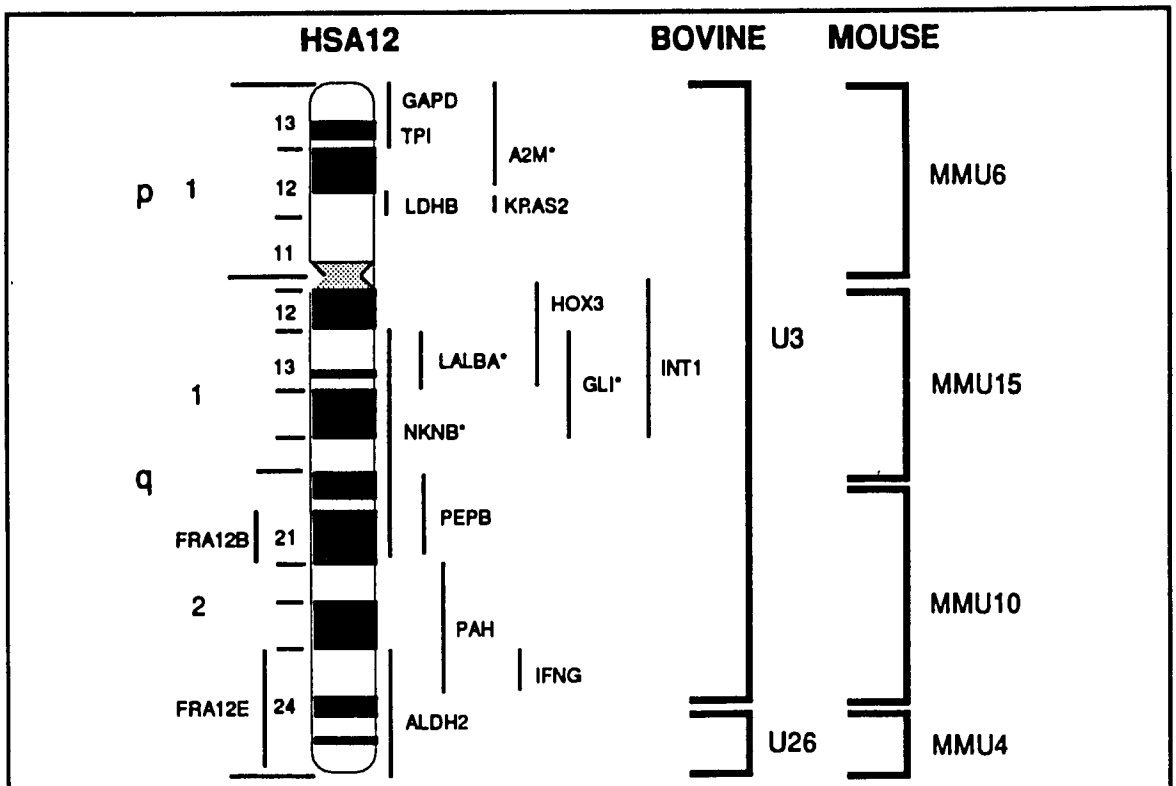


Figure 2. Comparison of Human Chromosome 12 with bovine and mouse chromosomes

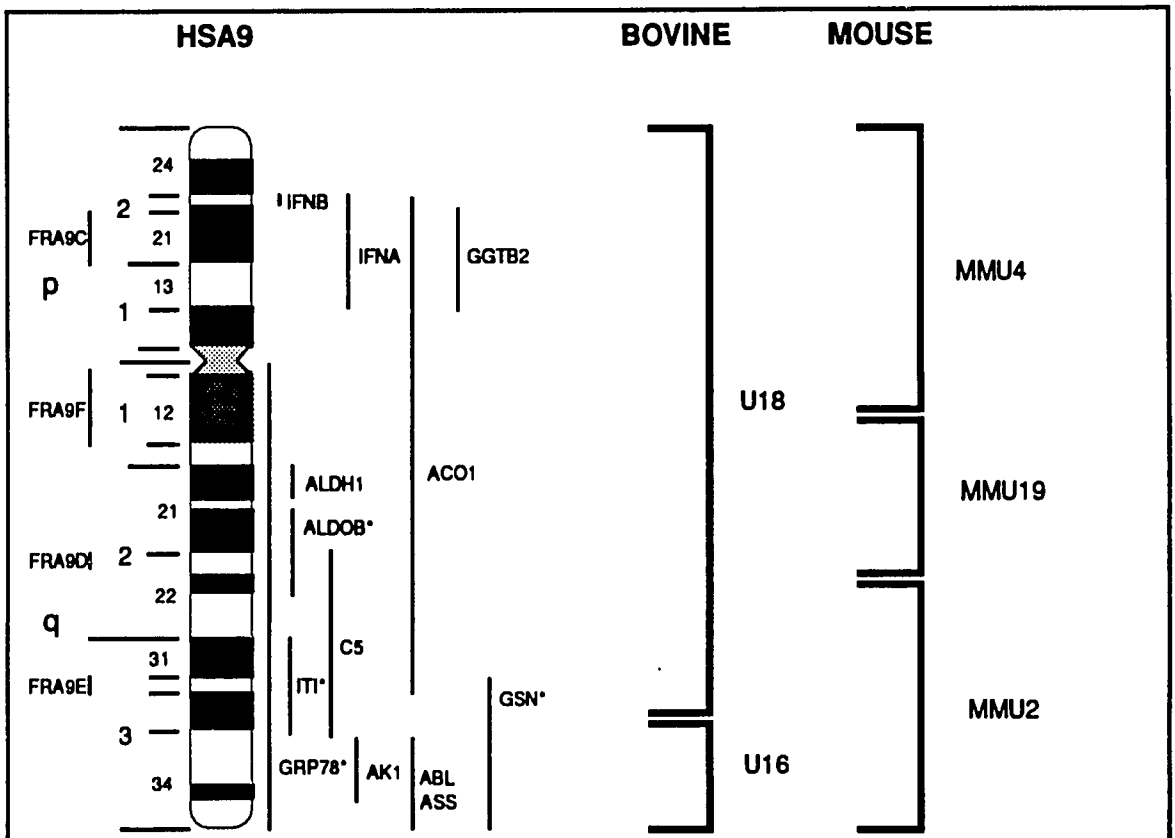


Figure 3. Comparison of human chromosome 9 with bovine and mouse chromosomes

selected animals "on-farm" for comparison with performance of relatives "on-station," it will allow the development of the infrastructure for the orderly transition of the project to the Kenyans once the SR-CRSP terminates its research work.

Small ruminants in tropical environments are constantly being challenged by internal parasites. Drugs have been only marginally effective and the parasites may develop resistance to them. A major but often unappreciated problem is the possibility of mishandling of these chemicals allowing for human ingestion or contamination of the food chain. If strains of resistant/resiliant goats can be identified and selected, a major constraint to production and food chain contamination can be alleviated. Studies in the United States, Australia, and New Zealand have shown that there is genetic diversity in populations of sheep and goats and this has been substantiated in our four-breed synthetic KDPG population. Rather than follow traditional breeding program designs intended to exploit quantitative variation, we hypothesize that the detection of major genes influencing resistance to *Haemonchus contortus* using molecular genetics approaches would allow for much greater opportunities to make genetic improvements using genotypes identified at the DNA level rather than phenotypic level. Marker genes associated with resistance would allow the identification of resistant genotypes in small ruminant populations worldwide to effect rapid and cost efficient genetic progress for resistance.

The U.S. government has launched "the human genome initiative," a super-science project with funding of at least three billion dollars. The mapping and complete sequencing of each of the human chromosomes will contribute greatly to our basic understanding of gene organization and will have application for the diagnosis and treatment of genetic diseases. The results of the human genome initiative also have important implications for the beef industry. Recent research at Texas A&M University has documented extensive conservation of synteny (syntenic genes occur on the same chromosome) between humans and cattle. For example, the majority of the genes found on human chromosome twelve are found on bovine chromosome U3 (Figure 2). In addition, the majority of the genes found on human chromosome nine are found on bovine chromosome U18 (Figure 3). This means that genes which are identified on a specific region of a human chromosome can be readily mapped to their corresponding location on a bovine and probably ovine and caprine chromosomes. The rapid progress made in genome mapping is evidenced in table 1.

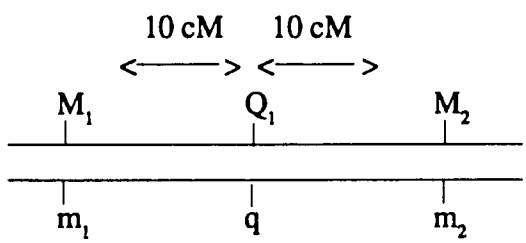
One of the best examples of the existence of major genes that impact a quantitative trait is given by human serum cholesterol. Everyone is now aware that a great deal of variation exists for serum cholesterol and that this variation may affect an individual's risk for coronary heart disease. This phenotypic variation has a significant genetic basis: 58% of the variation for serum cholesterol levels can be explained by genetic variation in the population (V_g), and 42% can be explained by environmental variation (V_e) [Boerwinkle and Sing, 1987]. Of the variation due to genes, 59% can be explained by a person's genotype at three loci which encode apolipoproteins A IV, B, and E (Talmud and Humphries, 1986; Boerwinkle and Sing, 1987).

Table 1. Progress made in genome mapping

Species	Chromosome Pairs	Number of Mapped Genes 1984	1987	1990
Man	23	820	1200+	9000+
Cattle	30	25	50	160
Sheep	27	14	27	35
Pig	19	30	38	40

Over one-third of the phenotypic variation in human serum cholesterol is determined by only three genes. Furthermore, by knowing an individual's genotype for these loci, it is possible to determine the individual's genetic propensity for high serum cholesterol.

A major goal of the gene mapping effort will be to identify additional RFLPs and RAPDs for use as genetic markers. The term marker is used to infer that these genes may be sufficiently closely linked (by proximity) to certain major genes, that the marker and major genes are inherited together as indicated in the following figure:



Historically, marker loci used by breeders and geneticists as selection aids were physiological and included coat color and polledness genes. These markers were themselves major genes that were not necessarily linked to other genes influencing QTL. These ideas are not new, and the use of visible markers to detect QTLs began in the 1920s (Sax, 1923). A major limitation of these early studies was the lack of sufficient numbers of variable markers to saturate the genomes of the target species. The detection of RFLPs and very recently RAPDs provides an additional suite of biochemically identifiable markers to allow detection of major genes.

The practicality of this approach has been demonstrated repeatedly. One of the best recent studies is that of Edwards *et al.* (1987) in corn. Edwards *et al.* (1987) used 25 variable genetic markers (less than half the number currently available in cattle) to search for QTLs affecting 82 traits of commercial importance. They were able to locate QTLs for every trait of interest. In a subset of 25 traits examined in great detail, 8% to 40% of the phenotypic variation could be explained by the markers, with individual markers explaining up to 16% of the phenotypic variation. In combination, the markers explained 30% of the variation in the trait of greatest economic importance--grain yield. Although the small percentage of variance accounted for by a single marker may seem minor, each may actually be of great importance. For example, the ADH 1 locus explained only 3.5% of the variation in grain yield, yet the alternate homozygote classes differed, on average, by 20 gm per plant, roughly 16% of the average grain yield. This reveals that genetic variation is a function of both gene effect and gene frequency. Desirable alleles, such as at the ADH 1 locus, may themselves be of large effect but contribute relatively little to total variation due to their low frequency. Such loci can contribute greatly to genetic improvement, since there is a large effect of a change in gene frequency on the genotypic mean.

Successful searches for QTLs with major effects are not limited to plants. Beever *et al.* (1990) used six polymorphic marker loci to look for genes of major effect in a large (n=146) halfsib family of Angus cattle. They detected markers that had a significant effect on preweaning growth and lean muscle content. This study examined only a very small fraction of the bovine genome and suggests that an exhaustive survey should reveal numerous QTLs of economic importance.

Genes have been mapped for all bovine syntenic groups, and restriction fragment length polymorphisms (RFLPs) have been identified for 16 of the 29 bovine autosomes. This work is proceeding at a rapid rate and research is focusing on three areas: assigning more genes to syntenic groups, assigning syntenic groups to specific autosomes, and locating RFLPs and other polymorphic DNA markers which are associated with mapped sequences. The goal of our research requires generation of a set of markers on all of the caprine chromosomes to detect linkage with potential major genes influencing resistance to *Haemonchus contortus*.

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Project Progress and Achievements

Development of the KDPG

A. Milk Production

A study was initiated in 1989 to investigate differences in potential milk yield of the KDPG, F1s, and indigenous East African (EAG) and Galla does. Seventy does were used to estimate once daily milking yields under conditions of intensive nutrition. The animals comprised 8 EAG, 17 Galla, 32 F1s, and 13 KDPG. The F1s comprised Toggenburg and Anglo Nubian crosses with EAG and Galla.

In addition to the routine housing, grazing, and veterinary protocols of the animals at Ol' Magogo, does in this study were fed lucerne hay ad libitum and were provided 1/4 kg of dairy meal concentrate at each morning milking. Does were hand milked by experienced milkers. There was a tendency for incomplete stripping of milk since the does were milked in the absence of their kids. Residual milk was estimated by the weigh-suckle-weigh method following suckling by the kids after milking. Total daily milk was the combined measure at milking and from the residual. The accumulated average daily milk yield for the period August-December, 1989, was analyzed for genotype variation.

The analysis assumed an operational model including fixed effects for breed of doe, sex, and breed of kid which were tested for significance against an error term defined as doe phenotype. Interactions and other variables of known biological importance to milk yield (including age of doe and stage of lactation) were not included in the analysis due to the relatively small sample size. The analysis of variance accounted for $R^2 = .72$ of total variation in average daily milk yield, with most of the variation due to doe breed. Neither sex nor breed of kid significantly influenced daily yields. Least squares means and standard errors for doe breed are in table 2.

Daily yields are averaged across the lactation curve and mask potential breed differences for peak yield and persistency. The very low average yields of the EAG are disturbing, but may be due to a sampling artifact where, for

Table 2. Least square means and standard errors for doe breed.

Breedtype	Number	Mean (g/d)	SE (g/d)
EAG	8	88.9	207.9
Galla	17	542.4	143.2
F1s	32	709.0	98.4
KDPG	13	1077.8	153.0

example, the EAG does may have been on average further into lactation than the other breed-types. The data evidences a considerable improvement in milk yield with infusion of genes from the dairy Toggenburg and Anglo Nubian breeds. The yield of the KDPG is consistent with a 3.5 kg peak daily yield and sufficient variation is evident in the breed-type to allow selection to ensure the breeding goal and also to reduce the variation in yield that is evident in the existing first generation KDPG.

Future work will gather daily yields for completed lactations on sufficient numbers of animals to allow quantification of sources of variation in milk yield including breed-type and to determine genetic parameters for evaluation of the sires of lactating does to facilitate selection.

Table 3. Distribution of Genotypes at Ol'Magogo Research Station

	October 1989			June 1990		
	EAG/Galla	F1	KDPG	EAG/Galla	F1	KDPG
Does	440	282	118	322	329	155
Bucks	32	201	114	38	233	135
Total	472	483	232	360	562	290

B. Multiplication

From October 1989 to June 1990, animal numbers at Ol'Magogo increased as shown in table 3.

Numbers of purebred indigenous goats are decreasing proportionally to F1s and KDPGs as the breeding program emphasis moves towards producing the four-way synthetic from F1s and inter se mating of KDPGs. An effort to utilize the purebred EAG/Galla as recipients in an Multiple Ovulation and Embryo Transfer (MOET) program was unsuccessful because of lack of supplementary funds to achieve this program. Vigorous efforts will be expended in an attempt to implement this program in February-March, 1991. In addition, efforts will be made simultaneously to run an ET training school in Kenya and produce greater numbers of KDPG from purebred EAG/Galla with the collaboration of reproductive physiologists from the International Dairy Goat Center at Prairie View A&M University and from the University of Nairobi.

C. Selection Response

A computer model that simulates small ruminant performance was used to project how sheep in northern Kenya would respond to selection for mature size and milk production. Three selection intensities were employed which corresponded to culling ewes at five, six, or eight years of age. In addition, rams were replaced every one or two years. With the simulation model it was possible to evaluate flock productivity as well as individual animal performance over 15 years. Flock performance, determined by protein efficiency, indicated that in this arid environment, culling ewes at eight years of age was the most beneficial practice in terms of increasing protein efficiency. Culling at five years of age decreased protein efficiency for much of the 15-year pg horizon and resulted in decreasing total flock size. These results suggest that selection could be practiced on this population but that the high rates of replacement usually recommended for optimizing genetic progress resulted in non-optimal levels of flock productivity due to decreased levels of flock maturity. Consequently, high level of selection intensity should be used to compensate for modest ewe replacement rates to maximize the merit of replacements.

Intensity of selection and culling strategies impact the rate of genetic progress obtained in selection programs. Several studies have addressed the issue of optimizing genetic progress by balancing culling rates and selection intensity. However, a question not completely addressed by these studies is how production changes over time as populations are undergoing selection. A major factor influencing the

flock's or herd's response is how selection intensity, which may be limited by the ewe culling policy, impacts flock performance. Systems analysis and computer simulation provide a mechanism by which major components of the system are allowed to interact. In this study, selection strategies for a population of Somali Blackhead sheep to obtain the desired selection goals were examined.

The simulated scenario was a nomadic pastoral production system in northern Kenya. Current genotypes for potential mature size (WMA) and potential peak milk production (GMLKL) were 35 and 1.30 kg, and selection goals were a WMA of 45 and GMLKL of 1.75 to optimize flock offtake. Three levels of selection intensity for each character were evaluated and are presented in table 4. Heritabilities and phenotypic standard deviations for WMA and GMLKL of 0.5 and 0.3, and 3.5 and 0.26 kg, were assumed, respectively. To incorporate the selection intensities, culling and replacement rates were altered to keep ewe numbers constant. Culling ages were set at five, six, and eight years. Rams were replaced annually or every other year. The ratio of total protein produced by the flock (from dairy milk and total weight of animals sold) to the total dry matter consumed provides insight into how selection impacted the productivity of the entire flock over time. Evaluation of efficiency is a measure of performance taking into account reproduction, mortality, growth, and milk production, as well as imposed selection.

For all culling practices, an initial increase in protein efficiency was observed within the first three years of simulation. This increase was caused by changing the culling policy from that of the base population. This change continued to impact efficiency for approximately 6 years of the simulation, after which time the results of selection begin to increase efficiency. The final levels of efficiency between culling practices indicate that these policies impacted differently on performance even though the sheep, at different points in time, have similar genotypes. The simulations indicated that allowing ewes to remain in the flock until eight years of age was the most beneficial practice, followed by culling at six years of age. Culling ewes at five years of age was a detrimental practice. Not only did efficiency remain below base levels much of the time but the flock size reduced over time. Culling at six years resulted in less perturbation in the system but also resulted in lower levels of efficiency when compared to culling at eight years of age.

When performance for two characters were compared, replacing the rams every year resulted in higher levels of milk production and sale weight. However, using rams for one versus two years did not have a large or consistent impact on flock performance as measured by protein efficiency. The effect of the increased performance characteristics were negated by increased consumption of dry matter which contributed to the denominator of the protein efficiency equation. Culling at six and eight

Table 4. Selection intensities and genetic progress for mature size (WMA) and potential milk production (GMLKL) when three culling strategies are planned.

Culling Practice	Character	Average Intensity	Expected Genetic Progress/ Generation (kg)
5 years	WMA	1.53	2.08
	GMLKL	1.53	1.19
6 years	WMA	1.62	2.83
	GMLKL	1.62	1.26
8 years	WMA	1.71	2.99
	GMLKL	1.71	1.33

years of age resulted in upward trends for milk and body weight, with the greatest response observed for culling at eight years. Culling at five years of age did not increase weight at sale or milk yield. Instead, production for these two characters dropped below initial values during the early stages of selection and returned to initial values at the end of the simulation.

Average breeding ewe generation number and average ewe age at the end of each simulated scenario are reported in table 5. As selection intensity increased, generation interval was longer and ewes were, on average, older as a result of culling intensity. By using rams for one year, number of generations increased; therefore, an increase in genetic progress was simulated. Increasing the rate of genetic change via the rams did not have an impact on flock performance. Instead, culling age of ewes created greater differences between selection schemes.

These simulations provide insight into the changes of flock performance as different selection programs were imposed upon a population of sheep where there had been no selection practiced. It was clear that in the harsh environment simulated, where both meat and milk offtake are important components of the sheep enterprise, care must be taken as to the speed with which programs are implemented. Using computer simulation provides an additional tool for animal breeders to use to make *a priori* evaluations of selection strategies and goals and the manner in which these objectives are obtained.

Resistance to Haemonchus contortus

A. RFLP Analysis

With the collaboration of the Washington State University Health project and Dr. R.M. Waruiru of the Department of Veterinary Pathology and Microbiology, University of Nairobi, a total of 95 kids have been artificially infected with 10,000 *H. contortus* larvae to screen for resistance. These animals are in addition to those monitored for natural infection. Of these animals, one doe has shown no detectable level of infection in fecal egg counts in three separate artificial infestations. This is an exciting discovery which may allow a unique opportunity to map the genes responsible for regulation of resistance to *H. contortus*. An embryo transfer program is planned to create a halfsib family as large as possible from this doe to augment existing family data.

In 1987, 134 weaned kids were placed on a one-year experiment to determine their resistance to internal parasites. Body weight change, packed cell volume (PCV), and fecal egg counts (FEC) were monitored. When PCV and/or FEC reached critical levels, the kids were drenched with an anthelmintic. Of the 134 tested individuals, 13 were never treated for parasite load. Several interesting results emerged from a summary of the data. Of the 25 sires represented by their progeny in this test, only six produced progeny which were resistant or resilient. The proportion of progeny on test which were resistant was 3.6% for an EAG buck, 7.4% for two Toggenburg bucks, and 15.4% for a DPG buck.

Table 5. Effects of culling and ram replacement strategies on genetic progress, average ewe age, final mature size (WMA) and potential milk production (GMLKL) after 15 yrs of simulation

Ewe Cull Age (yr)	5	5	6	6	8	8
Ram Replacement (yr)	1	2	1	2	1	2
Generation Number	10.5	5.94	9.62	5.59	8.34	4.93
Average Ewe Age (yr)	3.30	3.20	3.80	4.60	4.50	4.80
WMA (kg)	63.10	50.90	62.20	50.80	59.90	49.70
GMLKL (kg)	2.55	2.00	2.51	2.00	2.41	1.95
Avg Generation /Yr	.70	.40	.64	.37	.56	.33

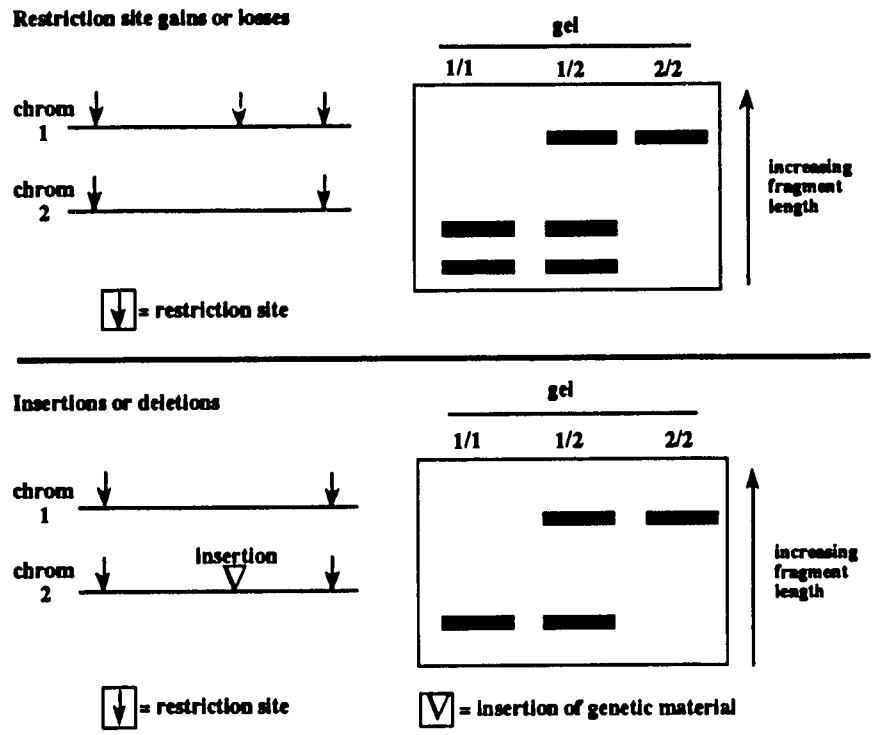


Figure 4. Originas of RFLPs

These preliminary results would indicate that resistance is not controlled by a single gene. It would appear that two or more genes, perhaps with several modifying genes, are involved in determining the phenotype of resistance. Sex linkage is probably not involved as six of the resistant goats were females and seven were males. The resistant kids were able to grow at levels in excess of the average of all tested goats. Resistant females had an average yearling weight of 19.5 kg versus an overall average of 17.7 kg, and resistant males weighed 19.6 kg versus an overall average of 19.0 kg. This indicates that selection can be applied for resistance without negative effects on growth.

To search for Quantitative Trait Loci (QTL) controlling resistance, blood samples were initially collected from 62 animals in families that were polymorphic for resistance. DNA was isolated from these samples for RFLP analysis, to look for associations between specific RFLPs and individuals with parasite resistance. The DPG's origin from four parental breeds provided an ample number of RFLPs for this analysis. RFLPs may be due to either insertions, deletions, or mutations at the restriction enzyme cleavage site as indicated in figure 4.

The framework for the analysis was the bovine gene map which consists of 160 gene markers with at least one gene known from each syntenic group. The degree of conservation between cattle and goats (all chromosomal arms are conserved), as evidenced by the human-bovine conservation already discussed, allows the bovine map to be used directly. The analysis focused on multilocus DNA fingerprints. Although DNA fingerprints do not allow the specific identification of individual loci, they do allow an investigation of large amounts of allelic variation from a single Southern blot analysis. Allelic variation detected in the goat fingerprints was associated with DNA fragments ranging in size from 2,069 to 29,186 bp. A total of 97 alleles of different sizes were found in the sample of 62 goats. Evaluation of the frequency of occurrence of the alleles showed that only three markers were present in a frequency greater than 70%. Another seven markers were found with a frequency of 40 to 69%. With these

Figure 5. Fingerprinted with the M13 probe. Individual 908 is the family sire. A + indicates the presence of a particular marker allele.

	Individual											
Marker	908	7099	7137	8030	7118	8039	7124	8041	8029	7164	7105	7218
M10	+	+	+	+						+		
M14						+		+				
M15							+		+			
M18				+	+	+						
M29												+
M30				+								
M33							+					
M36	+	+	+	+	+	+		+	+	+	+	
M37							+					
M41												+
M44	+	+	+									

ten markers, all family groups sampled were represented. These ten markers were grouped within five halfsib groups, or lines, and are the basis for comparison in the remainder of this report. Figure 5 shows multilocus genotypes for a halfsib group fingerprinted with the M13 probe.

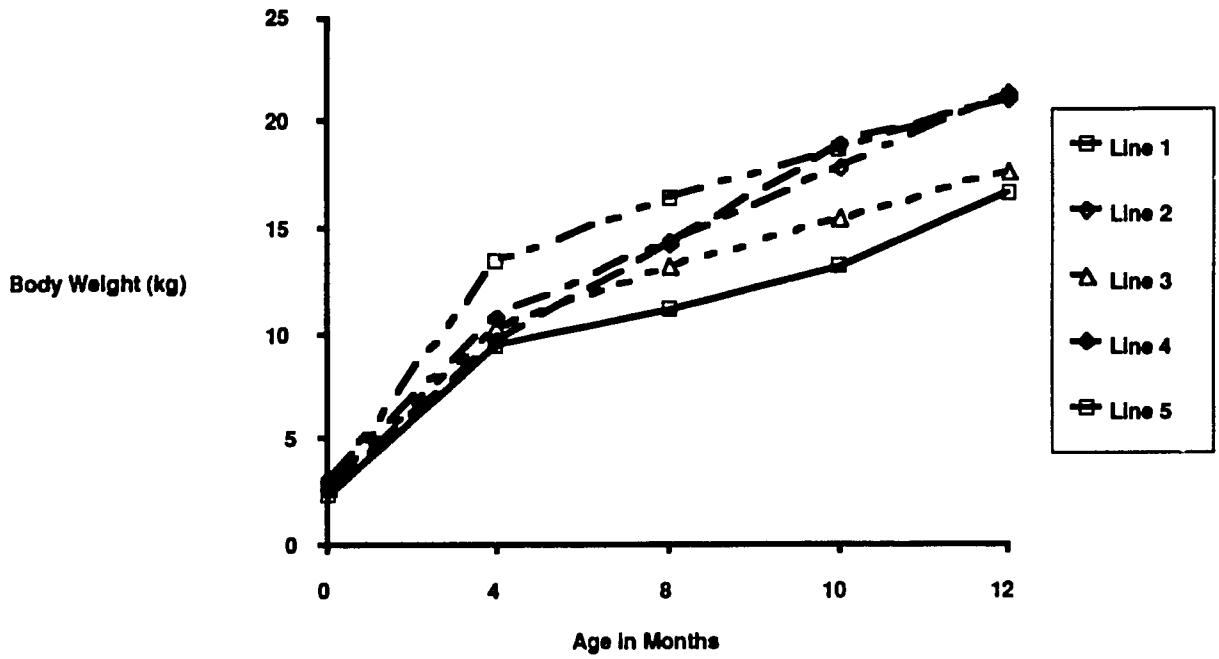
Statistical analysis of growth and indicators of parasitism were performed on those goats which had blood samples analyzed (table 6 and figure 6). Instead of breed effects, the goats were divided into five sire groups or lines and this designation was used in the model. Evaluation of body weight from birth to one year of age demonstrates the differences which existed between the different lines on test. Line 1 was consistently the heaviest group evaluated, while line 5 was the smallest. A number of factors besides genetic resistance to internal parasites could be responsible for those differences (e.g., breed differences). That is not to say that if genetic resistance is present, that it is not helping to facilitate the growth and development of the kids tested. As more animals are screened, it will be possible to perform a much more comprehensive analysis to discriminate between sources of variation.

A critical variable used in analysis of animal health was PCV. PCVs were collected every 14 days, however their interpretation was confounded by changes in animal status between times of measurement. For example, if worm burden was high enough to require a drench, PCV for the next measurement period might increase dramatically. The mean PCVs did not differ greatly between lines, however, the minimum and maximum measurements did. Differences between lines were larger for FEC than PCV, however, these differences were not significantly different between markers.

Table 6. Mean packed Cell Volume, Fecal Egg Counts and markers.

	Line				
TRAIT	1	2	3	4	5
PCV	31.2	30.9	31.2	30.8	31.6
FEC	5831	3610	6723	7929	7368
Markers	M9,M21,M60	M10,M36	M59,M61	M3,M52	M49

Figure 6. Growth of Different Lines of Goats



Due to the limited number of blood samples collected, t-tests were used to determine the association between the presence or absence of a genetic marker and measures of productivity. Table 7 shows the level of significance for tests of association between marker genotypes for weight traits and PCV. The M60 and M21 markers appear to have an impact on growth to weaning and eight months of age. Furthermore, both of these markers were found exclusively in line 1. The M60 marker was significantly (P=.02) associated with high levels of PCV, indicating an association not only with growth, but also with the immune response of the animal. Differences in FEC between lines appear large, however, these differences were

Table 7. Levels of Significance for Presence or Absence of Marker

Marker	Bir WT	Wn WT	8Mo WT	10Mo WT	12Mo WT	PCV
M9	NS	*	NS	NS	NS	NS (.10)
M60	NS	**	*	NS (.09)	NS (.10)	* (.02)
M36	NS	NS	NS	NS (.07)	NS	NS
M21	NS	**	**	NS (.08)	NS	NS
M10	NS	NS	NS	NS	NS	NS
M59	NS	NS	NS	NS	NS	NS
M61	NS	NS	NS	NS	NS	NS
M3	*	NS	NS	NS	NS (.08)	NS
M52	NS	NS	NS	NS	NS	NS
M49	NS	NS	*	NS (.07)	NS	NS

* $p < 0.05$
** $p < 0.01$

not significant. This could imply that if M60 is associated with resistance to helminths, its mediated effects are in lowering the impact that parasites have on the goats, rather than through a reduction in the number of worms established in the gut.

Currently, confounding in the data is a serious problem. When t-tests were performed within line for each production character, none of the previously significant differences were found, in part, due to the small sample sizes within lines. The differences which were found to be significant were most likely to have been due to chance. The lack of an association between markers and productivity within lines indicates that larger numbers of animals will have to be sampled. Some of the reasons for a lack of differences between lines are as follows. The markers present in relatively high frequencies were found only within lines (or sire groups); furthermore, breed effects and heterosis are also contributing to the confounding of the data. For example, line 1 is primarily KDPG, while line 5 is almost completely EAG. The variation in mature size, by breed, may be the primary factor controlling differences observed for growth. Heterosis, not only in terms of growth, but in terms of resistance to helminths may also be a part of the reason why line and marker differences were found.

Even though a number of problems exist with the collected data at this time, the initial results from this experiment are promising. As more data on animals are collected, we will be better able to assess the potential for using molecular genetics techniques in conjunction with other animal breeding practices. However, even if markers associated with resistance to internal parasites and productivity are not located, the breeding project will still be able to select for resistance based upon animal performance, PCV and FEC.

B. RAPD Analysis

One hundred and five goats were bled and DNA was extracted. The goats were of various breed types representing purebred Galla and East African, first generation two-way and four-way (KDPG) crosses and second generation KDPG goats. Genetic polymorphisms were detected using Randomly Amplified Polymorphic DNA marker techniques (RAPD). This procedure uses the polymerase chain reaction (PCR) to randomly amplify segments of an animal's genome which are surrounded by an arbitrarily chosen ten base primer sequence. After completion of the PCR, the contents are then electrophoresed on an agarose gel to separate DNA based on the length of the amplified products. Initially, five different 10 base primers were used to screen the caprine genome for polymorphisms. Three primers detected polymorphic bands: AP3, AP8d, and AP9 with three, three, and five polymorphic bands, respectively. The results of band scoring for AP8d and AP9 are in table 8.

Table 8. Band scoring for AP8d and AP9

Primer	Number Scored	Fragment Length (bp)	Occurrence	Frequency
AP8d	43	1020	32	.744
		920	28	.651
		850	1	.023
AP9	53	915	46	.885
		905	39	.750
		575	1	.019
		540	8	.151
		500	16	.302

Bands AP9:915 and AP9:905 were cut from a gel, the DNA extracted, and radioactively labelled for use as a probe in Southern hybridization. Gels containing DNA from goats amplified using AP9 as a primer were blotted onto nylon filters and hybridized to the probes to determine if a band homologous to the one used to make the probe was present on the filter. It was determined that bands AP9:915 and AP9:905 were homologous indicating that they are allelic bands and that an animal's genotype can be determined based on their banding patterns for these two bands. Of 53 animals scored, 14 were homozygous for band AP9:915, 32 heterozygotes, and 7 AP9:905 homozygotes. Gene frequencies were .566 and .436 for AP9:915 and AP9:905 alleles, respectively. While other bands have not been labelled to detect allelic bands, evidence from results in the bovine indicate that most of these bands will not have a homologous band present. Thus, animals exhibiting a band may be homozygous for the banding allele or heterozygous for the banding allele and a non-banding allele.

Four more 10 base primers were synthesized and have been screened on three second generation four-way cross goats and two of the primers have detected polymorphic loci. AP4 and APR2 have two polymorphic bands each.

Animals that had been scored for their genotype at AP9:915/950 and that had data for fecal egg counts (EPG), fecal coccidia oocyte counts (COC), and packed cell volumes (PCV) between the ages of 290 and 365 days or until the first anthelmintic treatment were included in analyses where EPG, COC, and PCV were dependent variables and breed type, month of measurement, genotype and animal were independent variables. Figure 7 contains genotypes of 16 goats scored at AP9:915/950.

Genotype was not a significant source of variation. The least squares constants and heritability estimates from these data are presented in table 9.

The use of RAPD technology appears to be a powerful tool for detecting polymorphic DNA markers which can be used in marker assisted selection. Differences in animals genotypes at the AP9:915/905 locus approached statistical significance for fecal egg count. With more data it is possible that this marker will be useful in marker assisted selection for fecal egg count. Further research needs to be conducted to determine animal's genotypes at loci which do not produce more than one band. Pedigree information, as well as quantification of band intensity, may allow differentiating between heterozygotes and homozygotes for the banding

Figure 7. Genotypes at AP9:915/950 for a sample of 16 goats.

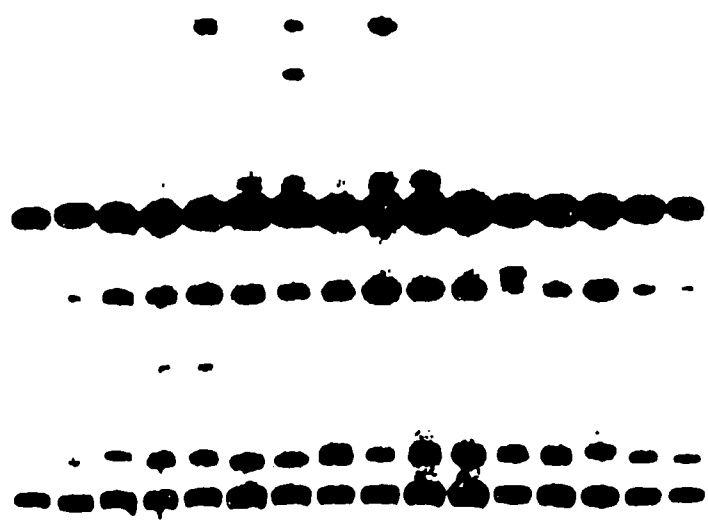


Table 9. Least squares constants & heritability estimates

Effect	Coccidia Oocytes	Fecal Egg Count	Packed Cell Volume	
AP9:915/915	-3208	-149	0	
AP9:915/905	-2243	-685	-.5	
AP9:905/905	0	0	-2.3	
Heritability	.000	.397	.185	
Mean		1959	951	25.6

allele which will make the testing of significant marker genotypes more powerful.

Training Progress and Institutional Development

Long-Term

Gary Rohrer, Ph.D., Genetics, graduated expected in 1991, Texas A&M

Evison Bhebe, Ph.D., Genetics, graduated expected in 1993, Texas A&M

Both students are partially supported by the Breeding project.

Joseph Kogi was selected to be a M.S. candidate in Animal Breeding at Texas A&M. He is expected to commence his program in January, 1991.

Short-Term

Dr. Bonfance Mwandotto attended the Third World Congress on Genetics Applied to Livestock Production. Edinburgh, July 1990.

Mr. Mkuu was to have attended a month long workshop on goat management to be held in June, 1990, at the International Dairy Goat Center at Prairie View A&M. However, the workshop was cancelled at the last moment.

Other Contributions

Contributions to U.S. Agriculture

The application of RAPDs to map polymorphic loci in the caprine in this study is, to our knowledge, the first use of this technique to gene mapping in domestic livestock species. Our results are very encouraging and a refereed journal article on this work is in preparation.

The results that demonstrate that disequilibrium between herd maturity and genetic progress causes considerable loss in productivity for three to four generation intervals, when herd culling rates are high, is a new result for animal breeders. This result will cause animal breeders to incorporate age-related production efficiencies into selection programs to offset extreme rates of replacement when breeders do not possess infinite planning horizons.

Contributions to Host Country

The production of the KDPG has produced a resource which is unique in the world for genetic segregation studies. The DNA from goat families will be extracted and stored as a resource for genetic mapping studies. The genotypic diversity of the genotype provides an enormously important resource as a foundation genotype from which lines may be selected for adaptation to various environments within LDCs.

Linkages and Networking

The executive committee of the Animal Production Society of Kenya, in response to an invitation by the Tanzanian Society of Animal Production, nominated Dr. Mwandotto to present a paper on "Smallholder Small Ruminant (Goat) Production" to the annual scientific meeting of the Tanzanian Society of Animal Production, 25-27 September 1990.

Conditional on availability of SR-CRSP funds, the Breeding project is interested in extending the Haemonchus gene mapping work into other LDCs and with sheep.

Publications

Refereed Journal Articles

Ruvuna, F., T.C. Cartwright, C.O. Ahuya and S. Chema. 1990. Factors affecting body weights of East African and Galla goats. Small Ruminant Research. (In press)

Ruvuna, F., J.F. Taylor, B.A.J. Mwandotto and C.O. Ahuya. 1990. Estimates of genetic parameters of purebred indigenous goats and their crosses in Kenya. Small Ruminant Research. (In preparation)

Abstracts and Presentations

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Ruvuna, F. J.F. Taylor, S.K. Davis and B.A.J. Mwandotto. 1990. A goat breeding program which exploits both selection and crossbreeding effects in a tropical environment: Kenya Dual Purpose Goat Development. Proc. Intl. Goat Symposium, Florida A&M University, October 22-26.

Ruvuna, F. 1990. Realities and practicalities of livestock research in Africa: Experience with the SR-CRSP in Kenya. Presented to the Summer Institute for African Agricultural Research, University of Wisconsin, Madison.

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Davis, S.K., J.F. Taylor, and F. Ruvuna. 1990. Restriction fragment length polymorphisms and strategies for genetic improvement. Proc. National Conference on Plant and Animal Biotechnology. Nairobi. Feb. 25 - Mar. 3, 1990. p. 26.

Cartwright, T.C., J.F. Taylor, B. Mwandotto, F. Ruvuna, H.D. Blackburn, and C.O. Ahuya. 1990. The Kenya Dual Purpose Goat breed. Proc. Eighth SR-CRSP Scientific Workshop. ILRAD, Nairobi, Kenya. March 7-8, 1990.

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Blackburn, H.D., S.K. Davis, J.F. Taylor, T.C. Cartwright, and F. Rurangirwa. 1990. Genetic resistance of goats to internal parasites. Proc. Eighth SR-CRSP Scientific Workshop. ILRAD, Nairobi, Kenya. March 7-8, 1990.

Blackburn, H.D., and J.F. Taylor. 1990. Simulation of flock performance when different intensities of selection are practiced. Third World Congress on Genetics Applied to Livestock Production. Edinburgh. July, 1990.

Taylor, J.F., M.A. Tomaszewski, J.P. Walter and F. Ruvuna. 1989. Genetic grouping and best linear conditionally unbiased prediction incorporating relationships. J. Dairy Sci. 72(Suppl. 1):30-31 and J. Anim. Sci. 67(Suppl. 1):30-31.

Sociological Analysis of Small Ruminant Production Systems in Kenya

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Summary

Sociological analyses of small ruminant production systems were conducted in Indonesia, Kenya, and Peru. Additional work in the U.S. was for purposes of arriving at general principles that apply across regions based on the past ten years of research. A series of publications and others in preparation cover this work. Among them are a bibliography aimed at providing information on low cost alternatives to the more costly and inaccessible ones for maintaining animal health; review articles on ethnoveterinary medicine for Africa and Asia; and a book on the role of social science in agricultural research based on the SR-CRSP experiences. Additional major publications are scheduled for 1991 that will bring together the knowledge and experiences of numerous authors both within and outside the SR-CRSP program.

A study of the sociology of range management in Africa based on past AID-supported projects provided insight as to why some projects failed. Among the reasons notes was that local officials and specialists in project planning, as well as livestock producers, had very little input into project design.

Work in Kenya monitored farmers' production and utilization strategies of SR-CRSP technology for dual purpose goats. The use and management of forages and other crops was examined and found to differ from place to place. Farmers did not perceive any exceptional health problems with dual purpose goats. In addition, smallholders in western Kenya did not use chemical fertilizers and manure was used on various crops. While farmers consume some

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milk on a regular basis, only a small proportion milk their dual purpose goats. All this indicated that refinement in the DPG packages were needed for it to be sustainable in the majority of on-farm applications.

Concerns were expressed as the Kenya project phases down on how other areas could benefit from the dual purpose goat program. It was concluded that the technologies would not be transferable to central Kenya. The project has been working with the Kenya Agricultural Research Institute (KARI) to adapt and extend the SR-CRSP model to other KARI research centers and other commodities in Kenya.

Research Results

Objectives

During 1989-90, the main thrust of the Sociology Project in Kenya was, in five of the six research clusters, to monitor farmers' production and utilization strategies of SR-CRSP technology packages for dual purpose goats (DPGs). The project also initiated research on the role of small ruminant production in central Kenya, with an eye to expanding SR-CRSP activities beyond western Kenya. In addition, Sociology was responsible for organizing farmer workshops.

Project Progress and Achievements

DPG Production and Utilization Strategies

Four areas were targeted here: farmers' management of recommended forage packages (Activity C6), farmers' breeding strategies for DPGs (C7); health treatment regimes (C8); and production and utilization strategies for manure (C9) and milk (C10).

Farmers' Management of Recommended Forage Packages (C6). As early as 1986, tree nurseries of sesbania and leucaena were established in the old clusters (Hamisi, Kaimosi, Masumbi). In 1988, farmers in the new clusters (Lela, Rabuor, Muhanda) were given seeds to establish their own nurseries. Both the old and new clusters also received planting materials for sweet potato vines and napier grass. The Sociology Project then began a study to examine cluster farmers' utilization and management patterns of the respective forages. The aim was to assess the impact of different ecozones, farming systems, and modes of seedling distribution.

Masumbi (an old Luo/lowland/low-density cluster) has the lowest proportion of participating farmers growing the recommended forages, the lowest number of forage trees, and the smallest area in napier and sweet potato vines. In Lela (the new Luo cluster), the relatively low proportion of participant farmers growing recommended forages is compensated for by the number of forage trees and the area in napier and sweet potato vines. However, Lela farmers do not normally feed these forages to DPGs. In contrast, the Luhya/highland/high-density clusters of Hamisi (old) and Muhanda (new) have the greatest percentage of participants growing all the recommended forages, plus the highest average number of forage trees and a substantial area under napier and sweet potato vines.

The same pattern holds for the care given the introduced forages. Hamisi and Muhanda overwhelmingly weed and fence their forages while Masumbi and Lela do not. The recommended cut-and-carry strategy is most commonly practiced in Muhanda (100%) followed by Hamisi (70%), Rabouor (69%), Masumbi (54%), and Lela (46%). What appears to be cut-and carry in Masumbi is in fact a tendency to tether the DPGs and feed them cuttings from fallow-land shrubbery. One would have expected more cut-and-carry in Lela, but farmers there prefer to graze their DPGs and save the cultivated forages for their cattle or for sale.

Farmers' Breeding Strategies (C7). This study focused on farmers' perceptions of priority problems in breeding their DPGs. Findings revealed that, in contrast to scientists' expectations, farmers did not consider that bucks were in short supply. Bucks were always available

for borrowing, as per longstanding traditional patterns. Instead, the major problem in breeding appeared to be farmers' inattention to and/or inability to detect estrus--in part because does are tethered and left unattended and with no buck nearby to signal does coming into heat.

Health Treatment Regimes (C8). In this subproject, farmers were interviewed about the general health and condition of their DPGs by sex and age groups (bucks, does, kids). Results indicate that, overall, farmers do not perceive any exceptional health problems among their DPGs.

Production and Utilization of Manure (C9). Surveys in western Kenya indicate that, for various reasons, most farmers do not use chemical fertilizers. However, whenever possible these farmers do use the manure generated on their farms. Sociology therefore began a study of the contribution and value of DPG manure in the overall farming system of participants.

Findings indicate that all clusters except Masumbi tend to distribute DPG manure on various farm enterprises on a daily basis. Hamisi gives preference to cash crops and vegetables, and Lela to food crops and vegetables. In most clusters, DPG manure is highly prized as fertilizer.

Production and Utilization of Milk (C10). Distribution of DPGs to participating farmers was in part aimed at providing them with a ready source of milk. The Sociology Project thus undertook to study the role of goat milk relative to other sources of milk available to participants.

Research reveals that, in all the clusters, only a small proportion of participating farmers milk their DPGs (Hamisi=10%, Masumbi=15%, Muhanda=10%, Rabuor=19%, Lela=4%). The two most prevalent reasons given for this were that does were dry or that lactating does produced only enough milk to feed their kids. The latter explanation was particularly interesting, given that farmers have been advised that they can wean DPG kids after only two weeks if they then feed weanlings sweet potato vines *ad lib.* Despite the low proportion of farmers milking DPGs, almost all households in all clusters were found to consume milk on a regular basis. This finding underscores the current secondary role of DPG milk relative to other sources.

Small Ruminant Production in Central Kenya

With the beginning of program phase-down in Kenya, concerns were raised about other areas that could benefit from the DPG techpacks developed thus far. Given ecological and demographic similarities between western and central Kenya, it was thought that SR-CRSP techpacks would be readily transferable between the two regions. Moreover, both goats and sheep are commonly reared in central Kenya, and inhabitants of the region consider goat meat a delicacy.

With an eye to providing pointers for the expansion of SR-CRSP activities, Sociology initiated a study of the role of small ruminants in central Kenya. However, findings revealed that farmers in this region depend more upon commodities by comparison with the more subsistence-oriented economies of western Kenya. Thus, it seems improbable that the two regions could easily exchange DPG technologies.

Farmer Workshops

These workshops brought together participating and non-participating farmers, livestock extension staff, and local leaders to meet with the SR-CRSP research team and share experiences in DPG management. Some of the issues that came up in discussions included:

- The relative vulnerability of the DPGs in the project area as compared with local goats;
- Frequent abortions and inactive bucks among newly introduced DPGs;
- Possibilities for expansion of SR-CRSP activities to cover more people and larger areas; and
- The value of DPG manure.

Training Progress and Institutional Development

Resident Scientist Mbabu, in collaboration with Economics Resident Scientist Nyaribo, supervised a KARI graduate student, currently on study leave at Clemson University (U.S.), in data collection for M.Sc. degree in social sciences (June-August, 1990).

Other Contributions

Along with Dr. Moses Onim, SR-CRSP/Kenya scientist, Sociology's Jere Gilles joined a multi-institutional, international team to conduct a global assessment of animal agriculture in Africa. This study is directed by Winrock International with funding from the World Bank, ILRAD, ILCA, CIDA, the Rockefeller Foundation, and TAC. Currently the study focuses on ways to generate and utilize livestock technology that will lead to sustainable production systems in Africa. The broader goal is to assist research and development agencies in setting priorities for African animal agriculture for the next 35 years. Meanwhile, Dr. Michael Nolan has been working with KARI to identify ways to adapt and extend the SR-CRSP's dynamic model of station-based + farm-based research to other research centers and commodities in Kenya.

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Economic Analysis of Small Ruminant Production and Marketing Systems in Kenya

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Summary

An economic analysis of feeding practices in Kenya prior to weaning young goats indicated that sweet potato vines provided the best replacement for milk among all previously analyzed forage supplements. This finding is particularly useful because sweet potatoes are widely grown in western Kenya. No additional capital is required unless production of sweet potatoes is increased, in which case extra labor is needed which is readily available.

Preliminary results with intercropping maize with food and forage crops in Kenya indicate that intercropping maize with sesbania is uneconomical compared to such intercrops as finger millet and pigeon pea. Results also indicated that marginal costs per kilogram of dry matter is lower for the phosphorous plus nitrogen combinations than for phosphorous alone. These results are preliminary since not all data has yet been analyzed.

Linear program models representing smallholder farms in Kenya with dual purpose goats and supporting technologies revealed increased net farm income by 30 to 80 percent compared against all other farm enterprises. With improved management, the dual purpose goats were better than Zebu cattle as a combined crops-livestock enterprise. Factors to consider in refining the dual purpose goat technology are: (a) extension education efforts to improve management quality, (b) available credit as herd sizes grow, and (c) strengthening the milk marketing infrastructure to absorb surplus milk.

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Research Results

After a period of nearly two years (1988-1989) without an agricultural economist in Maseno, western Kenya, the Economics project now has a resident scientist (Dr. F. Nyaribo) who has been on location since February, 1990. Due to the absence of an economist, there is a large backlog of biological data that needs economic analysis. Work on this is already underway.

Kenya Tech Pack

The first draft of the Kenya Tech Pack did not contain an economics section. Thus, one of the initial tasks for 1990 was to write an economics chapter. The first draft of the chapter was completed in May and later incorporated into the Kenya Tech Pack.

Economic Analysis of Feeding Practices

Several kid feeding alternatives have been looked at in an attempt to select the optimal pre-weaning practices. The most desirable practice is one that yields maximum milk for family consumption while maintaining acceptable kid growth rates. Given the scarcity of capital for collaborating farmers, the new practice must not only be technically promising but economically the cash benefits must outweigh the cash costs. The smaller the cash outlay to produce maximum output the better.

A partial budget was done to evaluate the costs and returns of using sweet potato vines (SPV) as a milk replacer for unweaned DPG kids. Similar analyses had been done for other forages but not for SPV. The biological data was generated by the Nutrition and Management project where it was found out that the quality of nutrients from SPV were comparable to those of milk. Economic analysis results indicated that using SPV as a milk replacer yields the highest economic returns of all previously analyzed forage supplements. This finding fits in well with current crop production since sweet potatoes are widely grown in western Kenya. Therefore, no significant additional capital is needed except for increased production if the farmer wishes to do so. The additional resource needed for this new practice is extra labor, of which most farmers have plenty, for the cut and carry of the SPV.

Economics of Intercropping Maize with Food-Forage Crops in a Maize Cropping System

Economic analysis is still continuing on these feed resources experiments. Partial budgeting is being done to determine the economic implications of intercropping maize with beans, sesbania, finger millet, and pigeon peas using two fertilizer treatments. As expected, analyses of three of the four sites (Masumbi, Hamisi, Kaimosi, and Maseno) are complete. Preliminary results indicate that economic returns are higher for fertilizer than phosphorous-based fertilizer alone. This also implies that the marginal cost per kilogram of dry matter (DM) across all treatments is lower for the phosphorous+nitrogen combinations than for phosphorous alone. Results indicate that it is uneconomical to intercrop maize with sesbania because of the lower DM yield compared to the higher food crop residue (DM) yields of intercrops such as finger millet and pigeon peas. This finding is subject to further analysis before final conclusions can be reached.

Mathematical Modelling of Smallholder Farms

Construction of linear programming models representing smallholder farms are complete. The models give a whole-farm representation which evaluates the DPG and supporting technologies against all other farm enterprises to determine how the goat competes economically with the most important crop-livestock enterprises. Results indicate that DPG technologies have the potential of increasing net farm incomes by 30 to 80 percent for different farm size groups and ecological zones. There is keen competition between different livestock species on the farms. In addition, research has shown that with improved management, the DPG out-competes the local Zebu cattle. A valuable by-product of the DPG (whose economic value is yet to be determined) is the goat manure.

With the DPG, farmers have acquired improved management and husbandry skills which have been transferred to other farm activities and particularly to management of other livestock species on the farm. This is a long-term contribution of the DPG project whose monetary value is not easily quantifiable.

As we strive to refine the DPG technology the following factors are important in improving the DPG's economic competitiveness:

1) The quality of management and its impact on productivity. Improved management can be achieved by focused extension education efforts.

2) Credit availability. Research results from economic modelling activities indicate that capital shortages have stunted the income generating potential of western Kenya farmers. This has implications for the widespread adoption of the DPG as it is likely to be hampered by lack of capital as herd sizes increase.

3) Marketing. The milk marketing infrastructure in western Kenya will need to be developed and strengthened to absorb surplus milk as more animals are reared and to serve as an incentive for greater regional adoption.

Training Progress and Institutional Development

Long-term

Fanny Nyaribo completed a Ph.D. in December 1989. Dissertation title: Integrating Dual Purpose Goats in Small Farms in Western Kenya: A Linear Programming Analysis.

Short-term

Peter Pelepenji Kwoba (Technical Assistant) completed a one month computer data management and word processing course in Kisumu in June 1990.

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Dual Purpose Goat Production Systems for Smallholder Agriculturalists in Kenya

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Summary

A major animal production constraint in western Kenya is the quantity of available forages. Integration of the animal and crop subsystems along with improved management and cultural practices can provide adequate dry matter intake for goats with higher genetic potential.

Many new feed resources were screened at Maseno and on local farms. One, *Sesbania sesbans* var. *nubica*, was clearly superior. In collaboration with the University of California, Davis, this species was found to contain no non-degradable toxins. Nearly 200 *Sesbania* accessions were tested for two years at Maseno by SR-CRSP/KARI in collaboration with PANESA,

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IDRC, and ILCA. The best performers (10% of the total) exhibit much genetic variability for several important characteristics and they will be selected for multiplication and for further improvement.

High protein forages are an alternative to the purchase of protein concentrates. *Leucaena leucocephala* is a tropical leguminous tree that is promising as a feedstuff to fill this need. Once established, it is the highest yielding among screened species, but in some locations it causes toxicity to animals caused by the amino acid mimosine. To test a hypothesis that goats fed only *Leucaena* develop microbes that degrade mimosine, a test was run comparing bucklings fed only fresh *Leucaena* with goats fed only on pasture. Results confirmed that these goats did not have microbes that degrade mimosine.

Among three other forage species, *Tylossema*, a wild-growing, tuberizing, drought resistant creeper, is highly palatable to goats. It is high in protein and digestibility. Attempts are being made to manage it as a domesticated plant.

Wilting of forages to reduce moisture content and enhance dry-matter intake improved mean weight gain of goat bucklings and also lowered the intake of *Haemoncus contortus* larvae. This in turn reduced the number of necessary dewormings and production costs.

The stripping and feeding of maize leaves after tasseling from a quarter hectare provided the maintenance and production requirements for two lactating does for five months. The defoliation did not affect grain yield.

Nearly 150 farmers from six clusters cooperated in a performance evaluation of crossbred dual purpose goats. Data were taken on milk yields, kid weights at various ages, mortality, and manure production. This, along with data on health, management, feeding, economics, and breeding will provide the basic information for a technology package that will reach completion in early 1991.

Seed of an improved Maseno double-cobber maize was provided to 66 farmers for production during the 1989-90 long rainy season. These farmers were later interviewed to assess their views of the variety. The conclusion was reached that the variety holds much potential for use in alley cropping. The Nyanza Provincial Director of Agriculture requested that seed be distributed during the 1991 long rainy season for farm production.

A 0.5 ha model demonstration farm was established and records kept on production of crops and goats. Based on market value, the feedstuffs produced were worth Kshs 16,198 (U.S.$709). Because of the high productivity on the model farm, 80% of the SR-CRSP respondent farmers became interested in trying similar practices on their farms.

The effective use of goat manure for small scale, low-income farmers can replace the use of purchased fertilizer. The higher levels of goat manure increased maize grain yields three fold compared to the control and had a favorable residue effect on maize yields the following year. High soil acidity impairs benefits from high application rates of diammonium phosphate.

Sweet potatoes are a useful crop for farmers with the dual purpose goats. The tubers are excellent as human food and the vines fed to goat kids permit weaning as early as two to four weeks of age. This results in increased milk availability to the farm family.

Research Results

The production systems component of the Kenya SR-CRSP program is under the guidance of Winrock International. It is composed of two major thrusts, *feed resources*, and *nutrition and management*, each under the supervision of a Winrock resident scientist and in collaboration with KARI research staff.

Objective

To integrate the dual-purpose goat and the crop production subsystems for sustainable land use in order to add to household income and develop a more balanced diet among smallholder agriculturalists.

Problem Statement, Justification, and Approach

Without integration, the current stocking rate of approximately 4.6 tropical livestock units (TLU) per hectare cannot be sustained in western Kenya. The main animal nutrition constraint in western Kenya is not quality of the available forages, but quantity (Table 3, 1988-89 SR-CRSP Annual Report).

Integration of the animal and crop subsystems, along with suitable management and cultural practices, is expected to enhance availability of feedstuffs and the necessary dry matter intake for the goats with higher genetic potential. More productive goats will result in more household net income. The goat component of mixed farms is expected to contribute to improved soil fertility and sustainability.

Progress and Achievements

Forage Wilting

Western Kenya receives between 1000mm and 2000mm of rainfall annually. Consequently, forage has a high moisture content. The moisture content of forages that are cut and carried can be reduced through wilting, a process which also enhances dry matter intake as shown in Table 1.

Another benefit realized from wilting is lowered intake of ineffective *Haemonchus contortus* larvae. Seven weeks following drenching, bucklings on wilted forage had an eggs per gram of feces (EPG) of 200 while their counterparts on fresh forage had 1100. By the 16th week it was 500 and 6000 EPG respectively. Because the EPG levels were reduced, it was not necessary to dose the goats as often, e.g. every five weeks rather than every four weeks. This has financial as well as labor implications because less money will need to be spent on anthelmintics.

Maize Plant Utilization

Maize is the staple food crop in the study area and in Kenya at large. A maize leaf stripping trial was designed in which two does in their last trimester of pregnancy were used to evaluate whether the maize leaves would provide adequate nutrition. In addition, the last trimester of pregnancy of the two does was also planned to coincide with the thinning stage of maize. The does were fed with the thinnings that provided supplementary feeding appropriate for their physiological status. The does

Table 1. Dry matter intake of dual-purpose goat bucklings at Maseno Station, Western Kenya.

Forage condition	As feed (Kg)	DMI (Kg)	DMI 0.75 (Kg)	DMI (%) of body weight	Mean weight (Kg)
Fresh n=6 goats	2.3	0.5	63	3.1	3
Wilted n=6 goats	1.4	0.7	86	4.2	5

kidded at the tasseling stage of the maize. After the tasseling stage, one leaf per plant was stripped and used as the sole diet for the two does. The diet was adequate for maintenance and production because of a high crude protein content of 12% and dry matter digestibility of 64%. The stripping or defoliation did not affect grain yield, yet it provided 300kg dry matter or sufficient forage *ad lib* for two does for 90 days. After 90 days the does were dried off and put on maize stover from the quarter hectare for 60 days.

Leucaena

Kenya and many other tropical countries are looking for a cheap source of protein for feeding livestock. Limited cash is available for purchase of protein-rich concentrates. High protein forages are an alternative which farmers can grow on their own plots. Leucaena (*Leucaena leucocephala*) is a tropical leguminous tree and is a very promising animal feedstuff. In some locations it has deleterious side effects of toxicity which is due to the amino acid, mimosine. Eight crossbred goat bucklings with a mean birth weight of 3.5 kg were used to ascertain potential toxicity of leucaena. Four bucklings were randomly allocated to each of two feeding treatments: fresh leucaena only or pasture (control). This trial was based on the hypothesis that goats exposed to no other forage than leucaena from birth will develop mimosine DHP (3-hydroxy-4-1(H)-pyridone)-degrading microbes. The hypothesis was rejected because, following the trial, goats on leucaena exhibited leucaena toxicity signs, and their urine was positive for the mimosine metabolite. The control group of goats did not exhibit toxicity signs. This research confirmed that goats in this region of Kenya do not have suitable microorganisms for degrading mimosine.

On-farm Evaluation

Performance data were collected on the crossbred goats placed in the clusters. About 150 farmers from the six clusters were involved in continued efforts to determine the suitability of crossbred goats and the recommended technical packages. Farmers are visited fortnightly by field assistants to confirm animal performance and to document management decisions. Table 2 provides an overview of the age composition and location of crossbred goats among the six clusters. Performance parameters based on data collected to date suggest:

- Lactating does yield between 0.5 to 1.2 liters of milk per day in addition to the milk consumed by kids. This yield occurs during a 60d to 150d lactation period. Does were fed forages alone.

- Kids weigh 3kg, 13kg, and 18kg at birth, weaning, and one year of age, respectively.

Table 2. Distribution of crossbred goats among the clusters.

Village	Number of Farmers	Age Group								
		1-6 Mon.	7-12 Mon.	1-2 Yrs.	Does	1-6 Mon.	7-12 Mon.	1-2 Yrs.	Bucks	Total
Hamisi	21	9	0	12	29	7	0	1	5	63
Masumbi	13	6	3	5	12	0	0	4	1	31
Kaimosi	18	6	3	11	25	7	1	1	8	62
Muhanda	32	11	0	0	48	20	0	0	5	84
Rabuor	27	10	2	0	43	11	10	0	9	85
Lela	10	1	0	0	15	1	3	0	3	23
Total	121	43	8	28	172	46	14	6	31	348

• Mortality rates have been 65% and 20% for kids and does, respectively.

• An average crossbred doe produces 130kg of manure (dry weight) per year, which is very beneficial to the farmer for fertilizer.

The final stages of techpack verification and the production of a techpack document have been reached. Techpack information includes materials on health, management, feeding, economics, and breeding. Winrock International and Dr. Semenye, in particular, have provided leadership in this endeavor.

Model Farm

A 0.5 ha area at Maseno was selected as a demonstration model farm. The food crops grown are the same as those grown in the area, i.e., maize, beans, sweet potatoes. Borders of forage plants including *Pennisetum* sp. and several multipurpose tree species are used. The animal component includes four dual-purpose does. The farm has been through one crop cycle. Preliminary results confirm that more than enough feed was available for the does without decreasing total food crop production. During 1990, maize seed of the double cob type and general planting instructions were given to farmers who volunteered in five of the six clusters. The double cob variety was derived locally and was used to compensate for cropping the land area which was planted with forage grass and the multipurpose tree species (MPTS). Results suggest no decline in yield of human food, more than enough feed for the four does, and a very significant yield response to the use of the goat manure on maize hills. All these elements are being verified in on-farm trials.

Response to Manure

Earlier work at Maseno suggested that the use of goat manure resulted in very significant yield responses of maize and beans. It was proposed the responses occurred because of manure influence on soil pH and on the availability of necessary major and minor nutrients. Continuing work this year examined the use of smaller volumes of manure, i.e., the use of single and half handfuls per hill rather than double handfuls. Resident scientists are examining several options for determining the economic value of manure. Suggested options include a value equivalent to the yield enhancement, or equivalent to commercial local market value of manure.

Early Kid Weaning and Sweet Potatoes

As a dual-purpose crop, sweet potatoes have found a niche in the dual-purpose goat production system. While the tubers are excellent human food, it has been determined that within the local area there are major differences in tuber yield among cultivars. Likewise, vine production varies and research has established that goat kids can be weaned from milk earlier and successfully fed sweet potato vines which provide all the needed nutrients, allowing the farmer to receive more milk.

Training Progress and Institutional Development

Long-term

The production systems project did not directly support any long-term training during 1989-90. However, Mr. Otieno did receive a scholarship to study toward his doctorate in the U.K. He returns to Kenya on occasion and the SR-CRSP to conduct research for his dissertation. Dr. Siamba, a veterinarian, was accepted to begin studies toward a M.Sc. at the University of Nairobi. His studies begin as this reporting year ends. Up to this time no full-time replacements for these two KARI resident scientists have been assigned to the western Kenya group.

Short-term

Dr. Onim participated in an international workshop on sustainable land use issues, including the tree-livestock-crop interface. The workshop was held in India, and Dr. Onim was named to serve on an international task force on the issue of sustainable land use.

Dr. Onim, Dr. Semenye, and Dr. Siamba presented papers at the SR-CRSP scientific

workshop held in Nairobi. Each presented data from completed and ongoing activities.

Several village workshops and an open day at the Maseno station were held during the 89-90 year. The resident scientists and associates answered questions, presented new information, and demonstrated some of the technology which had been developed.

Numerous school groups and agricultural classes visit the Maseno station to see demonstrations of new technology. The demand for this kind of service has been so pressing that one of the research associates has been assigned to coordinate all such groups. Real learning opportunities are created among the participants.

Other Contributions

Contributions to U.S. Agriculture

Much has been learned in Kenya about the value and application of participatory techniques in research and development and consideration of the experiential base of the client group and target audience. This informatiocritical to the success of development efforts and acceptance of improved technologies. Winrock International has already seen evidence of this as internationally learned techniques are applied to U.S. programs. The experiences from Kenya are helping make U.S. activities more sustainable.

Contributions to Host Country

Providing resident scientists for short-term consultancies contributes to improved research and development.

1. Dr. Semenye, in July 1990, served with the World Bank mid-term evaluation team for the Kwale-Kilifi development project in the Coastal Province, Kenya.

2. Beginning in September, 1990, Dr. Onim is serving as the agronomist on a study team examining animal agriculture in Africa. This is part of a global study of which the Africa component is the first to be initiated. Winrock International, under the direction of Dr. Ned Raun, is managing the global effort.

3. Dr. Semenye participated as a representative of KARI at the Africa Small Ruminant Network working group meeting in Addis Ababa where research proposals were presented and grants made.

4. Both Winrock resident scientists have participated in local agricultural shows and exhibitions as resource persons, as judges, and to present results of the collaborative research program in graphic form.

Linkages and Networking

The production system scientists maintain linkages with contemporaries in KARI, ILRAD, ILCA, ICRAF, and at several universities in Kenya and the region.

Both Dr. Onim and Dr. Semenye are active in formal networks such as PANESA, ASRN, AFRENA, and the animal feeds and by-products network. Several grants have been received by Onim and Semenye through these networks to pursue research on specific topics.

Publications

Refereed

Semenye, P. P. 1990. Toxicity response of goats fed on Leucaena leucocephala forage only. Small Ruminant 3.

Proceedings

Semenye, P. P. 1989. Techniques for measuring on-farm livestock research: problems and issues. CIMMYT East Africa Technical Networkship on On-farm Research, Arusha, December 4-8, 1989.

Semenye, P. P., L. Musalia, D. Siamba, K. Otieno, M. Onim, and H. Fitzhugh. Development of the dual-purpose goat production in western Kenya: Nutrition and management perspective. Proceedings of the 8th SR-CRSP

Annual Workshop, Nairobi, March 7-8, 1990 (in press).

Siamba, D. N., P. P. Semenye, and M. Shisya. Effective of wilting herbage on body weight, egg per gram of faeces and packed cell volume in dual-purpose goats at Maseno, western Kenya. Proceedings of the 8th SR-CRSP Annual Workshop, Nairobi, March 7-8, 1990 (in press).

Semenye, P. P. 1989. Utilization of Sesbania Sesban by goats. PANESA Regional Workshop, Kisumu, November 1-3, 1989.

Semenye, P. P., A. N. Mbabu, B. Mwandotto, F. Nyaribo, J.M. Onim, and F. Rurangirwa. 1990. Research highlights of the Small Ruminant Collaborative Research Support Programme. KARI 2nd Annual Scientific Conference, Panafric Hotel, Nairobi, September 5-7, 1990.

Other Communications

A brochure on SR-CRSP activities and research results highlights. So far 1500 copies have been given away to visitors, extension staff, and showgoers.

Note

Distinguished Visitors to the Maseno Research Station: Zambia High Commissioner and the American Ambassador to Kenya.

Breeding More Prolific Strains of Sheep

◆ University of California, Davis

Genetic improvement of sheep and goats in Morocco and Indonesia

◆ North Carolina State University

By-product and crop residue utilization in intensive sheep and goat production systems for limited-resource farmers

- In Morocco
- In Indonesia

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Genetic Improvement of Sheep and Goats in Morocco and Indonesia

University of California, Davis
G. Eric Bradford

Principal Investigator

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Summary

Advancements were made toward development of strains of sheep with predictable mean prolificacy levels in both Indonesia and Morocco.

Sheep flocks in Indonesia contain a mixture of highly prolific and non-prolific ewes, due to segregation of a gene (F^I) with large effect on prolificacy. Farmers with high levels of feeding and management could take advantage of the high mean litter size (2.0-2.5) of the F^IF^I (or F^I+) ewes, and those involved in lower input systems would be expected to have better net returns from the ++ ewes, with mean litter size of 1.2-1.5, i.e., singles and twins only. Measurement of ovulation rate can be used to classify ewes at an earlier age than with litter size alone, and is an important diagnostic tool used in this research. A criterion to distinguish between F^IF^I and F^I+ ewes was identified during the past year, and is expected to aid in the development of the two lines. To speed up further the creation of the two lines, 11 rams (which should include all three genotypes: F^IF^I, F^I+, and ++) are being progeny tested; those identified as F^IF^I will be used in the highly prolific line, and the ++ rams in the standard line.

Standard Moroccan breeds are of very low prolificacy. However, a specialized breed from the oases of the south, the D'Man, is highly prolific, and SR-CRSP research has shown that the D'Man transmits this prolificacy additively in crosses. This is potentially very useful to the areas where an intermediate level of prolificacy is desired. The aim of the Morocco project currently is to develop a new strain carrying 50% D'Man, 50% Sardi, with intermediate prolificacy. The goal is for the new strain to receive early puberty and an extended breeding season from the D'Man while receiving larger size and better fleece from the Sardi. The F_1's, F_2's, and F_3's are being intermated, and the resulting stock will be selected for early breeding, twinning, and lamb weight per ewe. Also, field testing is being carried out, with 50 ewes and 10 rams from the cross being tested on farms in the Rheraya valley. In the area of research on basis of the breed difference, physiological studies have shown that the higher relative growth rate of D'Man compared to that of Sardi sheep is apparently due to endocrine differences which lead to higher metabolic rate and higher relative feed intake.

Another important achievement of the Morocco project was completion and publication of the manual titled, *Sheep Production and Management in a Mediterranean Climate*, in English and French.

In Indonesia, evaluation of St. Croix hair sheep and their crosses with Sumatran sheep is being carried out. The St. Croix sheep and crosses are considerably larger, but the local sheep have exceptionally short lambing intervals. The latter suggests frequent lambings with moderate prolificacy as an alternative to high prolificacy, as a means of increasing lamb output per ewe per year which may be more suitable for limited resource farmers.

Research Results

Objectives

Indonesia

1. Development of high and low prolificacy strains of the Javanese sheep.

2. To continue on-farm performance evaluation of hair sheep and their crosses with local sheep in a management system involving grazing under rubber trees.

3. To utilize data from work with Outreach Pilot Project (OPP) to provide assistance for farmers in breeding and management.

4. To continue support for training of Indonesian scientific personnel.

Morocco

1. To continue on-farm performance evaluation of D'Man and Sardi crosses.

2. Development of a new strain of sheep [50% D'Man (D), 50% Sardi (S)], with emphasis on extended breeding season, twinning and growth rate.

3. To evaluate the cause-and-effect relationships between various hormone levels and performance traits in D'Man and Sardi breeds.

U.S.

To provide training opportunities in sheep breeding research to students from host countries, U.S., and other countries and to develop information needed for and complementary to the overseas research components (U.S.).

Problem Statement and Approach

(these are listed to correspond to the objectives)

Indonesia

1. Development of strains which will reliably produce either twins and triplets at a high proportion or almost exclusively singles and twins is of interest to farmers with varying levels of capital, feed supply, and management. To accomplish this objective, 11 Cicadas rams, mated to 30-40 local ewes each, were progeny tested at the Sei Putih Station in North Sumatra. Ovulation rate is being measured on the ewe progeny at 10-12 months of age and will be used as the main diagnostic tool to classify the rams as F^{l}, F^{l} + or ++ where F^{l} is the prolificacy gene. The rams have been returned to Cicadas where proven $F^{l}F^{l}$ and ++ individuals will be used in the high and low lines, respectively.

2. For the evaluation of hair sheep, all available pure St. Croix and three-quarter St. Croix (from St. Croix X local sheep matings) sheep have been included in a two-year trial designed to compare reproduction and lamb production of the respective genotypes and the local sheep, with and without supplementation of the forage available under rubber trees.

Supplementation is with feeds and at levels determined by the nutrition project participants. The goals are: (1) to determine, before releasing the St. Croix and its crosses, whether these animals could maintain acceptable fertility and viability without supplementation in this environment and (2) whether supplementation would be economically feasible (increase in meat production vs. supplemental feed and labor costs). Data are being collected on fertility, prolificacy, lamb and ewe viability, lamb growth, adult sheep weights, and health care required. Post-weaning growth of lambs on different diets is also being measured using surplus male lambs.

3. SR-CRSP participation was continued in collection, summarization, and interpretation of data from OPP and ORP farms.

4. Support for graduate studies continued for Subandriyo at the University of Missouri, and for Ismeth Inounu and Bambang Setiadi at IPB.

Morocco

1. Based on the excellent performance of DXS F_1

and F_2 sheep at the Tadla Farm and interest of farmers in the region for a field test of the F_1's, this project was continued for the development of a synthetic breed. F_1, F_2 and F_3 animals were 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. The Tadla flock is also expected to provide animals for field testing.

2. For the field testing of DXS sheep (Morocco), performance of 50 ewes and 10 rams that had been distributed to 10 farmers in the Rheraya Valley in January, 1989, was monitored.

3. In a comparison study of D'Man lambs and Sardi lambs, 20 three-month-old ram lambs of each breed were divided into *ad libitum* and restricted feeding (1.5 X maintenance requirements) groups, and their growth rate and endocrine profiles were measured. The study was designed to discover what causes the D'Man lambs to have higher levels of the following than Sardi lambs: higher relative growth rate, T_3, T_4, insulin levels, and feed intake. The lambs were slaughtered at the end of the trial, and body composition data were collected to estimate maintenance energy requirements.

U.S.

To further the objective of providing training experiences in sheep breeding research, Nathalie Bogui continued to analyze sheep data from the University of California's Hopland Station on measurement of ovulation rate, embryo survival, litter size, lamb viability, and weaning weight of selected lines of Targhee sheep and their linecrosses. In addition, Sagari Ramdas has been analyzing data from a University of California sheep crossbreeding experiment.

To provide information for the next phase of the CRSP in which sheep germ plasm may be transferred via frozen embryos, frozen-thawed embryos from the Targhee selection lines were transferred to 58 recipient ewes. The objective was to evaluate viability of the embryos following various periods of storage.

Dr. David Thomas of the University of Illinois has provided a two-month consultancy to the project, including a trip to Indonesia, assistance with laparoscopies, hair sheep evaluation, and serving on graduate student committees.

Justification

Indonesia

Prolific Sheep. At present, flocks are a mixture of highly prolific and non-prolific ewes. Feeding and management requirements for these two groups are quite different. By using the information on the F1 gene, we should be able to develop flocks consistently high or low so that producers can choose a genotype which fits their feed and management resources. The project is encouraging Indonesian agencies such as Balai Penelitian Ternak (BPT) and the Rubber Institute to develop a large multiplication center which could provide larger numbers of each of these two groups for distribution to farmers and for testing in both large flock and small flock systems.

Hair Sheep. Wool on these sheep is not used, and it causes heat stress in the animals. Because there is a labor cost to clip the wool on these sheep, it is planned to remove the wool genetically. A performance test of the pure St. Croix and its crosses with the local sheep is planned to obtain data on comparative total performance of these different types.

Morocco

Except for the D'Man breed, standard Moroccan breeds are of very low prolificacy. It is expected that the better environments of Morocco, e.g., better cereal production areas and areas with irrigation, could benefit from more prolific sheep. Developing types of different levels of prolificacy has been a primary goal and has been achieved. The next phase is to develop a reliable source of D'Man type for use directly in better areas and to cross on breeds of low prolificacy for use in intermediate areas. Also, it is planned to carry out field tests under different environmental conditions.

Physiology research needs to be continued for a better understanding of adaptation factors and to help the development of improved selection criteria for the DxS crosses.

U.S.

The U.S. component of the breeding project continues to involve complementary and supporting research in reproduction and physiology, and to support the training of graduate students toward academic degrees.

Project Progress

Indonesia

Data from 1983 to 1990 from the Cicadas flock have been summarized, and a criterion identified for distinguishing between F1 F1 and F1 + animals. The updated classification on all ewes was used in the 1990 mating plan. The first few progeny test ewes were laparoscoped. No data could be obtained from the second progeny group because most of the ewes were already pregnant. The rams included in this progeny test at Sei Putih have been returned to Bogor and will be used in the F1 F1 and ++ lines there as soon as the progeny test information is complete.

Preliminary data on F_1 progeny of St. Croix and local breed crosses suggested that the North Sumatran (NS) and the F_1 ewes were equal in litter size and fertility, F_1's were larger in size, and the NS had shorter lambing interval (about 1 cycle). There is preliminary evidence that the St. Croix and F_1 animals may be more susceptible to parasites than NS.

Because of lack of funds and personnel, no work was done on goats in Indonesia for the period covered in this report.

Due to administrative demands on Dr. Iniguez' time, in particular the time involved in organizing the successful workshop on Integrated Tree Cropping and Small Ruminant Production Systems (ITS) held in Medan in September, 1990, the proposed work on blood protein polymorphism was delayed.

Morocco

Publication of research results in scientific journals and conference proceedings was a major activity. The crossbreeding study of D'Man and Sardi breeds continued. The field test initiated in 1988-1989 in the Rheraya Valley involving DXS rams and ewes was continued. The 1990 mating plan to produce the DS synthetic and controls was initially as outlined in table 1. About 50 ewes unexpectedly turned out to be pregnant at the start of the scheduled mating season, and the actual number mated to the designated rams was less.

Table 1. Mating Plan for 1990-91.

	Females				
Males	Sardi	D'Man	F_1	F_2	F_3
Sardi	23	25			
D'Man	25	26			
F_1			67		
F_2				68	
F_3					26

The initial 3 X 3 diallel mating that provided the research material for this phase of the study was made among the Sardi (S), D'Man (D) and the DXS crossbred animals and described in detail in a Ph.D. thesis (Boujenane, 1989).

The studies on physiological differences between the D'Man and Sardi showed that the higher T3, T4 and insulin levels of the D'Man were also found under restricted feeding. This indicates that the endocrine differences are driving the higher feed intake, rather than the contrary. The continuation of this work, planned for Summer 1990, was unfortunately delayed due to an automobile accident in which two persons working on the project were seriously injured.

U.S.

Selection for growth rate and multiple births continues. A study of genetic and management factors affecting out-of-season breeding has been completed by W. Cushwa. A major

component of the U.S. participation in the CRSP program remains the training of graduate students.

Project Achievements

Indonesia

The most important achievement on the prolific sheep component was the development of a criterion for identifying homozygous (FI FI) ewes. This will significantly speed up the development of the two lines. In the hair sheep program, further evidence on the remarkable regularity of reproduction of the local North Sumatran ewes was obtained, and a health component was added to this program.

As shown in table 2, weight of lamb weaned per ewe per year by North Sumatran sheep approached that of the larger Finnsheep and Dorset breeds in a more favorable environment, on a per ewe basis, and was superior as a ratio of lamb weight to ewe weight.

A workshop entitled "Integrated Tree Cropping and Small Ruminant Production Systems (IPS)," sponsored by the Agency for Agricultural Research and Development (AARD), Small Ruminant CRSP and the International Development Research Centre (IDRC), was held in Medan, North Sumatra, on September 9-15, 1990. A total of 28 papers were presented. Attendance was approximately 60 people, with invited participants from USA, Australia, Thailand, Philippines and Malaysia. A proceedings is being prepared, which will include two papers from the breeding project.

An invited paper entitled "The Prolificacy Gene of Javanese Sheep" was presented at an international conference on "Major Genes for Reproduction in Sheep," held in Toulouse, France, on July 16-18, 1990.

Results of a two-year study that was a part of the Outreach Pilot Project (OPP) was summarized in a paper to be submitted to a research journal. A paper on the performance of North Sumatran sheep was accepted for publication in Small Ruminant Research.

Other publications from the Indonesia CRSP breeding project are reported in the "Publications" section of this report.

Table 2. Ewe productivity in North Sumatran sheep as compared to temperate breeds.

	North Sumatran	Temperate Breeds Finnsheep	Dorset
Ewe Weight (kg)[1]	21.9	39.3	46.8
Average Litter Size Weaned	1.22	1.49	1.22
Total Litter Weaning Weight (90 d)	11.4	26.2	22.0
Lambing/Year	1.82	1	1
Total Lamb Weight/Ewe/Year	20.7	26.2	22.0
Annual Wt. Lamb Weaned/Ewe Wt.	.95	.67	.47

[1] Average across four parity groups

Morocco

One of the major accomplishments was the publication of the manual, "Sheep Production and Management in a Mediterranean Climate: The Agropastoral System of Morocco," in English and in French.

Crossbreeding of D'Man (D) and Sardi (S) breeds contributed to our understanding of

Table 3. Ovulation rate and litter size in pure breeds and crossbreds

Breed Group	N	% D'Man	Ovulation Rate	Litter Size
S	85	0	1.06	1.03
DS X S	42	25	1.41	1.34
F_1	57	50	1.73	1.49
F_2	104	50	1.71	1.49
D X DS	56	75	2.31	1.85
D	70	100	2.79	2.00

the underlying genetic basis of reproduction in these breeds. Table 3 summarizes ovulation rate and litter size of these two breeds and their various crosses.

Both the ovulation rate and litter size increase in proportion to the increase in D'Man genotype in crosses, which suggests a quantitative inheritance.

Two papers were accepted, and another one has recently been submitted, for publication in the Journal of Animal Science. A total of four papers were presented at the annual meeting of the European Association for Animal Production, and 4th World Congress on Genetics Applied to Livestock Production (two papers in each). A paper on repeatability estimates of litter size is in progress and will be submitted to Animal Reproduction Science.

Complete citations for these papers are presented in the "Publications" section of this report.

U.S.

(Work supported primarily by the California Agr. Expr. Station but with some SR-CRSP support, e.g., for computing.)

The transfer of frozen-thawed embryos was highly successful as shown in table 4.

Table 4. Results of an embryo transfer study using frozen-thawed embryos

Embryo Classification	No. Transferred	No. Lambs	% Survival
Good	71	42	59.2
Fair	28	13	46.4
Poor	28	2	7.0

Of embryos classified as fair or good following thawing, 55% were represented as live born lambs. However, survival rate of embryos classified as poor was very low (7%), indicating that storing embryos of poor quality at collection, or transferring embryos which are morphologically abnormal on thawing is not justified. Most of the poor quality embryos were of questionable quality when collected; a very high proportion which were satisfactory at freezing were also of acceptable quality after thawing, and the overall results indicate this is a good method of storing and transforming sheep germ plasm.

An experiment on the "ram effect" in inducing out-of-season breeding was completed, and a paper has been prepared from the resulting M.S. thesis by W. Cushwa. It was determined that ewes joined with vasectomized rams two months prior to the start of the breeding season showed a higher response rate when joined with fertile rams. These ewes also lambed earlier than ewes that were completely isolated from rams until the regular breeding season. Data on ovulation rate and embryo

survival in lines of sheep selected for weaning weight and multiple births have been collected and are being analyzed by N. Bogui. Data from a study of different types of prolific crossbred ewes, including Barbados Blackbelly crosses, are being analyzed by S. Ramdas.

Changes in 1990 Work Plans and Reason(s):

Due to administrative duties of Dr. Iniguez, the proposed study on genetic variation within and among Indonesian sheep and goat populations using blood protein polymorphisms has been deferred.

Work planned on goats in Indonesia was not carried out because of changes in personnel and plans within the Indonesian Institute (BPT). Since this phase of the work is not to be included in the 1990-1995 program, CRSP work on goats in Indonesia has been terminated, except for the polymorphism study mentioned above still planned. The small scale project on D'Man goats in Morocco has also been suspended because the person involved has gone for overseas graduate training.

Training Progress and Institutional Development:

Long-term

Bambang Setiadi is taking courses toward a Ph.D. degree at IPB, Bogor.

Ismeth Inounu's M.S. thesis at IPB is near completion.

Subandriyo is expecting to complete his Ph.D. studies in November, 1990, at the University of Missouri.

Nathalie Bogui of Ivory Coast is analyzing her Ph.D. thesis data with a view to complete her studies next year.

Sagari Ramdas of India is analyzing a UC sheep crossbreeding data for her M.S. thesis.

Short-term

Workshop on "Integrated Tree Cropping and Small Ruminant Production Systems (IPS) held on September 9-15, 1990, in Medan, North Sumatra (jointly with other CRSP projects and IDRC).

Other Contributions

Contributions to U.S. Agriculture

The SR-CRSP project has made a significant contribution to research on sheep and goats by contributing to the training of graduate students from the U.S. and other participating countries, as well as foreign students from other non-participating countries. Increased knowledge of production practices in countries other than the U.S. has added to our understanding of various aspects of animal science, with benefit to the breadth of teaching programs. The diversity of sheep breeds available in Morocco and Indonesia has contributed importantly to understanding of the underlying genetic basis of prolificacy. In particular, the research on the major gene (F^l) in the Javanese sheep has increased our knowledge of patterns of inheritance of important reproduction traits. This was featured recently in a workshop in Toulouse, France.

Contributions to Host Country

In Morocco, the CRSP program has helped both financially and technically to implement the program of the Tadla Farm Project. Presently, research in various disciplines at Tadla contributes to improved animal husbandry practices in the region. As the Moroccan portion of the CRSP program will be phased out in 1993, the scientists at IAV are using the Tadla Research Center and the CRSP research base to get grants from other international agencies, e.g., International Foundation for Science, Stockholm (IFS).

In Indonesia, the Outreach Pilot Project (OPP) continues to make positive impact on incomes of smallholder farmers. The hair sheep

project continues to be a major component of the CRSP activities in Indonesia.

Linkages and Networking

The improved communication with the Malaysian Agricultural Research and Development Institute (MARDI) has led to an agreement for exchange of scientific information and collaboration in efforts to import new germ plasm from Barbados (Barbados Blackbelly Sheep).

The work done in Indonesia has received recognition in the scientific community, particularly via the IPS Workshop; also, the PI was invited to present a paper on the prolificacy gene in Javanese sheep at an International Workshop on major genes affecting reproduction in sheep.

Publications

Papers published or in press

Boujenane, I. and M. Akhazzan. 1990. Reproductive performance of D'Man, Sardi and their crossbred ewes joined to rams of terminal sire breeds. Proc., 4th World Cong. on Gen. Appl. to Livest. Prod. Edinburg, U.K., Vol. XV, pp.77.

Boujenane, I., A. Araba and G. E. Bradford. 1990. Postweaning growth and carcass traits of lambs of D'Man and Sardi breeds and their crosses with meat breeds. Proc., 41st Annual Meeting of EAAP. Toulouse, France, Vol. 1, pp.86.

Boujenane, I., G. E. Bradford and T. R. Famula. 1990. Inheritance of litter size and its components in crosses between the D'Man and Sardi breeds of sheep. J. An. Sci. (in press).

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Iniguez, I., M. Sanchez and S. Ginting. 1990. Long-term production of Sumatran sheep in an integrated sheep and rubber plantation system. Small Rum. Res. (in press).

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Setiadi, B. and L. Iniguez. 1990. Reproduction performance of small ruminants in an on-farm research evaluation of village farms in West

Java. Working Paper, SR-CRSP, Bogor, Indonesia. (To be submitted to Small Rum. Res.).

Technical publications

Sheep production and management in a Mediterranean climate: The Agropastoral System of Morocco. 1990. Y. M. Berger, A. Kabbali, and G. E. Bradford (Eds.), 251pp. SR-CRSP, Univ. of California, Davis. Also published in French translation: *L'elevage du Mouton dans un Pays a Climat Mediterraneen: Le Systeme Agro-Pastoral du Maroc.* A. Kabbali & Y. M. Berger (Eds.), 236pp.

By-Product and Crop Residue Utilization in Intensive Sheep and Goat Production Systems for Limited-Resource Farmers in Morocco

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Summary

In Morocco cereal stubble represents the main food available in the summer for sheep raised under a mixed crop-livestock system. Because sheep are a substantial source of cash income to farmers, good growth and reproduction are important considerations. Feed resources may be a serious limiting factor and locally available by-products such as carob meal and citrus pulp may be useful to improve the use of the straw and straw stubble.

Protein and energy supplementation of ewes grazing wheat stubble proved advantageous. Ewes on wheat stubble alone except for mineral and vitamin supplement lost 6.2 kg weight after 16 weeks. Added supplementation with 200g of cotton seed meal per day between week five and 16 resulted in a 3.8 kg weight increase; when an additional 200g of barley per day was added for the same period, weight gain was 5.0 kg. These results suggest that protein and energy supplementation of ewes after the first month on stubble grazing is necessary and may improve their fertility.

In 1990 an experiment with crossbred ewes compared unsupplemented stubble feeding with moderate supplementation (protein and energy) after the eighth week of stubble grazing. Determinations were made of ewe ovulation rate, body weight changes, prolificacy, lamb weight at birth, and lamb growth and ewe performance until the third month after lambing. Results are not yet available.

Carob pulp is an available by-product that is used for fattening lambs. Lamb feeding trials evaluated urea and sunflower meal as nitrogen sources in diets high in carob pulp. Results showed that increasing the crude protein from 12 to 16 percent did not necessarily improve lamb performance unless urea was included in the diet. It was economically and nutritionally beneficial to use urea as part of the supplementary nitrogen in diets containing carob pulp for fattening lambs.

A study was conducted to evaluate ammonification versus urea or natural protein as nitrogen supplements of citrus pulp for sheep diets. Although results are not yet completely summarized, it can be concluded that ammonification of citrus pulp as a method of nitrogen enrichment of this product may not have any advantage over simple urea addition to the diet. Use of non-protein nitrogen supplementation in the form of urea was comparable to that obtained from horse beans which are more expensive.

Supplementation of wheat straw diets for pregnant ewes provided greater ewe weight gains and straw intake with increasing protein and energy levels. Lamb birth weight and mortality were not affected by level of protein or energy.

Estimates were obtained of the bioavailability of calcium from some widely used feeds in Morocco. Lambs were used in feeding trials comparing a basal diet with diets supplemented with calcium carbonate, alfalfa hay, oat-vetch hay, or wheat straw. Lambs were slaughtered and body parts were analyzed. Calcium retention with the calcium carbonate treatment was 48.1%; alfalfa hay, 29.9%; oat-vetch hay, 33.3%; and wheat straw, 25.6%.

Research Results

Objectives

1. To characterize the nutritional value of locally available feedstuffs for small ruminants.

2. To develop guidelines for formulation of nutritionally and economically optimum diets, especially at critical stages of the production cycle .

3. To develop strategies for more efficient use of the feed resources available within intensive small farming systems.

Problem Statement and Approach

Sheep in Morocco are very integrated into the total farming system, especially in the dryland cereal production areas. Farmers depend on their sheep for cash income. Thus it is important to sheep producers to maintain good productivity (growth and reproduction) for their flocks. Feed resources, however, may be a serious limiting factor. In order to make maximum use of cereal by-products (stubble and straw), more information is needed about how to use other locally available feedstuffs (such as sugar beet and citrus pulp, carob meal, almond hulls, waste palm dates), of higher quality, in the right amounts, and at critical times during the animal production cycle to optimize economic efficiency.

Justification

a. Stubble Grazing Trials

Cereal stubbles represent the main feed available in the summer for sheep raised under a mixed crop-livestock system. Previous works have attempted to characterize stubble utilization in terms of collected diet nutritive value, level of intake, and animal performances. Different strategies for energy and/or protein supplementation in relation to body weight performance have been tested. However, since the mating period and early gestation usually take place during the first part of the stubble grazing period, more attention is now given to reproductive performance and its relationship to supplementation programs.

b. By-Product Evaluation and Utilization for Fattening Lambs

Growth and fattening of lambs for market is an important phase that has great impact on the overall productivity of sheep. The objective is to achieve normal growth after weaning and to increase carcass weight of slaughtered lambs.

The primary goal of this part of the SR-CRSP nutrition program is to establish feeding systems for growing and fattening lambs based on locally available and economical feed resources. Several by-products have been tested such as waste palm dates, beet pulp, citrus pulp, and carob pulp. These feeds are adequate as energy sources but need to be supplemented with nitrogen.

Under Moroccan conditions, urea is the cheapest source of nitrogen; however, sunflower meal as a source of true protein is becoming increasingly available at a competitive price. Ammoniation may have potential as a method of nitrogen enrichment of some of these by-products. The evaluation of these alternatives has been the main focus of the recently conducted trials.

c. Supplementation of Wheat Straw Diets

Wheat straw is an important crop residue in the cereal producing regions of Morocco and is usually fed to ewes during late gestation and lactation. However, cereal straw has many nutritional limitations and must be supplemented with both energy and nitrogen to prevent abortion, ensure normal fetus development, lamb birthweight, and adequate milk production of the ewe for rapid lamb growth. Evaluation of cereal straw-based diets supplemented with energy and nitrogen sources from locally available feedstuffs and urea is an important aspect of Moroccan sheep production.

Project Progress and Achievements

a. Stubble Grazing Trials

1989 Trial

The effects of protein and energy supplementation of ewes grazing soft wheat stubble on their body weight and reproductive performance were evaluated in a trial using 96 ewes (48 Sardi and 48 D'Man X Sardi). The ewes were randomly assigned to three treatments, A, B, and C, with two replicates per treatment. Stocking rate was set at 16 ewes/ha, and mating started the same day as stubble grazing. During 16 weeks of stubble grazing, ewes in treatment A were supplemented with minerals and vitamins only; those in B received in addition 200 g

of cottonseed meal/day between week five and 16; ewes in C received the same supplement as B in addition to 200 g barley/day from week nine to 16. During the 17th and 18th week, all ewes remained on stubble while receiving the same supplementation as treatment C. From the end of the 18th week until lambing, ewes from all treatments were pen-fed the same diet formulated to meet their energy and protein requirements. Stubble biomass and ewe weight were measured every four weeks and extrusa samples collected from esophageally fistulated rams.

Total stubble dry matter decreased from 6.5 T/ha at the beginning of the trial to 1.94 T/ha after 16 weeks of grazing ($P < 0.001$). Treatment had no effect ($P > 0.05$) on biomass. Stubble quality only was affected ($P < 0.001$) by period of grazing. Crude protein content (% of organic matter) and in vitro organic matter digestibility of extrusa samples collected during the third, 11th, and 15th week were, respectively, 7.26, 61.5%; 6.11, 57.5%; and 5.50, 51.0%. After 16 weeks of grazing, ewes in treatment A had lost 6.2 kg whereas those in B and C gained respectively 3.8 and 5.0 kg. Regardless of breed, conception rate was slightly lower in A than B and C (respectively 81, 91, and 88%). Prolificacy did not change.

These results suggests that protein and energy supplementation of ewes after the first month of stubble grazing is necessary and may improve their fertility.

1990 Trial

Forty-eight crossbred ewes (twenty-four F1 and F2 D'Man x Sardi and twenty-four 3/4 Sardi x 1/4 D'Man) were randomly assigned to two treatments, A and C (two replicates/treatment). Stocking rate was set at 16 ewes/ha. Ewes in treatment A did not receive any supplementation during the first 16 weeks of grazing. Those in C were moderately supplemented with protein (after the fourth week) and energy (after the eighth week). Mating started two weeks after grazing started and lasted eight weeks. Endoscopy was conducted to determine the ovulation rate. Ewes were weighed (on two consecutive days) at week 0, 2, 4, 8, 10, 12 and 16. Stubble biomass was measured at the beginning of the trial and every four weeks thereafter. At the end of the 16 week grazing period, all ewes were pen-fed the same diet (straw, alfalfa hay and concentrate) until lambing. Data related to prolificacy and lamb weight at birth are being collected. Lamb growth and ewe performance are being monitored until the third month after lambing. After lambing, ewes from all treatment groups will be fed the same diet.

b. By-Product Evaluation and Utilization for Fattening Lambs

Source and Level of Nitrogen in Diets Containing Carob Pulp for Fattening Lambs

The objective of this trial was to evaluate the effects of nitrogen source (urea or sunflower meal) and level of crude protein (12, 14, or 16%) in diets containing relatively high levels of carob pulp (30%) on digestibility and fattening performance of lambs. Thirty-two crossbred wether lambs (Sardi X D'Man) with an average initial weight of 26 kg were used. Four balanced groups of eight animals were randomly assigned to four diets (A, B, C, or D). Diet composition is shown in table 1.

Table 1. Composition of four diets fed to crossbred wether lambs.

Ingredients, %	A	B	C	D
Carob pulp	30	30	30	30
Alfalfa hay	25	25	25	25
Barley grain	39	38.9	38.6	24.8
Sunflower meal	4.0	3.3	2.8	18.2
Mineral mix	2.0	2.0	2.0	2.0
Urea	-	0.8	1.6	-
Diet crude protein, %	12	14	16	16

In diets B and C, urea provided 2 and 4% crude protein (CP), corresponding to 16 and 28% of total dietary nitrogen. Each lamb was housed separately and pen-fed individually. After 15 days of adaptation, lambs were fed *ad libitum* for 15 weeks, and intake and lamb weight changes were monitored. Diet digestibil-

ity was measured by total fecal collection on four animals per treatment during the 16th week of the trial. Carcass data was collected after slaughter at the end of the trial.

Intake and daily gain were significantly higher ($P < .05$) for animals fed diet C: respective values for A, B, C, and D were 101, 99, 109, and 103 g DM/kg $BW^{.75}$/day; 184, 187, 209, and 190 g/day. However, diet had no effect ($P > .05$) on feed efficiency (8.2 to 8.5 kg DM/kg gain) and carcass yield (54.4 to 54.9%). Increasing dietary CP level improved ($P < .05$) CP digestibility regardless of source of nitrogen (53, 61, 64, and 64%, respectively, for A, B, C, and D). On the other hand digestibilities of total organic matter (61 to 64%) and NDF (39 to 42%) were not significantly affected.

These results show that increasing CP level from 12 to 16% in diets containing carob pulp does not necessarily improve lamb performance unless urea is included in the diet. Urea feeding increases the level of ammonia in the rumen and this may overcome the inhibition of proteolysis caused by tannins present in carob pulp. Therefore it appears to be nutritionally and economically beneficial to use urea as part of the supplementary nitrogen in diets containing carob pulp for fattening lambs.

Ammoniation Versus Urea or Natural Protein as Nitrogen Supplements of Citrus Pulp Based Diets for Sheep

This study was conducted to evaluate ammoniation of citrus pulp as a method of nitrogen enrichment of diets containing this by-product. Citrus pulp was either evaluated with ammonium hydroxide (T1), supplemented with urea (T2), ammoniated with urea (T3), or supplemented with horse beans (T4). Citrus pulp was incorporated at a level of 45% in all four diets. A low nitrogen grass hay (6% CP) was used as the forage component in these diets which also contained 10% molasses and 2% mineral mix and were isonitrogenous (11% CP). Ammoniation of citrus pulp was carried out with a procedure similar to that usually used for straw or crop residues with the following parameters: 5% urea or 2.8% NH_3 on DM basis, 30% moisture, and eight-week reaction time.

Thirty-two Sardi lambs (six months old and averaging 18 kg BW) were used. Four balanced groups of eight animals were randomly assigned to one of the four diets. The trial lasted 105 days during which individual feed intake was measured. Growth was monitored and carcass data collected after slaughter. In vivo digestibility and nitrogen balance were also measured during a seven-day period on four animals for each group.

This trial has not yet been completely summarized. Preliminary data show that ammoniated citrus pulp resulted in somewhat lower gains (157 and 143 g/day for T1 and T3, respectively) than urea (173 g/day) or horse bean (189 g/day) supplemented citrus pulp. Intake on diet T4 tended to be lower (96, 99, 93, and 89 g DM/kg $BW^{.75}$/day for T1, T2, T3, and T4, respectively). This resulted in T4 having the best feed efficiency (6.3 kg DM/kg gain); values for T1, T2, and T3 were 7.8, 7.4, and 8.7 kg DM/kg gain, respectively. Carcass yield varied between 49 and 51% and was not significantly affected by dietary treatments.

In terms of digestibility, the lowest values were obtained with T1 and the highest with T4; respective values for T1, T2, T3, and T4 were 60.4, 65.4, 63.9, and 71.2% for DM; 49.2, 58.3, 56.6, and 62.6% for CP; and 60.8, 66.4, 64.4, and 72.3% for energy. It can be concluded that ammoniation of citrus pulp may not have any advantage over simple urea addition to the diet. Lamb growth performance obtained with non-protein nitrogen supplementation in the form of urea was comparable to that obtained with horse beans, which are a much more expensive source of nitrogen. However, animals fed diets containing horse beans required less feed per unit of gain than animals fed the others diets. When making practical recommendations these economical aspects should be taken into consideration.

c. Supplementation of Wheat Straw Diets

Protein and Energy Supplementation of Wheat Straw Diets for Pregnant Ewes

Forty-eight ewes were used to determine the effects of protein and energy intake during

the last month of pregnancy on ewe weight change, lamb birth weight, and mortality. Treatments consisted in two protein and three energy levels in a 2 X 3 factorial arrangement. Animals were individually fed 850 g of straw plus variable amounts of urea, sunflower meal, barley, and molasses to obtain the desired levels of protein and energy. Results show that ewe weight gain and straw intake were affected (P<.05) by protein and energy levels. Straw intake increased with increasing protein level and decreased with that of energy. Table 2 shows that ewe weight gain increased (P<.05) with increasing energy and protein levels. The gain was highest at the higher energy and protein level, indicating a significant energy-protein interaction. Lamb birth weight and mortality were not affected by level of protein or energy.

allocated to one of five treatment group: basal diet treatment, Ca carbonate treatment (reference feed), and alfalfa hay, oat-vetch hay, and wheat straw treatments (test feeds). Lambs were slaughtered and all parts were analyzed to determine total body Ca and P. Calcium retention was estimated and calcium availability from the Ca carbonate, alfalfa hay, oat vetch hay, and wheat straw treatments was estimated using the slope comparison technique. Corresponding values were 48.1, 29.9, 33.3, and 25.6%.

Calcium Requirements

Calcium requirements for growing Timahdit lambs were determined by the factorial method. First, Ca deposition during the growth period of the lambs was determined. Forty-two Timahdit lambs were slaughtered and analyzed to determine body Ca contents at different periods. The relationship between body Ca contents and lamb BW was derived. Endogenous losses of Ca were estimated from the literature and Ca availability was estimated from experiment one. The determined values for required Ca were greater than those reported by NRC (1985) and ARC (980), but were close to those reported by INRA (1988).

Table 2. Energy and protein feeding levels, intake, and daily weight gain of pregnant ewes.

Energy, UFL*/d	.38	.38	.50	.50	.60	.60
Protein,g/d	75	100	75	100	75	100
Total intake, g/d	891	930	1.019	1,024	1,058	1,106
Straw intake, g/d	650	720	620	650	630	660
Ewe wt. gain, g/d	90	116	123	140	123	200

*UFL = 3.17 megacalories of Metabolizable Energy.

d. Mineral Studies

Bioavailability of Calcium

Objectives of this study were to estimate Ca availability using the comparative slaughter method for some widely used feedstuffs in Morocco and to develop a less laborious technique to assess Ca availability. Seventy-one Timahdit lambs between five and seven months of age and weighing between 10.2 to 22 kg BW were used. A group of 11 lambs served as an initial group to estimate initial body and phosphorus for the experimental lots. In experiment one, 30 lambs were randomly allocated to one of five dietary treatments. The treatments consisted of a basal diet and the basal diet supplemented with different levels of Ca carbonate. In experiment two, 30 lambs were also randomly

Changes in 1989-1990 Work Plans

Experiments on chemical composition and nutritive value of almond hulls were postponed until this year (1990-1991) due to availability problems at the time when facilities, animals, and personnel were available. Instead, research work on ammoniation of citrus pulp, which is part of an ongoing Ph.D. dissertation, was continued.

Training Progress and Institutional Development

Long-Term

A. Ilham, ENA Meknes. Ph.D. Nutrition. University of Minnesota, St. Paul. Dissertation title: Bioavailability for ruminants of calcium from Moroccan feedstuffs and calcium requirements of growing Timahdit lambs.

A. Fares, IAV Rabat. M.S. Nutrition. IAV Hassan II, Rabat. Expected graduation: 1991. M.S. research focuses on stubble grazing by pregnant ewes.

E. El Maadoudi, IAV Rabat. M.S. Nutrition. IAV Hassan II, Rabat. Expected graduation: 1991. M.S. research focuses on source and level of nitrogen on diets for fattening lambs.

K. Ksyar, IAV Rabat. Nutrition. IAV Hassan II, Rabat.

Short-Term

Seminar: "Mediterranean Forages and By-Products." Montpellier, France. July 5-6, 1990. N. Rihani made a presentation on the utilization of citrus by-products. Proceedings of the seminar will be published in "Options Mediterranennes." (A publication of the International Center for Advanced Mediterranean Agronomic Studies.)

Other Contributions

To Host Country

Publications of scientific and technical manuals.

L'Elevage du Mouton dans un Pays a Climat Mediteraneen. Le Systeme Agro-Pastoral du Maroc. 1990. A. Kabbali and Y. M. Berger (Ed.). Editions Actes.

Sheep Production and Management in a Mediterranean Climate. The Agropastoral System of Morocco. 1989. Y. M. Berger, A. Kabbali and G. E. Bradford (Ed.). Univ. of California Printing.

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Guessous, F., N. Rihani, E. Dahbi and K. R. Pond. 1990. Affect of protein and energy supplementation during the wheat stubble grazing period on ewe weight and reproductive performance. 41 Annual Meeting EAAP, Toulouse. Vol. 1:236.

Kabbali, A. 1990. Protein and energy supplementation of wheat straw diets for pregnant ewes. J. Anim. Sci. 68 (Suppl. 1): 598 (Abstr.).

Kabbali, A., W. L. Johnson, D. W. Johnson, R. D. Goodrich and E. C. Allen. 1990. Effects of undernutrition and refeeding on weights of body parts and chemical composition of growing Moroccan lambs. J. Anim. Sci. (Submitted).

Kabbali, A., W. L. Johnson, D. W. Johnson, R. D. Goodrich and E. C. Allen. 1990. Effects of compensatory growth on some body component weights and on carcass and non-carcass composition of growing lambs. J. Anim. Sci. (Submitted).

Outmani, A., J-M. Luginbuhl, F. Guessous and W. L. Johnson. 1990. Utilization of wheat stubble pastures by gestating ewes. Small. Rum. Res. (In Press).

Guessous, F., J-M. Luginbuhl, N. Rihani and K. R. Pond. 1990. Influence of supplementation on the performance of gestating ewes grazing wheat stubble pastures. Anim. Feed. Sci. Technol. (Submitted).

Rihani, N., F. Guessous and K. R. Pond. 1989. Effect of protein level on the feeding value of carob pulp-containing diets for sheep. J. Anim. Sci. 67 (Suppl. 1): 493 (Abstr.).

Rihani, N., F. Guessous et A. Berrami. 1989. Utilization de quelques sous-produits de l'agroindustrie pour l'engraissement des ovins. Hommes, Terre et Eaux: 18(72):83-87.

By-Product and Crop Residue Utilization in Intensive Sheep and Goat Production Systems for Limited-Resource Farmers in Indonesia

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Summary

Bogor

Research in Bogor focused on summarizing and publishing the nutrient requirements of sheep and goats as well as the information on feed quality and chemical composition over the lifetime of the project. Many feeding, digestibility, and growth trials have been run on Indonesian sheep and goats which are smaller than those for which nutrient requirement tables were developed in the U.S., Europe, and Australia. Summaries were prepared that provide data on nutrient composition, agronomic characteristics, feeding strategies, and potential problems in the use of locally important feeds for small ruminants. This information was used to prepare recommendations which extension personnel can use with farmers.

The nutrient requirement tables have been compiled and are now used along with other data generated in Indonesia. A more formal publication is planned for wider distribution throughout Southeast Asia. Data on feed composition of the feedstuffs used in feeding studies are now part of the computerized data bank maintained at the Balai Penelitian Ternak. "Techpacks" on feeding have been developed, are available to farmers, and are continually updated. Evaluations of these technologies on farms was an important part of the 1989-90 activities.

Sei Putih

Supplementation studies were conducted with cross-bred ewes to determine their effects when grazing under rubber trees. The supplemented group received a concentrate consisting of rice bran, cassava meal, molasses, fish meal, urea, and limestone. After 21 months, the supplemented ewes were heavier, gave birth to more lambs, lambing intervals and mortality rates were reduced, and productivity per year was greater but supplementation did not result in economic gain.

Over 20 local and introduced grasses, legumes, and a forb were established under rubber trees to determine their production and probable value as a feed source for sheep. An introduced grass, *Seteria sp.*, proved to be the most productive but this is a long-term project to assess production as the rubber trees grow and develop a more closed canopy. Another study followed changes in the composition of forage species under 17-year old rubber trees when grazed by a rotational system. Grass species increased in both the first and second year of rotational grazing, legume species remained about the same, and forbs were reduced.

Tolerance to shading of forage species was studied in an experiment with numerous species grown in pots under various aged rubber trees and in the open. All the local grasses were more shade tolerant than the introduced species in the study. *Panicum maximum* gave the highest yield of all grasses.

A procedure was developed to produce salt blocks for providing adequate salt and minerals to sheep. Various mineral compositions were used in differing proportions to provide the essential minerals needed.

Molasses with 3% urea was provided *ad libitum* as a supplement to Sumatran thin-tailed ewes bred to Javan thin-tailed rams, grazing in a rubber plantation. The supplemented ewes were compared to those grazing in rubber plantations only. After 21 months, supplemented ewes gave birth to more lambs and had shorter lambing intervals. Lambs from supplemented ewes were heavier at weaning. The value of weaned lambs less the cost of the supplement was 21% greater than the value of the weaned lambs from the control group.

Research Results

Objectives

1. To characterize the nutritional value of locally available feedstuffs for small ruminants.

2. To develop guidelines for formulation of nutritionally and economically optimum diets, especially at critical stages of the production cycle.

3. To develop strategies for more efficient use of the feed resources available within intensive small farming systems.

Problem Statement and Approach

Sheep in Indonesia are integrated into farming systems of smallholders and integrated into plantation cropping. In highly populated areas and in many villages, sheep are kept by small farmers. In some cases they are allowed limited grazing and in other cases are fed in confinement, in a cut-and-carry system. In tree crop plantations, sheep are becoming integrated to utilize the forage under the tree canopy, thereby reducing mowing and herbicide costs. Lack of quantity and quality of feed is the major problem in both systems. The research in Bogor focused on summarizing and publishing the nutrient requirements of sheep and goats and the information on feed quality and chemical composition. In Sei Putih, North Sumatra, research focused on the problems associated with grazing sheep in rubber tree plantations and concentrated on the agronomic and chemical evaluation of native and introduced forage grass and legume species, the nutritive value of locally available supplemental feed, and supplementation strategies for productive sheep. In both Bogor and Sei Putih, new technologies were tested with on-farm validation.

Justification

Bogor

a. Publication of nutrient requirements of Indonesian sheep and goats

A significant number of feeding, digestibility, and growth trials have been conducted in Indonesia over the lifetime of the Small Ruminant CRSP, as part of the BPT/NCSU collaborative research. The objective of this activity was to integrate data from all the trials and estimate the nutrient requirements for Indonesian sheep and goats. Their small mature size limits the usefulness of nutrient requirement tables developed in the U.S., Europe, and Australia. Such a publication should fill a knowledge gap and be a significant contribution to developing feeding programs to optimize production.

b. Summarizing chemical composition of locally important feeds for small ruminants

The purposes of this activity were: 1) to systematize the contribution of feed composition data to the computerized data bank which is maintained at BPT and 2) to facilitate publication of data which can be useful for persons involved with ration formulation for small ruminants throughout the humid tropics. Nutrients included in the summaries were crude protein, cell wall fiber components, and major minerals, according to availability of data. In addition, agronomic characteristics, feeding strategies, potential problems, and information on expected gain makes the information more useful to the farmer.

c. Publication of small ruminant feed recommendations for village smallholders in the humid tropics

The culmination of projects a and b was the preparation of recommendations (techpacks) which extension personnel can use in their programs with farmers. Eventually, with information from other discipline groups, recommendations will be incorporated into a unified "technology package" for smallholder sheep and goat production systems in the humid tropics.

d. Testing technologies developed using on-farm evaluations

One of the last steps in developing new technologies is the testing of these technologies at the farmer level. Many technologies work well at research units but are not adopted by the farmer for various social, economic, or other reasons. Testing technologies with farms is an important step before releasing the technology.

Sei Putih

a. Supplementation of local North Sumatra and F1 ewes and lambs grazing native pasture under rubber trees

Research on supplementing ewes grazing pasture was initiated in 1984. The objective of this study was to apply and compare the recommendations reached in the previous North Sumatra ewe supplementation trials (conducted with Sumatra thin-tailed ewes) to the recently developed F1 ewes. Pregnant local (Sumatra thin-tail) and F1 ewes received supplementation during the last six weeks of pregnancy. The supplementation level during early lactation was adjusted to the number of lambs being nursed, and continued until a predetermined constant lamb weight. Creep feeding was tested for half of the lambs, in an attempt to reduce weaning stress, improve post-weaning growth, and accelerate puberty in ewe-lambs. Performance of local and F1 ewes was also compared.

b. Introduction of forage species and their establishment in new rubber plantations

Introduction and evaluation of forage grasses and legumes for eventual use under rubber trees began in January, 1988. More than 50 accessions from Indonesia and Australia sources were planted in replicated plots and their performance compared in full sunlight. Observations were made on growth, recovery after harvest by handcutting or grazing, persistence, nutritional quality, and resistance to diseases and insects. The best of these introductions were established under new rubber trees and evaluated by cutting and grazing.

c. Grazing management studies of sheep under rubber trees

Little is known about the proper management of forages growing under rubber trees and grazed by sheep. An existing area of native pasture under rubber trees (approximately 17 years old) was subdivided into one-hectare plots, using a solar-powered electric fence. The ewe breeding flock grazed the area in a rotational scheme, based on visual evaluation or remaining available herbage (for removal of animals from the plot) and forage regrowth (to decide on the length of the rotation cycle). Information on the botanical composition of the area was evaluated. With this information, better systems of grazing management can be developed that optimize animal performance and improve or maintain forage quality and quantity.

d. Effect of shading on growth of introduced forages

Pots with 25 different forages will be placed under rubber trees (same clone) that are 0-3, 3-5, 5-7, and 15 years old. Five pots will be set in three locations per age of tree. Growth of forage and light intensity will be measured under each canopy.

e. Formation and evaluation of molasses blocks with and without minerals

Molasses blocks have been successfully formulated and produced. Mineral deficiencies have been reported for some areas of Indonesia. A mineral preparation to meet potential deficiencies (based on mineral analyses of forages) was included or omitted from the blocks. Growth rate and feed efficiency of lambs fed the molasses blocks with or without the minerals was measured.

f. Free choice molasses supplementation to grazing ewes

The most economical source of supplementation energy has been molasses. Free choice molasses with 3% urea was offered to 60 ewes while 60 ewes received pasture only. Ewe

weights, lambs born, lamb birth weights, lamb weaning weights, lambs raised, and lambing interval has been measured since November, 1988. This study was designed to continue through three lambings and ended in August, 1990. With this information feeding systems that are biologically and economically effective could be developed.

Project Progress and Achievements

Bogor

a. Publication of nutrient requirements of Indonesian sheep and goats

The nutrient requirement tables were compiled utilizing data generated from experiments supported by the SR-CRSP and with other data generated in Indonesia. The manuscript was reviewed by scientists in the United States and their comments incorporated. The published tables are now used in Indonesia. A more formal publication is planned for wider distribution throughout Southeast Asia.

b. Summarizing chemical composition of locally important feeds for small ruminants

The composition of the feedstuffs utilized in all of the nutrition feeding studies are now part of the computerized data bank which is maintained at BPT. With the development of the small ruminant network, these data will now be available to many countries.

c. Publication of small ruminant feeding recommendations for village smallholders

Techpacks on feeding have been developed and are available to farmers. Technical information files were also developed for several feedstuffs. These continually updated files are important to scientists, extension personnel, and in same cases, to advanced farmers. This system allows updating as more information is available and is an excellent data resource.

d. Testing technologies developed using on-farm evaluations

The nutrition staff was very active in the on-farm evaluations that continued in 1989-90. These visits and continued observations are important to increase the awareness of scientists to the practical problems that farmers face and to help test new technologies. The multidisciplinary approach improves communication between scientists and develops more unified programs.

Sei Putih

a. Supplementation of local (Sumatra thin-tail) and F1 St. Croix crossbred ewes grazing native pasture under rubber trees

An experiment was conducted to study the effect of feed supplementation during the last six weeks of pregnancy, lactation, and mating on the reproductive performance of ewes and growth rates of lambs. A flock of Sumatran thin-tail (STT) and F1 (St. Croix x STT) ewes was divided into two similar groups: a control group (C), grazing under rubber plantations alone, and a supplemented group (S), which received concentrate in addition to grazing. The concentrate was made of rice bran (44.3%), cassava meal (31.4%), molasses (20.7%), fish meal (1.4%), urea (1%), and limestone (1.1%). After 21 months, the supplemented ewes were heavier postpartum (STT, 22.2 kg; F1, 28.0 kg) than the control ewes (STT, 21.0 kg; F1, 25.7 kg) and gave birth to more lambs (S, 100; C, 85). Birth and weaning weights and litter size were not significantly affected by treatment, but lambing interval was reduced with supplementation. Productivity per year was significantly higher in the supplemented ewes, both per head and per unit weight of ewe. Mortality of lambs was 17.6% for the control group and 14.2% for the supplemented group. This system of supplementation improved the performance of ewes, but did not result in economic gains.

b. Introduction of forage species and their establishment in new rubber plantations

Four local grasses, seven introduced grasses, nine legumes, and one forb were estab-

lished under new rubber trees in four blocks. Introduced grasses yielded more kg/m2. The highest yielding introduced grass was *Setaria*, followed by *Brachiaria* and the *Panicum* species. The local grass *Ottochloa nodosa* had the highest yield of the local grasses. *Stylosanthes guianensis* had the highest yield for the legumes. *Asystasia intrusa*, the forb, had yields comparable to most grasses. These yields were determined monthly and include the first eight weeks after planting the rubber trees. The long-term project will determine production as the tree canopy closes and the light penetration decreases.

c. Grazing management studies of sheep under rubber trees

A flock of Sumatran thin-tail ewes grazed in a rotational system of 12 one-hectare paddocks under 17-year old rubber trees. Plant species composition was determined before starting the rotational system and after one and two years of grazing. Pasture was improved by removing non-palatable species after the first grazing cycle, by planting empty areas with *Paspalum conjugatum* and *Mikania cordata*, and by spreading manure which had accumulated under the sheep barn. The main changes in the vegetation after the first year of grazing were: a reduction of forbs and an increase in the percentage of grasses, legumes, total edible plant species, and area covered with plants. At the end of the second year of grazing, grasses had increased to 61.2% of the total species present. *Paspalum conjugatum* replaced *Mikania cordata* as the dominant species in the pasture. The percentage of legumes remained the same, so the increases in grasses were at expense of forbs. During the first six grazing cycles (406 days) the stocking rate was 5.76 ewes per ha, and during the second (395 days) the average stocking rate was 5.89 ewes per ha.

d. Effects of shading on growth of introduced forages

An evaluation of shade tolerance was completed on four local grasses, *Axonopus compresus*, *Cyrtococcum oxyphylum*, *Ottochloa nodosa*, and *Paspalum conjugatum*; three introduced grasses, *Brachiaria mutica*, *Panicum maximum* var. Hamil, and *Paspalum dilatatum*; three legumes, *Centrosema pubescens*, *Clitoria ternatea*, and *Stylosanthes guianensis* var. Cook; and two forbs, *Mikenia cordata* and *Asystasia intrusa*. Each species was planted in four liter plastic pots (45 pots/species) in full sunlight in May, 1989. The three legumes species and *Asystasia* was planted from seed and the others by vegetative propagation. After a period of 16 weeks a standardization cut (5 cm from soil) was given to forages and the pots moved to two locations within each of four ages of rubber trees: 3.5, 5, 7, and 11 years old. One set of pots remained in the open in full sunlight and served as the control. There were five pots per species per location for a total of 540 pots. To remove the influence of root reserves present from the full sun establishment, after eight weeks all pots were harvested at 5 cm above soil level and then the trial began. Two forage harvest were completed at eight-week intervals. Measurements of light transmission were made at the experimental sites on two occasions using a LICOR instrument which records the photosynthetic active radiation (PAR). The estimated values taken between the two harvest were 0.232, 0.087, 0.027, and 0.060 of PAR for the 3.5, 5, 7, and 11 year old trees utilized in this experiment. Local grasses had lower yields when compared to introduces grasses, but there were no differences among local grasses. Under different shading, *Panicum maximum* gave the highest yields of all grasses in general. *Stylosanthes guianensis* gave the highest yields of the three legumes studied. The forb *Asystasia intrusa* had the highest yield of all the species. All the local grasses survived under all age treatments, supporting their reputation of shade tolerance. Their decline in productivity under shade was not as pronounced as with the introduced grasses. Two of the introduced grasses, *Brachiaria* and *Paspalum dilatatum*, did not survive the light conditions imposed by the seven-year old trees. Two legumes, *Centrosema* and *Clitoria*, also survived under all light regimes, but *Clitoria* showed much better yield with higher shading. *Stylosanthes* gave a very high yield in the open, second only to *Panicum*, but its yields decreased sharply under shade, and was the only legume species that could not grow under 7-year old trees (0.027 PAR). Both of the forbs grew in all age treatments, but

Asystasia was the best, especially under heavy shade.

e. Formulation and evaluation of molasses blocks with and without minerals

No salt blocks are available locally, therefore blocks were manufactured at Sei Putih. Cement was used as the binding agent. Four-liter pots were lined with plastic for easy removal of blocks, and before adding the mixture a bent wire (12 gauge) was placed in the middle and extended vertically from the bottom of the pot to about 15 cm above the pot. Once the mixture hardened, the wire was used to hang the blocks from the ceiling of the barn. After several attempts, the best proportion of cement in the pure salt block was 8%, a compromise between hardness and cost (cement should be wetted first before mixing with the salt). Drying can be done in the sun, or more rapidly in an oven. The consumption of salt from these blocks was 20 g/day per head during the time the animals spent in the barns (16 hours per day). The percent of cement had to be increased to 11% when a commercial mineral mixture (in powder) was added which made the mixture 69% salt, 11% cement, and 20% mineral mix (Ultra-mineral mix, Medan, containing 20% calcium, 25% phosphorous, 22% sodium, 0.35% manganese, 0.20% zinc, 0.8% iron, 0.2% iodine, and 0.15% copper). Average animal intake of this block was nine g/day. An additional formula that includes a source of phosphorous is 65% salt, 15% cement, and 20% bone meal. At Sei Putih, copper has been added to the blocks at the rate of 23 g of copper sulfate per standard pure salt block of five kg (8% cement). The estimated copper intake from this block is 21 mg per head per day. Modifications of formulas are required to provide other minerals or ingredients in various proportions. Salt blocks have facilitated the task of providing adequate salt and minerals to the sheep.

f. Free choice molasses supplemented to grazing ewes

An experiment was conducted with a flock of Sumatran thin-tail ewes bred to Javanese thin-tail rams to study the effect of continuous molasses/urea supplementation on reproductive performance and lamb weaning weights. The flock was divided in two groups: a control group (C), grazing in rubber plantations only and a supplemented group (M), supplemented with molasses/urea plus grazing in a rubber plantation. Molasses, containing 3% urea, was given *ad libitum* in the barn. After 21 months, supplemented ewes had given birth to more lambs than the control group (M, 166; C, 114), had larger litter sizes (M, 1.34; C, 1.24), and had shorter lambing intervals (M, 216 days; C, 232 days). Lambs from the supplemented ewe were not significantly heavier at birth (M, 179 kg; C, 1.61 kg) but were heavier ($p<.05$) at weaning (M, 8.90 kg; C, 7.55 kg). Ewe postpartum weights were higher ($p<.05$) in the supplemented group (M, 22.7 kg; C, 20.6 kg). Lamb mortality was higher in the control group (32%) than in the supplemented group (25%). Weight of lambs weaned per ewe per year was higher ($p<.05$) in the molasses group (20.2 kg of lamb per ewe) than in the control group (15.1 kg of lamb per ewe), as was productivity per weight of the ewe (M, 0.88 kg lamb/kg ewe; C, 0.71 kg lamb/kg ewe). The value of weaned lambs minus the cost of the molasses supplement for the supplement group was 21% greater than the value of weaned lambs from the control group.

Training Progress and Institutional Development

Long-term

Simon Ginting completed his M.S. training at the University of Missouri and returned to Sei Putih in July, 1990. He was completely supported by the SR-CRSP.

Silvia Buntinx completed a M.S. in Nutrition at North Carolina State University. Her research evaluated the Captec controlled release $CR_{20}3$ capsule and was supported by the SR-CRSP.

Oneas Mufandeazda, from Zimbabwe, is working on a Ph.D. in Animal and Crop Science and is supported (50%) by the SR-CRSP. Expected graduation is August 1993.

The research of H. Pulungan was supported by the SR-CRSP. The training and research of I. Wayar Mathius was initiated in August, 1990. Wayan is pursuing a Ph.D.. in Animal Nutrition at IPB and is conducting his research with the nutrition of prolific sheep.

The research of several students was supported by the SR-CRSP.

Name	Degree	Country
Silvia Buntinx	Ph.D. (Aug. 1993)	Mexico
Kelly Jo Driggins	M.S. (Aug.t (1991)	U.S.A.
Roger Merkel	Ph.D. (Dec. 1993)	U.S.A.

Publications

Haryanto, Budi, D. Yulistiani, and M. Rangkuti. 1989. Pemanfaatan Biji Kapas Sebagai Pakan Domba (Utilization of cottonseeds for feeding sheep). Simposium I Hasil Penelitian dan Pengembangan Tanaman Industri. Bogor.

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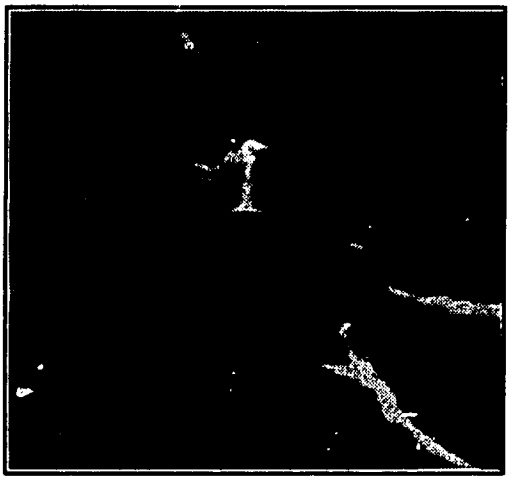

Animal Health Management

◆ Colorado State University

An investigation of small ruminant health problems in Peru

◆ Washington State University

Kenya animal health research and training program

An Investigation of Small Ruminant Health Problems in Peru

Colorado State University
James C. DeMartini

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Summary

Small ruminant health problems in Peru were investigated under three subprojects: major core protein purification and molecular cloning of the ovine pulmonary carcinoma retrovirus; enterotoxemia and colibacillosis in alpacas and lambs; and field studies on sheep respiratory disease control and epidemiology of bacterial and parasitic causes of newborn mortality of alpaca.

Assays were developed for the detection of the putative ovine pulmonary carcinoma (OPC) retrovirus in samples of lung tissue from affected animals. Large quantities of purified

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viral proteins are required for further progress toward development of a serological test for carriers of the virus and eventually a vaccine to prevent infections. Problems encountered in attempts to amplify OPC DNA have now been resolved and the project is preparing to try this approach again. Evidence has been obtained that a relationship exists between the OPC retrovirus and other type D retroviruses. This has permitted generation of probes and reagents that can be used to isolate and identify the cause of OPC. The project is thus wellprepared to successfully isolate and propagate the OPC retrovirus or its relevant genes for use in preparation of diagnostic or immunoproplactic products.

The second subproject investigated the protection of neonatal alpacas and lambs against enterotoxemia by vaccination of their dams with *C. perfringens* enterotoxin, and the identification of colonization antigens on *E. coli* isolated from cases of neonatal alpaca diarrhea. Enteritis is the major cause of death of young alpacas and lambs. *Clostridium perfringens* type A enterotoxemia has been established as the main cause of enteritis, and development and use of a toxoid vaccine has been purported as the best means for preventing enterotoxemia.

Vaccines are on hand to conduct vaccination trials of pregnant alpacas of the South American Unit in the Veterinary School, University of San Marcos. An earlier study in Cuzco could not be concluded due to local political interference. Anti-enterotoxin antibodies have been detected from the previous vaccination study. The results will be published under the title "*C. perfringens* enterotoxin toxoid induces humoral immunity in alpacas."

Immunological evidence was obtained that, in enterotoxemic llamas, *C. perfringens* enterotoxin is absorbed from the intestinal lumen to the bloodstream and then released from the bloodstream to the peritoneal cavity. These results are of vital importance for understanding the mechanism of pathogenesis, and to confirm the diagnosis of *C. perfringens* enterotoxemia in llamas and alpacas. Another significant accomplishment of this subproject was the identification of the pili on about 20% of the *E. coli* isolates from diarrheic alpacas.

Field studies were concluded on sheep respiratory disease control and epidemiology of bacterial and parasitic causes of newborn mortality of alpacas. During the past eight years, extensive field studies have been conducted in Peru to discover the causes, improve the diagnosis, and evaluate control strategies for chronic viral respiratory diseases of adult sheep. In this final year, the goal was to complete baseline studies which will facilitate future field testing of diagnostic tests and vaccine products.

The occurrence of ovine pulmonary carcinoma has been progressively decreasing in the experimental flocks at the SAIS Tupac Amaru. The rapid periodic elimination of all animals from the experimental flocks appears to result in decreased OPC losses. The offspring from these less-affected experimental flocks are being used to repopulate other flocks in the research unit. This is a means by which the producer can reduce OPC-associated losses.

Concluding studies on epidemiology of bacterial and parasitic causes of newborn mortality of alpaca investigated the correlation of death with nursing, the causes of death, and characterization of bacterial agents associated with pulmonary diseases. The importance of passively transferred immunoglobulin in neonatal mortality of newborn alpaca cria was verified in community herds as well as large enterprise herds. It is now imperative to investigate the nutritional and management failure of passive transfer and to study the role of novel bacterial agents in diseases of crias.

Many improvements were made during the last year in the capacity of San Marcos University and IVITA to perform research and teaching. A masters degree program in Veterinary Science has been developed and a biweekly seminar program initiated to disseminate recent research results. Teaching facilities and computer capabilities have been improved. Some of the laboratories have been partially remodeled to improve research and diagnostic efficiency.

Between 1980 and 1990, ten faculty members from the College of Veterinary Medicine at Colorado State University have contributed, some in a major way, to the SR-CRSP Animal health Project. In addition, two Peruvian Ph.D. students, two U.S. students, and four additional foreign Ph.D. or M.S. students have been wholly or partially supported by the SR-CRSP project. Research at Colorado State University has led to research linkages within Peru, the U.S., and to the Moredun Institute in Scotland.

Research Results

Subproject 1. Major core protein purification and molecular cloning of the ovine pulmonary carcinoma retrovirus.

Objectives

1. Purify and characterize the major core (*gag*) protein of OPC retrovirus using an affinity column with antibody to a heterologous type D retrovirus.

2. Prepare polyclonal or monoclonal antibodies to the OPC major core protein.

3. Obtain molecular clones containing OPC gene sequences.

Problem Statement and Approach

Our strategy to isolate and propagate the ovine pulmonary carcinoma (OPC) retrovirus depends in part on its known relationship to already characterized type D retroviruses of primates: Mason-Pfizer monkey virus (MPMV), Squirrel monkey retrovirus (SMRV) and Langur retrovirus (LRV). Based on materials available from these viruses, we have developed assays (competition radioimmunoassay and immunoblotting assay) for detection of the putative OPC retrovirus in samples of lung tissue and fluid from affected animals. Further progress toward development of a serological test for carriers of the virus and eventually a vaccine to prevent the infection depends upon production of large quantities of purified viral proteins. This can be most efficiently accomplished by *in vitro* propagation of the virus or some of its genes.

Purification of homologous OPC retrovirus major core protein from lung fluid or tissue of OPC cases will be attempted using affinity chromatography. Our previous work indicates that there is sufficient homology of this protein with p27 of SMRV in a competition RIA so that we can use a polyclonal goat serum to bind the protein in an affinity column. The OPC protein can then be eluted, concentrated, and used to prepare rabbit polyclonal antiserum or murine monoclonal antibodies using standard techniques. Several cloning strategies will be employed in attempts to obtain OPC gene sequences. A lamba gt11 expression library produced from OPC cDNA which had been reversed-transcribed from virus containing nucleic acid will be screened using heterologous (anti-MPMV p27) or homologous (produced above) antiserum and subcloned into a plasmid vector (pSP72). If the lambda gt11 library does not contain OPC sequences, efforts to amplify OPC DNA sequences using the polymerase chain reaction will be attempted. *Gag*, *pol*, and *env* gene regions highly conserved among type D retroviruses will be used as templates for construction of oligonucleotide primers to initiate the reaction. Amplified OPC DNA as detected in Southern blotting with MPMV probes will be cloned directly into phage vectors.

Justification

It is widely recognized that OPC (also known as sheep pulmonary adenomatosis or jaagsiekte) is the most highly prevalent disease affecting adult sheep of the Central and Southern Sierra of Peru, and that it is also of major importance in developing countries of Africa, Asia, the Middle East, and the Far East. Because of the high prevalence of OPC in many areas of the world and the lack of diagnostic tests for infected sheep, cull and quarantine procedures have not been effective in limiting its economic impact. Further progress in controlling this disease is dependent upon identification and *in*

vitro propagation of its causative retrovirus in order to develop serological tests to detect subclinically infected sheep and eventually a safe, reliable vaccine.

Project Progress

Initial attempts to obtain homologous OPC capsid (major core *gag* polypeptide) were based on affinity chromatography using a Sepharose CL 4B column with anti-SMRV serum. This column was shown to bind and concentrate culture supernatant SMRV, but when OPC lung homogenate was passed through the column, the eluted proteins were found to be sheep serum protein rather than OPC capsid protein. This was found to be related to antibody to bovine albumin in the anti-SMRV serum crossreacting with sheep serum proteins in the sample. Therefore, this approach was temporarily abandoned.

In attempts to rescue the OPC virus, we previously cocultured infectious material with a variety of cell lines and attempted transfection of Cf_2th cells with high molecular weight DNA from OPC-affected lungs; this was not successful. Additionally, using virus pelleted from lung fluid, we generated a cDNA library in the expression vector lambda gt11 in order to identify and isolate OPC molecular clones. Preliminary screening of the library showed that about 30% of the plaques contained insert. However, the positive reaction of most of these plaques with antiserum to MPMV p27 was found to be due to antibody of *E. coli* present in the serum. We will therefore attempt to absorb out these non-specific antibodies and rescreen the library.

Finally, we decided to attempt to amplify OPC DNA sequences using the polymerase chain reaction (PCR). For screening the PCR products, we obtained a plasmid containing the full length MPMV genome and produced four subclones in riboprobe vectors (p72, p73). These were mapped and found to be useful in detection of LTR, *gag*, and *pol-env* regions of MPMV. Primers were designed for OPC DNA in the *gag*, *pol*, and 3'*env* taking advantage of short consensus sequences among several type D or type B virus. These were found to amplify MPMV and SMRV sequences in the homologous regions, but the *pol* primers also amplified ovine lentivirus DNA. Attempts to amplify OPC DNA using the *gag* and *env* primers yielded multiple bands, some of which hybridized in Southern blots with the MPMV probes. However, the *gag* bands were found by sequencing analysis to represent MPMV plasmid insert contamination, a common problem using the extremely sensitive PCR technique. The *env* bands did not have open reading frames and probably represented non-specifically amplified sheep DNA rather than viral DNA. We have now dealt with these problems and are preparing to attempt this approach again.

Project Achievements

We have obtained evidence of the relationship between the OPC retrovirus and other type D retroviruses. This has permitted generation of probes and reagents that can be used to isolate and identify the cause of OPC. We are thus well-poised to successfully isolate and propagate the OPC retrovirus or its relevant genes for use in preparation of diagnostic or immunoprophylactic products. This work will continue during the present year.

Changes in 1990 Workplans

There were no significant changes in the workplans for this subproject.

SUBPROJECT 2. Enterotoxemia and colibacillosis in alpacas and lambs.

Objectives

1. Evaluation of protection of neonatal alpaca and lambs against enterotoxemia in by vaccination of their dams with *C. perfringens* enterotoxin.

2. Identification of fimbriae (colonization antigens) on *E. coli* isolated from cases of neonatal alpaca diarrhea.

Problem Statement and Approach

Analyses of serum antibody levels to enterotoxin are currently underway. Following modified vaccination procedures, the serum samples collected from dams and neonates must be analyzed for anti-enterotoxin content in order to optimize immunoprotection. Following optimization, large-scale vaccination programs can be established. Generally, the procedures for evaluation of the enterotoxin toxoid as a vaccine will be those described in a previous workplan. Adult alpacas and ewes will be vaccinated with enterotoxin toxoid and serum samples will be collected from all vaccinated and control dams and neonates. These sera will be assayed by ELISA for anti-enterotoxin antibodies. Then morbidity/ mortality data for vaccinates and controls will be compared.

The research to date has been directed at identifying colonization antigens on the alpaca *E. coli*. Antisera developed have been used to identify at least two new colonization antigens. The new isolates will be tested to determine whether these same, or different, colonization antigens are produced. Control of colibacillosis in calves, pigs, and lambs has been successful using colonization antigen-based vaccines. When we are confident that we have identified the most common colonization antigens in alpaca *E. coli*, a bacterin could be produced that would stimulate protection against *E. coli*.

For objective 2, to identify and characterize fimbriae of alpaca *E. coli*, agglutination experiments will be performed using rabbit antisera to alpaca *E. coli* colonization antigens one and two (developed at Colorado State U.). Then monoclonal antibodies reactive with alpaca *E. coli* colonization antigens will be prepared. Thirdly, all 140 alpaca *E. coli* isolates will be examined for expression of colonization antigens using monoclonal antibodies. Finally, if results indicate two or three antigens are predominant, an *E. coli* bacterin for prevention of colibacillosis in alpacas will be developed.

Justification

Enteritis is the major cause of death of young alpacas and lambs. *Clostridium perfringens* type A enterotoxemia has been established as the main cause of enteritis. The development and use of a toxoid vaccine has been purported as the best means for preventing enterotoxemia. In addition to *C. perfringens*, *E. coli* has been established as a cause of neonatal enteritis. Sixty-five isolates are currently in the culture collection at Colorado State University. An additional 80 isolates were obtained in 1989.

Project Progress

1.1 Evaluation of protection of neonatal alpacas and lambs against entero-toxemia by vaccination of their dams with *C. perfringens* enterotoxin.

Both the sporulated *C. perfringens* type A (CPA) vaccine and crude ET toxoid have been demonstrated to possess antigenic properties which induce the production of IgG in rabbit. Fifteen pregnant alpacas were immunized in an alpaca herd in Cuzco, but we could not carry out the sampling of the offspring due to administrative interference in the project. However, we have on hand the vaccines in order to conduct the vaccination trial in pregnant alpacas of the South American Unit in the Veterinary School, University of San Marcos. On the other hand, we have been analyzed the detection of the anti-enterotoxin antibodies from the previous vaccination study. The results from this study will be published under the title "*C. perfringens* enterotoxin toxoid induces humoral immunity in alpaca."

1.2 Immunological evidence for intestinal absorption of *C. perfringens* enterotoxin in enterotoxemic llamas.

The presence of *C. perfringens* type A (CPA) enterotoxin in serum and peritoneal fluid as well as intestinal contents from 15 presumptive enterotoxemic cadavers of neonatal llamas (4 to 29 days old) was demonstrated by a monoclonal antibody-mediated immunoperoxidase dot assay. Nine (100%) peritoneal fluids exam-

ined had variable levels of CPA enterotoxin ranging from reciprocal dilution of 40 (11.1%), 80 (33.3%), and 160 (55.5%). Thirteen (86.6%) intestinal content specimens were positive for CPA enterotoxin in neat specimens (13.3%) and at reciprocal dilutions of 10 (6.7%), 20 (13.3%), 40 (20%), 80 (13.3%), and 160 (20%). The titers of CPA enterotoxin in peritoneal fluids (130 ± 41.4) were significantly higher ($P<0.025$) than those in intestinal contents (58.7 ± 67.7). The CPA enterotoxin was also higher in sera (160 ± 0) than in intestinal contents (60 ± 87.2). The 15 dead neonates were confirmed as enterotoxemic cases by detection of CPA enterotoxin in corporal fluid and intestinal content (46.7%), corporal fluid (13.3%), and intestinal content (40%) in an estimated amount of 0.1 ng/2 ul. The immunological detection of the CPA enterotoxin in peritoneal and serum specimens allows us to conclude that it is absorbed from the intestinal lumen to the bloodstream, and then released from the bloodstream to the peritoneal cavity. These results are of vital importance for elucidation of the mechanism of pathogenesis, and to confirm the diagnosis of the CPA enterotoxemia in llamas and alpacas.

2.1 Identification of fimbrial (colonization antigens) on *E. coli* isolated from cases of neonatal alpaca diarrhea.

One hundred forty *E. coli* isolates from neonatal alpaca were examined for expression of colonization antigens. It is the first time that defined pili expressed by pathogenic *E. coli* in domestic species were demonstrated in camelids from Peru. The pili were found in the following frequency:

Pilus	Percentage
F-41	7.1
K-88,F-41	2.1
K-88	8.6
K-99	4.3

Future efforts on *E. coli* isolates from alpaca have to be focused in their pathogenic role in neonates and the development on the assays for diagnosis and pili antigen-based vaccines evaluation.

Project Achievements

The most significant accomplishments are:

1. The proof that *C. perfringens* type A enterotoxin is transported into the bloodstream and subsequently disseminated throughout the body of the neonatal llama or alpaca.

2. The identification of the pili on about 20% of the *E. coli* isolates from diarrheic alpacas. We plan to continue these studies in order to control enterotoxemia and colibacillosis in neonatal camelids.

Changes in 1990 Workplans

One change was that we were not able to produce monoclonal antibodies to the unique pilin antigens of alpaca and llama *E. coli* isolates. This was due to budget constraints. The other change was that, due to security problems and travel restrictions in Peru, we were not able to carry through the vaccine study analyses for the enterotoxemia objective.

Subproject 3. Conclusion of field studies on sheep respiratory disease control and epidemiology of bacterial and parasitic causes of newborn mortality of alpaca in Peru.

Subproject 3A. Conclusion of epidemiologic and laboratory studies and data evaluation.

Objectives

1. Complete the epidemiologic and laboratory studies on the prevalence of ovine lentivirus infection in sheep in Peru.

2. Complete data evaluation for the ovine pulmonary carcinoma field control project at SAIS Tupac Amaru.

Problem Statement and Approach

Ovine pulmonary carcinoma (OPC) and lentivirus-induced interstitial pneumonia produce severe economic losses in Peruvian sheep. The natural coexistence of both oncogenic type D and non-oncogenic retrovirus (lentivirus) suggests a possible cofactorial role of lentivirus in the development of lung tumors. In an attempt to decrease losses in affected Peruvian sheep farms, one of seven sheep production units (mean = 25,000 head) at a large sheep enterprise of the central sierra was selected for research on retrovirus-induced chronic pneumonopathies. This production unit has been isolated from the others for six years, during which time no animal from any of the others unit was allowed to enter the research unit. Three of the ten flocks of ewes (mean = 2,500) of this unit were selected as experimental flocks and seven were left as controls. Ewes suffering from chronic respiratory disorders were eliminated periodically from the experimental flocks, and annual serum tests were conducted to determine the prevalence of OvLV antibodies by the AGID test. The prevalence of chronic pneumonopathies was determined by gross examination at death by local veterinarians.

Justification

During the last eight years, extensive field studies have been conducted in Peru, particularly at the SAIS Tupac Amaru, to discover the causes, improve the diagnosis, and evaluate control strategies for chronic viral respiratory diseases of adult sheep. In addition to ovine pulmonary carcinoma (sheep pulmonary adenomatosis), lentiviruses have been found to contribute to respiratory disease and have been implicated as a cause of a severe indurative mastitis which limits milk production in affected ewes. Serological tests and histopathology have been used to determine the prevalence and geographical distribution of these diseases in Peru. This year the goal was to complete baseline studies which will facilitate future field testing of diagnostic tests and vaccine products as they become available.

Project Progress

The occurrence of ovine pulmonary carcinoma has been progressively decreasing in the experimental flocks at the SAIS Tupac Amaru. In 1985, the prevalence of pulmonary carcinoma in the control flocks was 127/10,000 compared with 109/10,000 in the experimental flocks. However, by 1989, the prevalence was 147/10,000 for the controls and only 48/10,000 in the experimental flocks. In order to compare these results with the disease status of the entire sheep operation (seven production units), the prevalence of OPC during the last three years was investigated in a second production unit. The frequency of OPC in ewes of the latter unit was found to be similar to the control flocks during 1987-1989, with a prevalence of 114/10,000 for 1989.

That the occurrence of the disease is decreasing in the entire research unit and not just among the experimental (ewes) flocks is corroborated by the disease prevalence among other classes of animals (adult and young). In 1989, the prevalence of OPC in young animals (yearling rams, yearling castrated rams, and yearling ewes) was less than 20/10,000. A similar pattern has been observed among rams (140/10,000) and castrated rams (55/10,000). However, the prevalence of OvLV antibodies in the experimental and control flocks of the research unit was similar (22 and 25% respectively). The rapid periodic elimination of ill animals from the experimental flocks appears to result in decreased OPC losses. The offspring of these less-affected experimental flocks are being used to repopulate other flocks in the research unit, which may also result in diminished disease losses. The unchanged prevalence of OvLV in the research unit may well be related to milk-borne transmission of the virus.

Project Achievements

The long-term study to evaluate the possibility of reducing the prevalence of OPC through low-cost management changes has been completed. The value of using young, primiparous ewes as a flock foundation and of consistently removing clinical OPC cases from the

flock has been verified. Although the disease was not completely eradicated, its prevalence was markedly reduced. This, then, is a means by which the producer can reduce OPC-associated losses.

Changes in Workplans

Because of the security problems in the Central Sierra, it was not possible to collect the desired number of samples for OvLV testing. Seroprevalence studies of OvLV infection in flocks of large enterprises, communities, and individual families are still incomplete.

Subproject 3B. Conclusion of field studies on epidemiology of bacterial and parasitic causes of newborn mortality of alpaca.

Objectives

1. Correlate the death in newborn alpaca with nursing.

2. Determine the causes of death in newborn alpacas.

3. Characterize the bacterial agents associated with pulmonary diseases.

Problem Statement and Approach

Mortality of alpaca crias constitutes one of the major problems in alpaca herds. This year, to complete former observations on alpaca newborn mortality, our study was carried out in Quinsachata (INIA Research Farm) located at the district of Lampa of Puno department. One herd was monitored. Initially all animals were checked for pregnancy by ballottement two months before calving. Two groups of dams and crias were formed according to nursing management: Group A, supervised for suckling colostrum within first two hours of life (79 crias) and Group B, not supervised (81 crias). All animals were identified. The relative low number of observations in both groups was because only one or two newborn were examined daily (Table 1). For neonates the following parameters and characteristics were considered: breed, age, sex, color, birth weight, time to rise, and suckling time for taking colostrum. In the case of ill crias which subsequently died, the following information was registered: history of the case, duration of clinical disease, and diagnosis. In case of the dam, parameters were: breed, age, color, maternal chararacteristics, physical condition, udder condition, etc. Samples for bacteriological, parasitological, immunological, and histopathological studies were obtained.

Table 1. Dead alpaca crias in both groups.

Animals	Group A Supervised	Group B Non supervised	Total
Total dams	160	170	330
Crias born	160	170	330
Crias observed	79	81	160
Dead crias	4	7	11*

* Besides these dead crias, 7 were killed by foxes.

Justification

Taking advantage of the infrastructure of the INIAA farm (Quinsachata) and its camelid facilities, we wanted to complete our observations on alpaca newborn mortality related to the relationship between causes of death and levels of immunoglobulins in the cria and other correlated studies as mentioned. More field information is needed relating to alpaca newborn mortality and serum immunoglobulin levels.

Project Progress

Huacaya was the predominant breed in both groups. The average birth weight was 6.30 ± 0.997 kg. At 30 days the mean body weight was 10.79 ± 1.696 kg. The mean time to standing up after birth was 62 min. The time to first suckling of colostrum was 94 ± 25 min. Bacteriological isolations from dead crias (11) were

Pasteurella multocida (5=50%); *P. hemolytica* (2=20%) and *E. coli* (3=30%). *C. perfringens*, type A, was isolated from three intestinal samples. For immunological studies, the sodium sulfite precipitation test of serum proteins was used. From eleven dead crias (four in group A and seven in B), 75% in group A (supervised for suckling) presented complete failure for transference passive immunity and 42.8% in group B (Tables 2 and 3). Samples for histopathological studies are being evaluated.

The low number of dead crias was probably related to the fact that the dams were adults. However, the average birth weight was lower than those reported in organized enterprises of same area. It was interesting to find *P. haemolytica* (20%), besides *P. multocida*, which was isolated last year. However, more characterization of these bacteria is needed to determine their role in disease in newborn alpacas. The immunological findings reveal that complete failure in transfer of passive immunity was

Table 2. Results of the sodium sulfite precipitation test for serum immunoglobulin levels in eleven dead crias

Dead crias	Groups					
	A		B		Total	
Ig transfer	N°	%	N°	%	N°	%
Complete failure	3	75.0	3	42.8	6	5 4.5
Normal	1	25.0	4	57.	5	45.5
Total	4	100.0	7	99.9	11	100.0

Table 3. Correlation of some parameters and cause of death with serum immunoglobulin level by the precipitation test in eleven alpaca crias.

Protocol N°	Age (days)	Body weight (Kg)	Cause of death	Precip. Test	Results
1	3	6.2	Starvation	+	C.F.
2	2	2.5	Born weak	-	C.F.
3*	2	3.5	Born weak	+++	Normal
4*	11	11.0	Starvation	-	C.F.
5*	3	3.0	Born weak	-	C.F.
6	1	4.5	Umbil.hemor.	-	C.F.
7*	7	7.5	Starvation	-	C.F.
8	7	6.5	Starvation	+++	Normal
9	1	3.5	Born weak	+++	Normal
10	3	4.0	Pneumonia	+++	Normal
11	20	8.0	starvation	+++	Normal

* Crias of group A, the remainder were in group B.
C.F: complete failure in transfer of passive immunity.

quite frequent in these groups. Perhaps this is related to the relative low birth weight and / or the poor nutritional condition of dams. Apparently there was no correlation between the isolated organisms and the immunoglobulin level.

Project Achievements

The importance of passively transferred immunoglobulin in reducing neonatal mortality of newborn alpaca cria was verified in community herds as well as large enterprise herds. It is now imperative to investigate the nutritional and management failure of passive transfer and to study the role of novel bacterial agents in disease of crias.

Changes in 1990 Workplans

Due to the lower number of animals compared with former studies done at large cooperative enterprises, the number of diseased animals was smaller. Although other procedures may have been superior, the sodium sulfite precipitation test for determining levels of immunoglobulins in dead crias was done because this test was more available than others for application to the field.

Training Progress and Institutional Development

Long-term

Pedro Yi Araujo. Thesis for DVM degree. Detection of rotaviral genome in alpaca diarrhea. University of San Marcos, Lima, Peru. 1989.

Alberto Manchego. Thesis for DVM degree. Serological analysis of viral infection in mixed herds from Arequipa Communities. University of San Marcos, Lima, Peru. 1989.

Mirtha Luna. Thesis for DVM degree. Ovine lentivirus-associated mastitis in the Central Sierra of Peru. University of San Marcos, Lima, Peru. 1989.

Mwaengo, Dufton. Ph.D. candidate. Molecular virology. Expected graduation, 1994. Colorado State University.

Short-term

Training in Peru consisted of seminars, short courses, and technique-oriented individual training sessions in university settings, on INIAA and IVITA field stations and on-farm in the field to the extent that security conditions permit, and in workshops in Cajamarca, Lima, and Puno, Peru, and RioBamba, Equador (see abstracts, technical communications and verbal presentations below). Peruvian veterinary students were involved as trainees in some of the research being conducted in IVITA laboratories. In accordance with Technical Committee, Board of Directors, and EEP directives, no new graduate training positions for Peruvians were initiated during this budget year.

Drs. Ramirez and Rosadio spent productive short visits at CSU during which research results were discussed and interpreted and manuscripts were prepared. Dr. Fernando Villafane, a veterinary pathologist from Columbia, spent a six-month sabbatical leave at CSU, terminating in November, 1989. He was engaged on a pathology study of ovine pulmonary carcinoma, completing some studies initiated by Dr. Rosadio.

Institutional development

Many improvements in the capacity of San Marcos University and IVITA to perform research and teaching functions have been made during the last year. Dr. Rosadio, who received a Ph.D. at CSU in 1987, is Director of Graduate Studies in the Veterinary School at San Marcos University and he has been instrumental in developing a new Master's degree program in Veterinary Science at the University. The postgraduate unit of the Veterinary School has implemented a biweekly seminar program to disseminate recent research results in veterinary science among the staff and students of the school. Some of the offices, including the postgraduate unit, have been funded by the National Council for Science and Technology

(CONCYTEC) to improve teaching facilities, as well as computer capabilities. The Virology and Bacteriology laboratories at the College have been partially remodeled to improve research and diagnostic efficiency and new laboratory equipment has been procured. Work-study student positions have been established at IVITA to encourage highly motivated veterinary students to pursue a career in research.

Other Contributions

Contributions to U.S. Agriculture

Six faculty members in the College of Veterinary Medicine at Colorado State University have participated in a major way in the SR-CRSP Animal Health Project and four others peripherally between 1980 and 1990. All ten have made one or more trips to Peru during this period. In addition to the two Peruvian Ph.D. students, two U.S. and four additional foreign Ph.D. or M.S. students have been wholly or partially supported by the SR-CRSP project. Partial support was provided through a USAID strengthening grant to assist one undergraduate student and one faculty member from another institution to work in Peru for a short time. The SR-CRSP has been a driving force in lending an international perspective to graduate and undergraduate programs in the Departments of Pathology and Microbiology. Much material derived from the Peru trips and research on diseases of sheep and alpacas in Peru has been incorporated into lectures and seminars given in the veterinary college at CSU. Furthermore, the SR-CRSP has been a significant component of the international programs of Colorado State University.

The SR-CRSP has been the primary source of continued research support for ovine diseases at Colorado State University during the last decade. It is notable that the SR-CRSP funds as much research on sheep and goat diseases as does the USDA nationwide through its extramural competitive research grants program. Further, it is significant that the SR-CRSP, through its presence on the CSU campus, has stimulated faculty to undertake such activities as: 1) to obtain Fulbright research or teaching fellowships (one each) in Peru; 2) to become involved in a World bank animal disease project in Puno, Peru; 3) to sign an academic exchange agreement with the University of Puno; and 4) to attend and present research results at the Pan American Veterinary Congress in Lima, Peru, and other meetings in Latin America.

Research supported at CSU by this program, and conducted in part by Peruvian scientists, has led to new methods for diagnosis and increased understanding of such diseases as ram epididymitis, ovine pulmonary carcinoma, ovine progressive pneumonia, and neonatal enteritis of alpaca and llamas. Advances have been made in the understanding of the virology, pathogenesis, and immunology of retrovirus infections of sheep, especially those affecting the respiratory tract. Extension of some of the research currently underway eventually will lead to new vaccines for control of these important diseases of sheep in the US. Most of the work undertaken in the CSU/SR-CRSP animal health project has direct application to the U.S. livestock industry.

Contributions to Host Country

The capacity of the host country counterpart institution, IVITA-San Marcos University, to conduct research and post-graduate education involving sheep, goats, and alpaca diseases and their control has been greatly strengthened by the SR-CRSP. Three veterinarians who have received Ph.D. degrees at CSU and TTU have returned to Peru and have set up research and education programs at IVITA. All three Ph.D. dissertations were conducted on major Peruvian small ruminant problems. Their findings have resulted in a better understanding of these topics and have led to productive areas of investigation for the American investigators. The returned trainees brought with them a new trend of collaborative research between U.S. universities and the veterinary school. This trend promoted more local investigators to be involved in research activities, leading to generation of preliminary data which could be used to search for additional funding from international institutions. The identification of constraints at IVITA, such as lack of functional

laboratories and deterioration of the animal research facilities, has led to concentrated efforts to built minimal facilities that will make it possible to fulfill the objectives of the SR-CRSP and IVITA.

In addition, the post-DVM program was a missing link in the improvement of badly needed transfer of technology. The Director and the Advisory Committee of the post graduate unit, all trained by the SR-CRSP, have created a Master's program for veterinary sciences that will be initiated shortly. The main objective of this program is to develop new leaders in veterinary sciences. The graduate students will be an excellent pool of researchers that will contribute to generation of new information that will be used to improve animal production and productivity.

Through our findings on research of the alpaca species, we are contributing to the fund of knowledge on some aspects of animal health, specifically on cause of death in crias, one of the main constraints in raising alpacas in Peru. According to the bacteriological results we now know better the causal agents of infectious diseases in crias. Through the parasitological studies, we understand better the true role of coccidial infection in alpacas, which was not considered previously as an important cause of alpaca death. The histopathological studies are of importance because there are few studies of this kind in alpaca. These findings will contribute to a better understanding of the control of disease in this species.

Clostridium perfringens type A enterotoxemia has been documented as a leading cause of neonatal mortality in alpacas and llamas. Recently, it has also been described as the cause of significant morbidity and mortality in pigs, calves, dogs and lambs. We are at the threshold of implementing a diagnostic test to detect enterotoxin in intestinal and other body fluids of animals with enterotoxemia. These applications will develop clinical diagnoses and, in species other than camelids, should help define causes of death which previously were undefined. We believe that we will be able to protect neonatal camelids from enterotoxemia by vaccination of the dams. We also have made moderate progress in colibacillosis research. To date, it appears that the *E. coli* which cause colibacillosis in camelids are quite unique and are not related, as far as enterotoxins or pilus antigens are concerned, to other mammalian enterotoxigenic *E. coli*. We have made progress in defining pilus antigens common to camelid *E. coli*. We will continue to define this aspect of neonatal diarrhea in camelids.

Linkages and Networking

The work at CSU and in Peru on retrovirus diseases of sheep and goats has led to linkages with researchers working in the this field at the Moredun Institute, Edinburgh, Scotland; Washington State University; the U.S. National Cancer Institute; and the U.S National Sheep Station, Dubois, Idaho. A veterinary pathologist from Colombia spent a sabbatical leave engaged in sheep retrovirus research at CSU during 1988-89. Support for collaborative research linkages between CSU and Peruvian institutions has been provided by the World Bank, USAID Mission in Peru, USAID Title XII Strengthening Grant to CSU, and the Council for the International Exchange of Scholars (Fulbright grant).

Linkages, especially for the exchange of faculty working on retroviruses of small ruminants at CSU, have been funded by the governments of Colombia, United Kingdom, and the U.S. With USAID (non-CRSP) funding, a linkage has been established between IVITA and Tel Aviv University to investigate CAE virus in goats in Peru. Additional linkages have been developed between Peruvian investigators and the Agropastoral Colombian Institute (Colombia), International Center of Tropical Agriculture (Costa Rica), and the Heifer Project International. Thus collaborative linkages have been fostered within the U.S. as well as worldwide.

Within Peru, linkages have been established with the following organizations and national institutions: Yanapay group, Regional Institute of Andean Technology, Coordinating Commission of Andean Technology, Center of Rural Studies Bartolomé de las Casas, Andean

Medical Center, Cusco; and the Parasitology lab and Traditional Medicine Departments of the Private University Cayetano Heredia, Lima, Institute for Tropical Veterinary Medicine, Lima, Faculty of Pharmacy and Biochemistry of the San Marcos University, Lima, Faculty of Chemistry of the Catholic University, Lima, Research Center of Industrial Production of the Lima University, Research Institute for Social Development of the Altiplano, Puno, and the Museum of Natural History of San Marcos University, Lima.

We have phased down SR-CRSP-supported research activities in Peru. However, research will be continued in the U.S. on diseases of critical importance to livestock production in Peru as well as many other developing countries of the world. These include ovine retrovirus-induced respiratory diseases, neonatal diarrhea in alpaca and sheep, and coccidiosis of sheep and goats. Linkages will be maintained with SR-CRSP-trained scientists in Peru, and if conditions permit, new vaccines developed for these diseases will be field tested in Peru with the assistance of Drs. Ameghino, Rosadio, and Ramirez.

To promote networking within Peru, the SR-CSRP provided consulting scientists for INIA research projects at eight of its Experiment Stations which are under control of the Livestock Research Division of INIAA. This also improved inter-institutional relations between IVITA and La Molina and strengthened the livestock research programs of INIA. Detailed plans for this project were developed by the Peru PAC. Three Animal Health consultants (Drs. Ameghino, Ramirez, and Rosadio) each spent time at one of the named Experiment Stations during the year.

In order to continue collaborative research between CSU and San Marcos University, funding must be available. A good relationship has been established between CSU and San Marcos collaborators. Infectious Disease research activities have been enhanced at both institutions. We plan to compete for linkage funding available 1990-1991.

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a Yi Araujo. "Detection of rotaviral genome in alpaca diarrhea." DVM Thesis. University of San Marcos, Lima, Peru. 1989.
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Summary

Infection of dual purpose goats and other small ruminants with *Haemonchus contortus* requires regular treatment with expensive drugs in Kenya. Previous results have indicated marked differences among individuals in challenge infections. Four does showing a low egg count per gram of feces, when bred to a buck from the same group, produced five kids, one of which showed an undetectable egg count following primary and secondary challenges. Additional groups of goats are being screened for further identification of individuals with low egg counts. These will be used in breeding programs toward the production of resistant strains of dual purpose goats.

Another disease in goats, heartwater caused by the rickettsia *Cowdria ruminantium*,

can be devastating in susceptible populations. It is transmitted by ticks that are widely distributed in Kenya. A vaccine, if available, could be used to prevent the disease. The first step toward that goal is the identification of the recombinant surface protein of the organism. While evaluating recombinant libraries, a DNA probe was found for *Cowdria ruminantium* which can be used to detect individual infected ticks. This could be very important for epidemiology studies to define areas where the disease occurs and to define conditions where goats are at risk of infection.

The SR-CRSP and the Kenya Agricultural Research Institute developed an inactivated vaccine for contagious caprine pleuropneumonia vaccine for goats that induces protection for at least a year. Current research is directed toward development of a multivalent vaccine. In addition to vaccine development, a minimal intervention health program is being developed for dual purpose goats in western Kenya. Control measures must be economical if they are to be used. They include assurances goats are free of brucellosis, are vaccinated for contagious caprine pleuropneumonia, provided worm control as needed, and assurance that kids obtain colostrum as soon as possible after birth.

Research Results

The results will be reported under four activities.

Activity No. 1. Evaluation of Possible Genetic Resistance to *Haemonchus contortus*.

Objective

Compare responses of kids with different fecal egg counts to *Haemonchus contortus* challenge.

Problem Statement and Approach

Infection of dual purpose goats and all other small ruminants with *Haemonchus* is a problem in Kenya. Infections of goats in western Kenya require regular treatment with expensive drugs. One approach to alleviate the problem is to identify goats genetically resistant to either infection or the effects of infection. To identify such goats, fecal egg counts are done after natural challenge of kids. Those kids with low fecal egg counts are treated and challenged with parasite larvae and the results compared to challenge of kids that have high fecal egg counts.

Justification

If genetic resistance can be further demonstrated and exploited, then placing a more resistant goat on farms is the best long-term control method for *Haemonchus* infections. A resistant goat would save on the costly oral and injectable drugs to control parasites, thereby reducing a significant expense in the production of dual purpose goats.

Progress

Our previous results indicate that marked differences occur in the number of *Haemonchus contortus* that become established among goats in challenge infections. Since these observations may indicate genetic resistance that could be incorporated into the ongoing breeding program, our objective was to compare responses of kids with different fecal egg counts to *H. contortus* challenge. We initially planned to compare two groups of at least 10 goats each—one group with low egg counts averaging less than 300 eggs per gram of feces (EPG), and the other group averaging more than 1000 EPG. Because of insufficient kids available for the low EPG group, we have focused our efforts on obtaining additional kids that resist *H. contortus* infections. We have used two approaches to identify these kids. In the first, four does from a low EPG group were bred to one buck from the same group. This produced five kids that were raised in confinement and challenged with 10,000 *H. contortus*. One doe had undetectable EPG on both the primary and secondary challenge infections. Additional kids will be available from this breeding stock for testing in the coming year.

The second approach was to continue screening kids raised in confinement by challenge with 10,000 *H. contortus* larvae. Two groups (42 and 27 kids) have been screened. Two bucks and three does have been identified that had fewer than 500 EPG in challenge infections. These results are interesting because other kids had greater than 10,000 EPG. We plan to screen two additional groups of kids before January 1991 using the same design. In addition, we will expose kids with less than 500 EPG (in primary infections) to a secondary challenge for confirmation. Kids experiencing low EPG identified in these two approaches will be included in breeding challenge experiments planned for 1991.

Project Achievements

Goats have been identified that resist *H. contortus* larval challenge.

Changes in Workplan

We initially planned to compare two groups of at least 10 goats each--one group with low egg counts averaging less than 300 eggs per gram of feces (EPG), and the other group averaging more than 1000 EPG. Because of insufficient kids available for the low EPG group, we have focused our efforts on obtaining additional kids that resist *H. contortus* infections. We have used two approaches to identify these kids. In the first, four does from a low EPG group were bred to one buck from the same group. This produced five kids that were raised in confinement and challenged with 10,000 *H. contortus*. One doe had undetectable EPG on both the primary and secondary challenge infections. Additional kids will be available from this breeding stock for testing in the coming year.

Activity No. 2. Identification of Antigens for the Diagnosis and Prevention of Heartwater in Goats.

Objective

Identify and evaluate *Cowdria ruminantium* surface proteins.

Problem Statement and Approach

Heartwater is caused by the rickettsia *C. ruminantium* and infects goats, sheep, and cattle. In goats, the disease causes a very high mortality and can be devastating in susceptible populations. Transmission is by ticks, primarily *Amblyomma variegatum*, which is widely distributed in Kenya. The approach is to identify *C. ruminantium* surface proteins in expression libraries made from genomic DNA.

Justification

The identification of recombinant surface proteins of the organism is the first step toward development of a subunit vaccine for the disease. Such a vaccine could be used to prevent the disease and eventually become part of a multivalent recombinant vaccine that would induce protection against the major goat diseases.

Project Progress

During the evaluation of the genomic DNA library for expression of surface proteins it became obvious that one or more of the cloned genes could be used to develop a diagnostic DNA probe. The DNA probe could be used to identify infected goats and ticks. This identification could be very important for epidemiology studies to define areas where the disease occurs and to define conditions where goats are at risk of infection.

Two DNA clones were identified: pCR9, which is derived from the Kiswani, Kenya, isolate of *C. ruminantium* and pCS20, which is derived from the Crystal Springs, Zimbabwe, isolate. Initial specificity was determined by hybridization with labeled DNA from infected culture cells, but not to DNA from uninfected cells. In further studies, it was found that the labeled DNA insert from pCR9 bound to large amounts of some bacterial DNAs causing specificity problems. In contrast, the insert from pCS20 was more specific and did not bind to 400 ng of DNA isolated from several different rickettsia, bacteria and protozoa. Neither probe bound to DNA extracted from *A. variegatum*

nymphs and adults. However, a high number of DNA extracts of nymphs fed as larvae and adults fed as nymphs on heartwater-infected goats bound to the DNA probes. Based on the relative specificity, we are currently pursuing the use of pCS20 in epidemiological and other studies. In addition, the DNA sequence is being determined so that the probe can be widely used. For instance, investigators in other countries can make synthetic oligonucleotide probes from the DNA sequence and not have to obtain the DNA probe.

Project Achievements

1. Development of a DNA probe for *C. ruminantium* and detection of individual infected ticks.

2. Completion of Dr. Suryakant Waghela's Ph.D. program.

Changes in Workplan

The focus on identification of surface proteins was temporarily interrupted in order to characterize the DNA probes to detect organisms. The primary reason was to complete Dr. Waghela's Ph.D. program.

Activity No. 3. Contagious Caprine Pleuropneumonia (CCPP) Vaccine.

Objective

Immunize goats with expressed F38 surface protein that reacts with neutralizing monoclonal antibody.

Problem Statement and Approach

CCPP is the most serious disease of goats in Kenya, causing high mortality and great economic loss. The disease occurs in epidemics in all areas of the country, including western Kenya. The SR-CRSP project and KARI developed an inactivated vaccine for CCPP. This vaccine is very effective and one dose induces protection for at least one year. All the SR-CRSP goats and the KARI goats are routinely vaccinated. In addition, several hundred thousand doses of vaccine have been distributed to farmers in Kenya. There is a high demand for the vaccine by farmers and several million doses are needed. We continue to work with government and commercial sources to get more vaccine made.

Since we have considerable experience with the CCPP system, it is a logical target for initial inclusion in a multivalent recombinant vaccine for goats. To this end, we are identifying F38 proteins expressed by recombinant organisms.

Justification

Delivery of individual monovalent vaccines, several of which are required to protect against the important goat diseases, is not possible in the case of farmers with a small number of goats and limited resources. Therefore, multivalent vaccines are needed and to incorporate CCPP antigens into a multivalent format, we are using recombinant DNA to obtain F38 surface proteins.

Project Progress

The plan was to use a monoclonal antibody developed by SR-CRSP that causes growth-inhibition of F38 to identify an F38 surface protein expressed in a genomic DNA library. Initial experiments were done to verify that the monoclonal antibody bound to a protein epitope, providing a rationale for screening proteins expressed by recombinant *E. coli* that are not glycosylated. The carbohydrate antigen that is used in the latex agglutination test was found to block the growth-inhibition caused by the monoclonal antibody. This indicated that the monoclonal antibody recognized a carbohydrate epitope and could not be used to screen the *E. coli* recombinants expressing F38 proteins.

An antibody was needed that reacted with F38 surface proteins and could be used for immunoscreening. To obtain this antibody, large numbers of F38 organisms were grown, isolated, and reacted with complement inacti-

vated serum derived from goats immune to F38 challenge. After removing the unbound antibodies and other serum proteins by washing, the antibodies bound to surface proteins were eluted with a dissociating agent and reacted with F38. These antibodies are being further characterized with regard to specificity for surface proteins and for protein and not carbohydrate binding activity. When these tests are completed the recombinant libraries will be screened for F38 surface proteins.

Project Achievements

1. Demonstration that a monoclonal antibody that causes growth-inhibition of F38 recognizes an epitope on our carbohydrate diagnostic antigen, providing new possibilities for vaccination.

2. A graduate student, Stanley Kihara, is completing his M.S. thesis that emphasizes work on identifying and developing reagents to F38 surface proteins.

Changes in Workplans

The only change has been to switch from a monoclonal antibody to a polyclonal antibody to identify F38 surface proteins expressed by recombinant bacteria.

Activity No. 4. Continue Development of a Minimal Intervention Health Program for Dual Purpose Goats Introduced to Farms in Western Kenya.

Objective

Develop a minimal intervention health program for dual purpose goats in Western Kenya.

Problem Statement and Approach

Diseases and death in dual purpose goats placed on farms in western Kenya continue to constrain efficient production. These diseases must be controlled if use of these goats is to be increased. Interventions must, however, be inexpensive and economically justified. The approach is to integrate the health program into the technical package for the production of dual purpose goats.

Justification

If the cost of disease control is too high, the dual purpose goat production system will not be used. Therefore, the control procedures have to be economical.

Project Progress

Because of the nature of the SR-CRSP project, precautions are made to ensure that all goats associated with the project are free of brucellosis. Also, all goats are vaccinated for CCPP. Other interventions, such as worm control, are used only as often as absolutely required. Management strategies to control disease in young kids, including ensuring the kids obtain colostrum as soon as possible after birth, are explained to farmers as a part of the technical package. Rather than use expensive dips or sprays, tick are removed from the goats by hand.

Training Progress and Institutional Development

Long-term

Suryakant D. Waghela completed his Ph.D. in veterinary immunology at Washington State University in December 1989.

Stanley Kihara is continuing his Master's thesis research in Kenya.

Francis Karanu completed his coursework for a master's degree in December 1989 and returned to Kenya to begin thesis research in April 1990.

Short -term

The project's on-site coordinator, Dr. Fred Rurangirwa, completed a one-week USAID-sponsored course on polymerase chain reaction in September 1990. The course was held in Washington, D.C.

Other Contributions

Contributions To U.S. Agriculture

1. Studies on genetic resistance to *H. contortus* by goats in Kenya are directly applicable to U.S. sheep and goats. The studies on vaccination against *H. contortus* also are directly applicable to small ruminants in the U.S.

2. The DNA probe for *C. ruminantium* organisms can be used to help prevent entry of this disease into the U.S. This preventive measure is important because heartwater occurs in some Carribean islands.

Contributions To Host Country Agriculture

Contributions are listed under achievements.

Linkages and Networking

We believe that our work with CCPP has direct application to other countries because of the occurrence of clinical signs of the disease in at least 33 countries in Africa, the Middle East, and western Asia. Morbidity and mortality rates of 100% and 68%, respectively, in susceptible herds made development of an appropriate vaccine an important priority. To extend the use of the vaccine SR-CRSP scientists have developed, it is necessary to document the presence of F38 (the putative causative agent of CCPP) in countries where the disease occurs. To date, F38 has been isolated from CCPP cases in Sudan, Tunisia, South Yemen, Chad, and Turkey. Since F38 is difficult to isolate, a serologic test specific for F38 would aid in identifying the presence of the organism in additional countries.

Several serologic tests detect serum antibodies to F38. Routine use of these tests is constrained by lack of equipment and trained personnel. Recently, a latex agglutination test (LAT) for field detection of goats with antibodies to F38 polysaccharide was developed by SR-CRSP scientists. The specificity of LAT was further confirmed by evaluating specific growth inhibiting rabbit antisera to various *Mycoplasma* isolates.

Nine hundred and fifty-four goat serum samples from Mali were evaluated by the LAT and 354 (37%) were positive. Since the LAT detects antibodies to a F38 polysaccharide that are not induced by other goat *Mycoplasmas*, it is assumed that F38 infects goats in Mali.

Although confirmation of the presence of F38 requires isolation of the organism from goats with CCPP, the LAT can be used to identify herds in new countries where F38 isolation is likely.

Publications

Thesis

Suryakant D. Waghela. A cloned DNA probe to detect *Cowdria ruminantium* in infected animals and *Amblyomma variegatum* ticks. Unpublished Ph.D. thesis. Washington State University, Pullman, Washington, 1989.

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Mwamachi, D.M., Rurangirwa, F.R., Musoke, A.J. and McGuire, T.C. Immune colostrum induces trypanotolerance in goat kids challenged with *Trypanosoma congolense*. Acta Tropica. (In press; previously reported as submitted for review.)

Rurangirwa, F.R., McGuire, T.C., Mbai, L., Ndung'u, L. and Wambugu, A. Preliminary field test of lyophilised contagious caprine

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Papers from SR-CRSP Kenya workshop

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Agropastoral Systems on Marginal Lands

◆ Montana State University

Evaluation and improvement of small ruminants in extensive management systems

◆ Utah State University

Range research for increasing small ruminant production in Morocco

◆ Texas Tech University

Improving small ruminant nutrition, management, and production of native range and improved pastures

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Evaluation and Improvement of Small Ruminants in Extensive Management Systems

Montana State University
Peter J. Burfening

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Collaborating Institutions

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Instituto Nacional de Investigacion Agraria y Agroindustrial (INIAA), Lima, Peru

Summary

Results of sheep breeding studies over the past ten years have shown that heritabilities under the harsh high elevations of the Andean environment were similar to those observed elsewhere in the world. Considerable variation is available within breeds for a selection program to make progress. However, general selection based upon phenotypic values are not accurately assessed and as a consequence little progress has been observed.

In the sheep breeding program, Criollo ewes were crossed with imported Targhee and Finn cross rams and with Junin and Corriedale rams. The resulting crossbred lambs in general grew faster and produced more wool than did the Criollo lambs. Criollo ewes, however, had higher reproductive rates and higher lamb survival than the crossbred ewes. Therefore when measured in terms of kilograms of lamb per ewe exposed, there was little difference in productivity.

Research at Montana State University evaluated physiological factors that have changed as a result of selection for high and low reproductive rates in Rambouillet sheep. Rams selected for low reproductive rates had a significantly smaller percentage of testis volume represented by interstitial area. High line rams had a higher percentage of the total testis area represented by Leydig cells compared to the low selection line and the control. Further, the high line rams had more LH receptor sites than did

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the low or control lines. These results indicate that selection for reproductive rate using an index that measures reproductive rate in females resulted in significant changes in testicular parameters.

Much of the last half of the year was devoted to phasing down the active research projects and planning for the establishment of an Andean Small Ruminant Network. The breeding project has produced a book that is currently in press that is a compilation of the biology of the alpacas written by many of the biological scientists involved with the SR-CRSP in Peru

Research Results

Objectives

The objectives of the breeding component of the of the Peru project this year was to complete as many publications as possible and to continue to analyze as much of our backlog of data as possible.

Justification

Over the last ten years the animal breeding component of the SR-CRSP in Peru had collected large amounts of data that were ready to be analyzed to evaluate the results of genetic improvement projects. Therefore, in the final year of the project in Peru work was focused on analyzing and publishing much of the data collected.

Project Progress

In the 1989-90 workplan, a long list of publications was outlined; many of them were completed (see publication list).

In summary, we found that heritabilities estimated under the harsh high elevation Andean environment are similar to those observed elsewhere in the world. This indicates that there is considerable genetic variation and a sound selection program within breed should result in considerable genetic progress. However, selection in general is being practiced on phenotypic values that are not accurately assessed. Thus little progress has been observed.

In criollo sheep we have crossed the ewes with imported Targhee and Finn-cross rams and with Junin and Corriedale rams. In general, the crossbred lambs grew faster and produced more kilograms of wool than did the criollo lambs. The criollo ewes had higher reproductive rates and higher lamb survival than did the crossbred ewes. This is probably a result of better adaptation to the environment of the criollo ewes. Therefore, when expressed as kilograms of lamb weaned per ewe exposed there was little difference between the productivity of the criollo ewes or the crossbred ewes, with the criollo ewes having a small advantage.

Work at MSU has dealt with the evaluation of physiological factors that have changed as a result of selection for high and low reproductive rate in Rambouillet sheep. This year's work has evaluated testicular and hormonal factors that have changed as a result of selection. Cardenas (1990) found that there was no difference in the area of the testis volume represented by seminiferous tubules but rams selected for low reproductive rate had a significantly ($P<.05$) smaller percentage of testis volume represented by interstitial area. High-line rams had a higher percentage of the total testis area represented by Leydig cells compared to the other two lines ($P<.05$). Furthermore, the high-line rams had more LH receptor sites than did the low or control line rams ($P<.05$). These data indicate that selection for reproductive rate via an index that measures reproductive rate in females resulted in significant changes in some testicular parameters in the male (table 1).

Project Achievements

February 1990: "INIAA Livestock Research Committees" were formed in the areas of sheep, cameloids, cattle, breeding, and pastures. For each committee aCo-PI was designated to work as a consultant to the committee.

April 1990: The Co-PIs in each research committee completed the review of the actual research

Table 1

Effect of Selection Line on Selected Testicular Characteristics

	Selection Line			
	Low	High	Control	Mean
Seminiferous tubule area (%)	80.7[a]	81.6[a]	82.2[a]	81.5
Interstitial area (%)	19.3[a]	18.4[b]	17.8[b]	18.5
Leydig cell as a percent of testis area	2.3[a]	2.7[b]	2.2[a]	2.4
No. of leydig cell per g testis ($x10^6$)	23.2[a]	24.8[a]	23.8[a]	23.9
LH receptor sites per leydig cell ($x10^3$)	10.2[a]	15.3[b]	9.1[a]	11.5

[a]From Cardenas M.S. thesis, 1990, Montana State University, Bozeman.

projects being carried out by the Peruvian experiment stations and made suggestions and changes to each research project.

July 1990: The document "INIAA Livestock Research Program at a Medium Term (1990-1995)" was prepared by the committees. The document contains:

a) Situation analysis, location, technologic levels
b) Breeding characteristics and problems
c) Technologies available
d) Objectives and goals at Medium Term 1990-1995
   * Research program objectives
   * Research priorities
   * Specific actions (definite research)
   * Goals: Number of experiments per year

August 1990: With the changes of government in Perú, the new INIAA Chief was appointed and is now formalizing these actions of INIAA with the new Peruvian regions.

Conclusions

In spite of the economic restrictions that INIAA suffered during 1990, the support of the Co-PIs of the SR-CRSP has been important. Besides developing research plans at the medium range 1990-1995, some consultation and training activities have been accomplished with many of the research stations. Likewise, the continuous contact of the Co-PIs with researchers of the experiments has allowed the researchers at the stations to improve their professional level and at the same time to transfer technology generated by the SR-CRSP.

Changes in 1990 Workplans

With the phase down of the active research projects and the decision to establish an Andean Small Ruminant Network (ASRN), considerable effort was devoted during the last half of 1990 to this activity. The breeding project purchased a laser printer, a 386-SX computer with a large hard disk (80 MB), and a laptop computer (286 with a 20 MB hard disk) to use in the network activities. In addition, Dr. Arturo Florez and Dr. Peter Burfening travelled to Bolivia, Chile, and Argentina to discuss the ASRN with principals in each country. Subsequently Dr. Florez traveled to Ecuador and Venezuela to make similar contacts. During these trips we were able to identify the principles from each country to represent their countries as network representatives. The first meeting of the ASRN was held in Lima from December 2 to 4, 1990.

The second major change was that the breeding project supported a major publication *Producción de Rumiantes Menores: Alpaca* which is a compilation of the biology of the alpaca chapters written by many of the biological scientist involved with the SR-CRSP in Peru. The book is

currently in press. In addition, a bibliography was published in Spanish about goat production in Peru by E. Nolte, entitled, *Bibliografia Sobre Produccion Caprina en el Peru.*

There is no volume that summarizes the scientific information related to alpaca production, much of which was generated by the SR-CRSP.

Training Progress and Institutional Development

Long-term

Horarico Cárdenas, M.S., Animal Science, expected completion Dec. 1990, MSU.

Miguel Paz, Ph.D, Statistics, expected completion June or September, 1992, MSU.

Short-term

Dr. Juan Chavez visited Bozeman for a mini-sabbatical and completed two papers from his Ph.D thesis. He also updated his bibliography and edited a paper, "El Ovino Criollo en el Perú," which has recently been translated into English.

A workshop in Cuzco, Peru, September 11-13, entitled, "Research results of the SR-CRSP in Perú (1980-1990)," was attended by 40 professionals from INIAA, the Ministry of Agriculture, universities, and cooperatives.

A workshop was held in Riobamba, Ecuador, November 29-30, 1989. Fourty-eight professionals attended from the Ministry of Agriculture and Livestock, the Institute of Agrarian Reform, three universities, and private institutions. The publication "Corso Taller Resultados de Investigacion del Programa Rumiantes Menores (1980-1990)," was used in this workshop.

A workshop on "Radioisotopes use in Molecular Genetics" was held May 15-25 with 15 participents sponsored jointly by The National Agarian University, International Atomic Energy Commission, and the SR-CRSP.

Dr. Juan Chavez attended the Latin American Association of Animal Production Meetings in Campanis, Brazil, July 22-27 and presented a paper entitled "Respuesta Productiva al Cruzamiento de Carneros Targhee y Targhee-Finnish con Borregas F1 Targhee x Junin y Targhee-Finish x Junin en Predras de la Sierra Central del Perú."

Other Contributions

Contributions To Host Country

The Peruvian collaborating scientists in genetics, reproduction, animal health, and range and forages programs were to provide in 1990 in-country training and consultation services to the Livestock Research Division and Research Experimental Stations of INIAA. The training will include workshops, conferences, meetings as well as individual instruction and guidance on small ruminant production and research.

Publications

Refereed Journals

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Miscellaneous Publications

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Range Research for Increasing Small Ruminant Production in Morocco

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Summary

Alfa grass (*Stipa tenacissima*), a dominant species of most of the semi-arid steppe in North Africa, has an adaptive chemical reaction to defoliation that reduces palatability of the regrowth and protects it against grazing. Defoliation increased wax and silica content of the regrowth which in turn depressed digestibility and palatability.

Supplementary feeding is necessary over the summer and early autumn for sheep and goats grazing native range land in order to maintain or increase body weight. Preliminary results from a feeding trial indicate supplementation was profitable and that a less expensive energy supplement than barley should be found if possible. A second year of a grazing study to determine intake, diet composition, and diet quality of small ruminants grazing *Stipa tenacissima* produced anomalous results, requiring further analysis before reporting.

A clipping intensity study of two *Stipa* species growing in pots revealed that *S. barbata* was more tolerant to defoliation than *S. tenacissima* because of its more rapid rate of regrowth. Alfa grass, while not a very desirable rangeland species, is ecologically valuable in stabilizing against erosion. It is a poor colonizer and seed producer. A long-range study seeks to learn more about seedling establishment, seed dormancy, and longevity.

Three years of data have been gathered on the plant demography and community dynamics of the white sage ecosystem. Data are

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being collected on shoot growth, the population of achenes in the soil, seedling establishment, and plant mortality of *Artemisia*.

Data collected in a previous study are being used in a simulation model of growth and shoot demography of white sage under various rainfall regimes. Some general features are emerging from this study. These are: a summer mortality of 20-27% irrespective of rainfall, new shoots appear following late spring rains, and only three to four new shoots occur on woody branches irrespective of moisture conditions.

Steppe vegetation is a mosaic of *Artemisia*-dominated and *Stipa*-dominated communities covering 50 million hectares of the semi-arid zone in North Africa and the Middle East. These lands are used for grazing by small ruminants. Heavy grazing imposes additional pressure on these areas and it is important to learn which stocking rate both the animals and ecosystems will tolerate. Four stocking rates using rams are being studied, with 1991 providing the third year of data. Since effects occur over time, preliminary results must be viewed with caution. As stocking rates increased, animals spent more time grazing and walked further but the rams were able to maintain diet quality. Daily gains declined with heavier stocking rates. When these studies are completed, the results will be an important contribution to the literature.

Another important component of the SR-CRSP in the Eastern plateau system has been a study of 45 flocks managed by producers. The objective was to characterize the total livestock production system and identify the limits on production. An important finding was that producers with large flocks with more intensive management have lower mortality and more offspring per breeding unit than producers with smaller flocks of sheep.

Research Results

Introduction

The 1989-90 year was the final year in a decade of SR-CRSP range research in Morocco. Three years ago USU assumed responsibility for the last phase of the range management component of SR-CRSP; activities in the temperate Middle Atlas region were terminated and the project focused its attention on the semi-arid steppe ecozone dominated by *Stipa tenacissima* (alfa grass) and *Artemisia herba-alba* (white sage) vegetation. The semi-arid steppe covers extensive areas of Morocco and North Africa and is an important resource for small ruminant production; indeed, it has little agricultural value for any commodity other than livestock due to the low and highly variable rainfall.

Some of the range research projects conducted during these last three years have been completed; some will continue into 1991 and be supported by the Institut Agronomique et Veterinaire Hassan II (IAV) and, hopefully, the assistance of a small linkage grant. The present reporting period (1989-90) whose research highlights are reported below, has been marked by an emphasis on synthesizing research results, an on-going activity that will continue for another year or two.

The medium-term goal is the production of a technical package presenting state-of-the-art knowledge on the Mediterranean steppe typified by the Moroccan ecosystems, with recommendations for management for resource conservation and sustainable production. Publication of this bulletin may be linked to an international symposium on the same topic to be held in Morocco. Thus, although we have reached the end of a fully funded SR-CRSP range management program in Morocco, we anticipate continuation of the collaborative relationship forged during the CRSP years.

Grazing and Animal Nutrition Studies in the Alfa Grass Ecosystem

Wax and Silica Content of Alfa Grass in Relation to Defoliation

The coarse alfa grass (*Stipa tenacissima*) that dominates the physiognomy and productivity of a major part of semi-arid steppe vegetation in North Africa is well known to be of relatively low nutritional quality and palatability, as described in earlier SR-CRSP reports. An experiment conducted at the El Faijah and Plaine de l'Aarid research stations in 1990 examined the theory that the low palatability of the grass was due to defenses against defoliation in the form of wax and silica in the leaves. Wax and silica are known to depress digestibility and therefore relative palatability of forage grasses. It was hypothesized that silica and wax content of the alfa grass leaves increased in response to defoliation. On March 31, four clipping treatments were applied, plus a control. Plants were clipped to the base of the shoot, to the ligule at the junction of leaf sheath and blade, or down to 10 cm above the ligule. Regrowth, or new growth in the case of the control, was sampled at 46, 92, 135, and 179 days after clipping and measured for crude protein (CP), ash, the Van Soest fractions of acid detergent and neutral detergent fiber (ADF and NDF) and acid detergent lignin (ADL), as well as for silica and wax content. The experiment was conducted on 3x3 m plots with 12 replications at each site. The data are summarized in terms of percent dry matter (%DM), and significant differences are reported at the 5% level. The results of this study are being prepared for publication with Dr. Hamid Narjisse as senior author.

Samples at El Faijah tended to be higher in wax content and lower in silica content: 1.50 vs 1.37, and 0.99 vs 1.43, respectively, for El Faijah and Plaine de l'Aarid when all samples are combined. For other nutritional parameters there were generally only slight differences between sites. Ash content across all samples and treatments was lower at El Faijah (3.45 vs 3.87 %DM) while NDF and ADL were higher (78.03 vs 77.23, and 7.44 vs 6.73, respectively). The effect of sampling time was expressed most strongly in crude protein and to a lesser degree in NDF, as shown in table 1. ADF was lowest at the 46 day sample (43.80%DM) compared to later sampling dates (48.48 for the average of the 92, 135, and 179 day samples), and similarly ADL was lower at the first sampling time (6.41%DM) compared to the other times (7.31 for the average of the three), when analyzed across all treatments and both sites.

Table 1. Trends in crude protein (CP) and neutral detergent fiber (NDF) over the four sampling times, all treatments and both sites combined. Data are expressed as percent dry matter.

	days after clipping treatment			
	46	92	135	179
CP	10.96a	7.64b	6.75c	5.95d
NDF	75.76a	80.08c	78.66b	77.64b

Means followed by the same letter in a row are not significantly different ($p<0.05$)

Among the clipping treatments, the most severe treatment of clipping to the base of the shoot produced regrowth of the highest nutritional quality compared to the other treatments. This was particularly evident in the crude protein content, which rose to 15.71 %DM, but was also apparent in lower percentages of lignin and fiber. [These results concur with those of Mouttaqui at the Plaine de l'Aarid station, reported last year.] The heavy clipping treatment had regrowth with significantly more ash than in the case of other clipping treatments, which was associated with a higher silica content. Wax content, on the other hand, was lower in regrowth from the basal clipping. The data comparing treatment effects are summarized in table 2.

The principal hypothesis of the experiment, that defoliation increases wax and silica content of the regrowth, was confirmed by data in table 2. Regrowth from the clipped plants

had more than twice the silica levels as new growth from the control plants; in the case of the most severe clipping treatment the increase was more than threefold. The treatment effect on wax content was also significant, but less pronounced. On average, defoliation increased wax content of young shoots by 32%. These results suggest that alfa grass has an adaptive chemical reaction to defoliation which reduces palatability of the regrowth and protects the species against grazing. This conclusion complements that of Mouttaqui working at Plaine de l'Aarid, as reported last year, who found that rate of regrowth after defoliation was slower than growth rate of leaves on non-defoliated shoots, also suggesting a low tolerance for grazing.

Table 2. Effect of clipping alfa grass at different levels on wax and silica content of the regrowth, and on various nutritional parameters measured on the regrowth. Data are combined across all four sampling times and both sites, and expressed as percent dry matter.

	Clipping Treatment			
	base of shoot	ligule	10 mm above ligule	control
silica	1.74a	1.47b	1.14c	0.49d
wax	1.42a	1.51b	1.65b	1.16c
CP	15.71a	7.54b	6.84c	6.42d
ash	4.78a	3.80b	3.32c	2.75d
NDF	73.85a	77.68b	78.28b	80.72c
ADF	45.58a	48.44b	47.91bc	47.53c
ADL	5.59a	7.55b	7.57b	7.67b

Means followed by the same letter in a row are not significantly different ($p<0.05$)

Supplementary Feeding During the Summer-Autumn Nutritional Stress Period

Earlier SR-CRSP studies in the semi-arid steppe of Morocco identified the problem of nutritional deficiency for sheep and goats grazing native rangeland during the summer. Some kind of supplementary feed is necessary over the summer and early autumn period in order to maintain body weight, and especially to achieve increase in liveweight. A supplementary feeding trial was undertaken in August-November, 1989, to determine whether the principal summer-autumn nutritional deficiency was protein or energy, and to assess the economic benefit from a supplementary feeding program. The treatments comprised four feeding regimes, all of which included a mineral/vitamin supplement of 30 g/head /day, including the control. Three forms of supplementary feed were tested: a nitrogen supplement in the form of 50 g/head/day of sunflower cake (26% protein), an energy supplement in the form of 300 g/head/day of barley grain, and a combination of the nitrogen and energy supplements. Thirteen animals were assigned to each of two replications per treatment; they averaged 19 kg per head liveweight at the beginning of the experiment. The animals grazed the native alfa grass community and individual treatment groups received their supplement while penned at night. The various treatments affected body weight change over the four months of the experiment, and the daily intake of range forage. Daily intake on the range is expressed in two forms: intake per kg of metabolic body weight (using the exponent of 0.75) and intake per animal. Total daily intake comprises the range intake plus supplements.

These data are presented in table 3, along with the cost (in dirhams) per kilogram of liveweight gain, the market value of the liveweight gained (assuming 13 dirhams per kg), and the profit per animal from applying the treatment.

Table 3. Results from the supplementary feeding trial in terms of daily intake of range forage, liveweight gain per animal (kg), the cost per kg gained (dirhams), the market value of the weight gain (at 13 dh per kg), and the profit per animal (dirhams).

	Supplementary Feeding Treatments			
	control	N suppl	E suppl	N + E suppl
average daily intake, range (g/kg metab. wt)	79.4g	70.2	50.3	56.5
average daily intake, range (g/head)	754g	688	518	593
total daily intake,range + suppl (g/head)	754g	738	818	843
weight change (4 mo)	1.5kg	3.9	7.2	7.8
cost per kg gain	6.4dh	4.8	9.6	10.0
cost of weight gain	9.6dh	22.2*	69.1	78.0
value of weight gain	19.5dh	50.7	93.4	101.4
profit per animal	9.9dh	28.5	24.3	23.4

*The cost per kg gain is 4.8 dirhams at the government's subsidized price for sunflower cake, which translates into a profit of 32 dirhams per animal.

The analysis presented in table 3 constitutes a preliminary stage; a publication on this trial is being prepared by Dr. Hamid Narjisse as the senior author. At first glance it would appear that for small ruminants grazing summer-autumn rangeland on the Moroccan steppe, energy is the main nutritional constraint. However, the barley supplement of 300 g/head/day which affords additional energy in the diet, reflected in a compensatory drop in intake from the rangeland of about 236 g/day, contains significant protein content in addition to the carbohydrate, and thus it becomes difficult to isolate a specific energy effect in the diet. At an estimated 10% protein content, the barley supplement of 300 g included 30 g of protein, whereas the sunflower cake contained only 13 g of protein supplement per day. The combination of barley plus sunflower cake provided a total of 43 g of protein supplement per day. The principal effect of the protein and barley supplements seemed to be an increase in digestibility of the range forage, with a more efficient use of the total diet. The daily intake per kg of four-month weight gain was 502, 189, 114, and 108g for the control, sunflower, barley, and barley plus sunflower treatments, respectively.

Perhaps the most important component of this study is the preliminary economic analysis. Providing a 50 g/head/day supplement of sunflower cake gave a profit of 28.5 dirhams per animal based on the weight gain for this treatment, or 18.6 dirhams more than the profit from an animal in the control group. [The profit differential would be greater if subsidized prices were used in the analysis.] This analysis is very simple and fails to take into account other costs of providing supplementary feed apart from the purchase of the supplements, such as feed storage and feeding costs. Although the barley supplement gave the greatest weight gain over the four-month trial, it was not the most profitable strategy due to the relatively high price of barley grain. The experiment clearly demonstrates, however, the biological benefit of a

barley supplement, and suggests that it would be worth exploring the availability of cheaper equivalent feeds.

Dietary Intake on Alfa Grass Vegetation

The grazing study to determine intake, diet composition, and diet quality of small ruminants utilizing *Stipa tenacissima* (alfa grass) vegetation at El Faijah, as described in last year's annual report, was repeated again in 1990. Due to normal variability in animal grazing behavior and high annual variability in type and quantity of forage available on semi-arid rangelands, it is scientifically prudent to conduct range grazing trials for at least two, preferably three, years. [Some journals will not accept papers for publication based on only one year of grazing trial data.] The data collected from this study in 1990, however, appear at the initial analysis to be anomalous, especially with regard to the proportion of alfa grass in the diet at different seasons of the year. The computer data records need to be verified with the raw data sheets, and the data analysis or field data collection procedures need to be checked, before any of the results can be reported.

Response of Two *Stipa* species to Defoliation

Data analysis was finally completed by Brahim El Bare (studying under Omar Berkat) on a study to evaluate the responses of two *Stipa* species to different defoliation regimes, *S. tenacissima* (alfa grass), a coarse and relatively unpalatable grass dominating much of the semi-arid steppe, and *S. barbata*, a palatable forage species in the alfa grass community. The experiment was a factorial design of four clipping intensities (clipped at the leaf ligule, 50% of the blade, 25 % of the leaf blade, and a control) and four clipping frequencies (intervals of one, two, four, and six weeks between defoliations). This was a pot trial conducted over a three-month period in the winter of 1988-89 with transplants from the Plaine de l'Aarid experimental area near Midelt; the pots were not irrigated during the experiment.

The results showed that *S. barbata* has more tolerance of defoliation than *S. tenacissima*, due to a greater ability to replace leaf tissue removed. Rate of leaf elongation for *S. barbata* was two to three times higher than for the alfa grass, and the former species was able to retain more of its leaves. *S. barbata*'s tolerance of defoliation extended to the most severe treatment. As might be expected, the harvested phytomass decreased with increasing frequency and intensity of defoliation, but cumulative phytomass increased with more frequent clipping, though not with more intensive leaf removal.

Community Dynamics and Regeneration of Alfa Grass

Although alfa grass may not appear to be a very desirable rangeland species in North Africa, given its low value as livestock forage and preemption of soil resources, it plays an important ecological role of stabilizing areas that it dominates against site degradation. At places in the semi-arid zone of Morocco where the alfa grass has been removed by repeated burning or long-term heavy grazing, harvested for fuel, or cleared for cultivation, the soil is highly vulnerable to erosion. One cannot rely on other desirable perennials, such as *Artemisia* species, to fill the niche vacated by a diminishing alfa grass population. Therefore, rather than looking for a substitute for alfa grass on semi-arid rangeland, a more rational strategy may be to enhance the productivity of more palatable species associated with the alfa grass and manage the range to preserve the integrity of alfa grass dominance. We know from observation that successful establishment of alfa grass from seedlings is a rare occurrence, and the species is a poor colonizer of new sites. Thus it is important to know the ecological factors that favor viable seed production and seedling survival of *Stipa tenacissima*, and to understand the germination characteristics of the species.

An ongoing study to improve our understanding of the regeneration of *Stipa tenacissima* was continued in 1989-90 at the Plaine de l'Aarid research station. Seedling emergence and establishment are being followed in fifty $1m^2$ permanent plots arranged along five transects (10 quadrats per transect) in an alfa

grass area protected from grazing. By its very nature this is a long-term study which will need to continue for several more years before useful results can be derived from the data. Additional research has been initiated to look at longevity of alfa grass caryopses ("seeds") in the soil by means of a buried seed trial and to test various seed dormancy alleviating treatments. Mohamed Yessef and Dr. Omar Berkat are directing these monitoring and seed ecology studies.

Ecological Characteristics and Plant-Animal Interactions in the White Sage Ecosystem

With the support of the SR-CRSP, a considerable body of knowledge has been assembled on the ecological characteristics of *Artemisia herba-alba* (white sage) communities at Plaine de l'Aarid, their utilization by small ruminants, and their response to grazing. A summary of work in this area conducted by five Moroccan graduate students was presented in last year's report. The 1989-90 year of the project saw a continuation of both data collection and synthesis activities.

Plant Demography and Community Dynamics

The five-year study on adjacent heavily grazed and ungrazed communities of white sage continued through 1989-90 and is now in its third year. In 64 1x3m permanent plots on each site, data are being collected on shoot growth, the reproductive output of *Artemisia* plants, the achene (fruit) bank in the soil, mortality of individual plants and recruitment of established seedlings into the population. When concluded, this study will, among other things, allow Dr. Berkat to validate models of *Artemisia* growth and population dynamics.

Simulation Models of Plant Production

A critical synthesis effort is the development of models simulating growth and shoot demography of white sage. The principal data base for these models comes from a research project carried out in 1987 by Benkhalifa Abdellah under Dr. Berkat's supervision, but they will also take advantage of all the information collected on *Artemisia herba-alba* at the Plaine de l'Aarid station, as well as available literature on the species.

In Benkhalifa's project, six large (60x3m) plots were subjected to six different rainfall regimes. The rainfall regimes were derived from frequency distributions of precipitation data by year and season at the nearby city of Midelt from 1951-1986, whose average annual rainfall was 226 mm. Dry years or seasons were defined as those having precipitation in the twentieth percentile or less; wet years or seasons with precipitation above the eightieth percentile; and average years or seasons with rainfall between the twentieth and eightieth percentiles of the frequency distributions. The set of six rainfall regimes represent almost all the rainfall patterns encountered over the 36 years of climatic data. The six precipitation treatments are: two dry years, one with an average spring-summer (S1) and one with a dry spring-summer (S2); two average years regarding annual rainfall, but one treatment with average spring-summer rain (M1) and the other with an average spring and dry summer sequence (M2); and two wet years, but one with an average spring and dry summer (H1) and the other with a wet spring-summer period (H2). The treatments were implemented by supplementing the actual rainfall of 1987 with spray irrigation to bring the precipitation up to the prescribed regime. Total rainfall in 1987 was average at 183.5 mm, but fortunately the spring and summer seasons were dry (18.4 mm for March-May and 4.2 mm in June-July), which permitted a realistic implementation of the two dry treatments. The total of rainfall plus irrigated supplements for the seven months April-October in the experimental year were 116.6 mm for S1, 97.2 mm for S2, 147.5 mm for M1, 147.7 mm for M1, 203.1 mm for H1, and 378.8 mm for H2.

The sampling scheme included both destructive and non-destructive sampling. The population of white sage in the plots was divided into two size classes for sampling purposes, which represented two-thirds of all plants in the white sage population. The smaller size class contained shrub plants with from 5 to

15 main wooden branches, the larger class contained shrubs with more than 15 main branching axes. On average there were 834 shrubs per plot that fell into these two size class categories, with a little more than half (58%) of the sample group in the larger class. Every month, 12 plants in each size class in each plot were harvested, and a corresponding number of permanently marked shrubs was measured. Measurements on marked plants were taken on permanently marked axes, three axes in the case of plants in the small size class and five for plants in the large size class. On each marked main axis, the number of branches and the number and length of shoots on each branch were measured. For the destructive sampling, axes comparable to the marked plants were chosen and number of branches on each axis was recorded, the length of each shoot on a branch was measured, and the dry weight of each shoot (current growth) determined. Total plant weight and dry weights of woody and consumable fractions were obtained. Data were also taken on plant and soil water potentials each month.

The above experimental design and methodology are presented at some length to show the detail and magnitude of the data set and to justify its use in the current synthesis effort as a data base for a model which simulates plant growth and shoot demography under a variable climatic pattern. General features are emerging as these data are being massaged, such as the recruitment of new shoots that occurs if there are late spring rains (after May 10), the summer mortality (20-27%) of all young shoots irrespective of rainfall regime, and the tendency for there to be only three to four new shoots growing on woody branches no matter how wet or dry the year.

The data are being analyzed by means of correlation and regression, relating dimensional and categorical records to weight measures, and relating shoot demographic behavior and growth patterns to rainfall and soil water status. Model conceptualization and development is under the direction of Drs. Berkat and Norton, with assistance from Jean-Pierre Bertrand, a French plant ecologist at IAV.

Plant-Animal Interactions Under Different Grazing Intensities

Steppe vegetation in a mosaic of *Artemisia*-dominated and *Stipa*-dominated communities covers 50 million hectares of the semi-arid zone in North Africa and the Middle East. The primary use of these rangelands is for grazing by small ruminants, and hence they constitute a major economic as well as ecological resource. Both the low *Artemisia* shrubs and the *Stipa* grass tussocks are harvested for fuel by the growing rural population, and the most productive steppe sites are progressively being preempted for farming. Heavy grazing imposes additional pressure on the North African steppe, and therefore, in order to manage these shrub-and-grass rangelands for sustained productivity, it is important to understand the levels of grazing pressure for which the ruminants can make adequate adjustment, and that the ecosystem will tolerate. A grazing experiment was initiated near Ain Beni Mathar in 1989 to study plant-animal interactions as stocking rate increases. The work is under the direction of Dr. Ahmed El Aich.

Four stocking rates were employed, ranging from 0.43 to 1.43 young rams per hectare, with the stocking rate effect implemented by adjusting paddock size for a standard herd of five rams, in two replications. [Rams were preferred over ewes as the experimental animals because of the relative ease of fecal collection for intake and diet digestibility determinations.] The trial began in January and continued for six months, covering the spring growing season and terminating in the summer when supplementary feed is normally provided.

As the stocking rate increased, the animals spent more time grazing (468 vs. 545 min/day at the SR extremes), less time resting (resting time almost halved at the highest SR), and walked further each day (6.3 vs 8.3 km at the SR extremes). By these behavioral changes the rams were able to maintain diet quality, although intake declined by 9% and harvest efficiency also suffered (22% less intake per minute and 31% less per km walked, expressed on a metabolic liveweight basis). As one might

expect, animal daily gains were influenced by stocking rate despite the grazing behavior compensations. The temporal data series on grazing behavior and intake suggested that seasonal changes in the vegetation were more important than stocking rate in determining diet and animal production, within the range of stocking rates tested.

As with all stocking rate studies, conclusions from only one year of data must be treated with caution. The spring of 1989 was relatively dry compared to that of 1990. Fortunately the stocking rate trial was repeated in 1990 at the same location with the same methodology, and hopefully will be repeated again in 1991. The three years of data, which include estimates of forage available in each treatment over the study season, will comprise a most valuable data set. The third year of data should begin to show whether the higher levels of stocking rate affect vegetation composition and productivity, a key question from a management point of view.

The native vegetation has difficulty maintaining livestock on a positive plain of nutrition during the summer months. Many sheep owners rely on access to post-harvest cereal stubble, waste patches around irrigated fields or supplementary feeds to bring small ruminants up to market weight by the end of summer. The stocking rate trial at Ain Beni Mathar has a included a supplementary feed treatment to address the problems of the summer forage shortage.

The data from the first year of the study (1989) were analyzed in the current reporting period (1989-90), and data collected in 1990 were prepared for analysis later in 1990. The timing of data analysis is related to the schedules of students working on the project who are using the SR-CRSP research for their Memoires. The results of the stocking rate trial will be published after the three years of data have all been analyzed. This paper will be largely a description of the treatment effects, comparing seasons and years, and looking at cumulative impacts on the vegetation. A second paper will examine the role of feed supplements during the summer.

This particular piece of research should make a significant contribution to the literature. There are few grazing trials that have employed more than two or three stocking rates; many studies last only one or two years; and such trials as the SR-CRSP work reported here are not often conducted in the semi-arid zone. Furthermore, other grazing research by the Moroccan scientist directing the study (Ahmed El Aich) in the more humid Middle Atlas region with a different breed of sheep provides an opportunity to examine some theoretical questions on the effects on stocking rate on livestock production.

Synthesis and Theory

A key aspect of the collaborative research in 1989-90 was to develop a series of analytical approaches to the treatment of the data. Stocking rate experiments are confounded by variability in forage on offer from year to year, as well as from season to season. The effect of a specific stocking rate on daily weight gain will vary depending on that year's forage supply, or the forage available in a particular month. That is why it is critical to conduct stocking rate trials over several years, especially in a semi-arid environment where rainfall is highly variable. But the analysis and interpretation of such variable data has often presented problems For each curve relating stocking rate to daily weight gain, however, there is always one data point that represents the stocking rate at maximum production per hectare. These data points can be graphed in relation to season, or for comparing years in terms of peak biomass, or used to compare sheep breeds and contrast their ability to be productive under adverse conditions. Another approach to minimizing the influence of temporal variability in data analysis is to employ grazing pressure instead of stocking rate as the independent variable, where grazing pressure is expressed as intake relative to available forage. By this means we can determine at what point in a situation of declining forage the intake is affected, which should be an attribute of the specific breed of sheep. The SR-CRSP and Middle Atlas data sets also allow us to examine different ways to quantify how animals compensate for declining forage

availability, described by such parameters as distance walked, time spent grazing, biting rate, grazing efficiency, and diet quality.

Characterizing Livestock Production Systems in the Semi-Arid Steppe

Most of the range research in the Moroccan SR-CRSP has addressed technical questions regarding the forage resource and its utilization by grazing small ruminants. The value of this kind of research can only be appreciated in the context of specific production systems, which are a function of social, cultural, and economic factors as well as biological and climatic ones.

A component of the SR-CRSP in the Eastern plateau region has been a study led by Dr. El Aich of 45 flocks managed by producers with the objective of characterizing the total livestock production system and identifying principal constraints to production. The relevance of this study to the more technical research is apparent in the following example. The production system study found that the majority of lambs sold are between three and six months of age; young goats are sold slightly older on average. The sale of lambs is particularly affected by both the religious festival of Aid el Kebir and the onset of summer. By the end of summer the price of lamb in the market is increasing and more goats are being sold. Improved management would allow producers to carry their lambs over the summertime and sell them at a higher weight and better price. Thus research on the use of supplementary feeds in combination with range forage and perhaps crop residues can have a direct economic payoff. Even providing a simple mineral/vitamin supplement with 5% urea to sheep grazing alfa grass (*Stipa tenacissima*), an abundant but generally low quality grass in summer, will almost double the intake of alfa grass and increase its digestibility from 46 to 70% (result of a pen trial by Dr. Narjisse using alfa grass from Ain Beni Mathar).

This survey of production systems also illuminated the importance of management in determining the productivity and economic value of flocks. As illustrated in table 4, producers with large flocks and more intensive, specialized management have lower mortality and more offspring sold per 100 breeding sheep than producers with smaller flocks.

Table 4. Productivity of sheep in three producer groups (gp 1, small producers with less than 150 head; gp 2, producers with flock size of 150-500 head; gp 3, large producers with more than 500 head) and of goats.

		Group 1	Group 2	Group 3	goat
offspring born		94	108	120	136
% mortality of young	>3 mo	21.3	11.1	10	32.4
	3-10 mo	16.2	9.4	8.3	26.1
number offspring sold	3-6 mo	31	43	42	31
	6-12 mo	18	29	39	13
total offspring sold		49	72	81	44
kg production per animal unit		10.8	18.4	22.7	8.3

Training Progress and Institutional Development

In the last three years there have been no American students trained under the range management component of the SR-CRSP.

Partial support was provided at Utah State University for the following foreign students:

Roberto Distel (Argentina). Ph.D. "Effects of dietary experience early in life on consumption of blackbrush (*Coleogne ramosissima* Torr.) by goats" (completed 1990).

M'barek Fagouri (Morocco). M.S. "The effect of planting method on the germination and establishment of perennial wheatgrasses in the Upper Moulouya Plain of Morocco" (to be completed in 1991).

Mohammed Tigma (Morocco). Ph.D. "Sustaining livestock production on forest rangelands of Morocco" (to be completed in 1993). The research project will be supported by Eaux et Forets, Morocco.

A number of Moroccan students doing research projects for their Memoire required for the "Third Cycle" degree at IAV have received support for their research from SR-CRSP funds. This support has been in the form of travel to field research stations, hired labor to help with data collection, use of equipment purchased wholly or in part by SR-CRSP funds, and expendable research supplies and expenses.

A significant portion of the 1989-90 budget was spent on buying equipment for the laboratories and field stations of the three collaborating Moroccan scientists. This equipment is listed below.

Major equipment items:

- Automatic liquid sampler (to facilitate analytical procedures of a gas analyzer already installed)
- Wiley mill (for El Faijah field station)
- Drying oven (for El Faijah field station)
- Infrared AG multimeter
- Binocular microscope
- Two condensers for a growth chamber purchased by SR-CRSP in 1981
- Digitizer
- IBM PS2 computer, color monitor and printer
- Three laptop computers to facilitate research at the remote field stations of El Faijah, Plaine de l'Aarid and Ain Beni Mathar

Minor equipment items:

- Weighing scales for field work
- Pedometers
- Fence stretchers
- Two external disk drives for IBM computers
- Miscellaneous computer software
- Miscellaneous books

The equipment items listed above considerably strengthened the institutional capacity of the range research scientists to continue the research program initiated under SR-CRSP auspices.

Prospects for continued funding of the research program lie mainly with the Moroccan Ministry of Agriculture and Agrarian Reform (MARA). During the past three years the Ministry has recognized that its management divisions are neither equipped nor inclined to do ecological surveys, baseline studies, and applied research projects, nor develop management plans without technical input from specialists. MARA has therefore adopted a policy of contracting this type of work to outside bodies, and the *pastoralisme* (range) researchers at IAV have been and continue to be participants in these contractual arrangements. Furthermore, the Ministry is initiating a very large IFAD project to develop the eastern plateau region of Morocco, which is almost entirely composed of the semi-arid steppe ecosystems that the SR-CRSP range collaborators have been working on these past three years. The project includes civil services and infrastructural developments as well as agriculture, in which the livestock sector is paramount. The director of the IFAD project has already approached our SR-CRSP collaborators with a view to obtaining technical informa-

tion and conducting studies and applied research where and when needed.

Linkages and Networking

The range component of the SR-CRSP was awarded a linkage grant of $15,000 to complete the research highlighted above and to provide bridging support for the Moroccan collaborating team as it seeks to secure alternative financial resources to sustain its range research program.

Other Contributions

In April, 1990, the Fourth International Rangelands Congress will be held in Montpelier, France. Our SR-CRSP range research collaborators in Morocco have been involved in the preparations for this major international meeting. In particular, the Moroccan Co-PI, Dr. Hamid Narjisse, is in charge of organizing an eight-day post-Congress tour of Morocco, April 27 to May 5.

The Groupe d'Etude et de Recherche sur le Pastoralisme (GERP) at IAV continues to function as an integral part of the Institute, directing the pastoralism curriculum and student research projects dealing with rangeland and livestock. GERP is governed by a council consisting of three representatives from each of three departments at IAV, the departments of Plant Ecology, Animal Production, and Human Sciences.

The College of Natural Resources at Utah State University has decided to expand and strengthen its collaborative relationship with IAV, Rabat. The basis of the agreement is an understanding that USU and IAV are sister institutions that come together as equals to pursue mutual objectives in training, research, and resource development. The evolution of IAV to its present standing and reputation as a tertiary agricultural institution owes much to the USAID-funded, twenty-year Minnesota training project. But it has been projects like the SR-CRSP which have enabled a truly collaborative working relationship to emerge between IAV and American universities.

To borrow a phrase from Jim Lowenthal, ADO/Rabat, we can now move into "second generation" development, which is less a case of development in the traditional sense but rather a program of collaboration for the benefit not only of Morocco and the United States but also of the Francophone Africa region as a whole. To pursue these objectives, a high-level mission from Utah State University composed of the University President, Vice-President for Research, Vice-President for Extension, Provost, directors of international programs, and the deans and department heads in the College of Natural Resources, visited IAV in March, 1991.

Publications

El Aich, A., and L.R. Rittenhouse. 1989. Relationship between habitats selection and diet selection by Timahdit sheep. Actes Inst. Agron. Vet. 9: 5-10.

El Aich, A., L.H. Rittenhouse, S. El Khamkhami, and T. Ait Mhand. 1990. Timahdit sheep production and behavior at three stocking rates in the Moyen Atlas of Morocco. J. Range Manage. 43: 390-396.

Narjisse, H. 1990. Range forage resources in the Mediterranean region. International Symposium on Livestock in the Mediterranean Cereal Production Systems. Oct 7-10, 1990. Rabat. Published abstract.

In Preparation

The 1989-90 year was a light one in terms of publications appearing in press. However, a number of publications arising from SR-CRSP research are currently in the preparation or planning stages. Titles identified include:

Utilization by sheep and goats of *Stipa tenacissima* plant communities in Morocco.

Nitrogen and energy supplementation of Timahdit sheep grazing *Stipa tenacissima* vegetation.

Effect of site and defoliation intensity on silica and wax concentration in *Stipa tenacissima*.

Productivity of *Artemisia herba-alba* in response to simulated rainfall regimes: model description.

Productivity of *Artemisia herba-alba* in response to rainfall regimes: model validation.

Effect of heavy grazing on the population dynamics of *Artemisia herba-alba*.

Shoot demography of *Artemisia herba-alba*.

Sheep production and behavior under different stocking rates in the Moroccan oriental steppe.

Supplementation of sheep in the Moroccan oriental steppe.

A conceptual model of sheep production in the Eastern steppe region of Morocco.

Improving Small Ruminant Nutrition, Management, and Production of Native Range and Improved Pastures

Texas Tech University
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Summary

The project on grazing management and nutrition with sheep, llamas, and alpaca in Peru is being terminated and emphasis in this last year was on completing and publishing the results. Studies concerned with the complementary grazing of the three animal species aimed at understanding the reasons for discrepancies in digestibility reported in the literature. The reasons may be the result of selectivity in the choice of the forage species consumed. In earlier reported studies sheep were found to be more selective than alpacas and refused those species which usually were more lignified. Another reason for discrepancies may be the quality of feed used. With lower quality feed, differences between alpaca and sheep were greater than with higher quality feed as measured by dietary crude protein.

Greater efficiency of digestion in South America camelids may be due to such characteristics as the frequency of contractions of the forestomach, the rumination cycle, and the ratio of salivary flow to forestomach size. Alpaca in

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Peru consumed mainly tall grasses in the wet season and short grasses in the dry season. Grass consumption was highest during the driest months. Forbs in the diet increased in the early wet season. Alpacas were noted as being highly adaptable grazers, responding not only to season but to the kind and mixture of plant species available.

Studies of the dietary composition of llamas, alpacas, and sheep on pastures of differing quality showed that sheep preferred legumes. Lower selectivity for legumes by South America camelids may explain why bloat has not been reported. On range lands llamas selected the tall coarse bunch grasses and they ate more stems and less leaves than alpacas and sheep. In a complementary grazing system, llamas and sheep offer the most efficient way for harvesting available forage. South American camelids are physiologically adapted to high altitudes and the sparse fibrous vegetation of the Altiplano.

Greater digestion capability was observed in South American camelids than in sheep when fed *Avena sativa* (oat straw) and *Chenopodium quinona* used as crop residues. Oat straw treated with ammonia increased the consumption by all three animal species when compared with untreated oat straw.

Field work ceased and publications are pending on projects on digestion of tree and shrub foliage by goats and diet quality and intake by goats on the North Coast rangelands. Herded Corriedale sheep grazing native range in southern Peru shifted from shortgrass in the dry season, to grasslike plants in the early rainy season and to tall grasses in the late rainy season. Crude protein decreased with increased maturity of the vegetation and was highly correlated to digestible energy.

A three-year study with sheep in the central Andes using native and improved pasture showed that ewes grazing the cultivated pasture for seven weeks prior to breeding had a higher percentage of lambs born. Ewes grazing improved pasture during the last trimester of gestation and early lactation produced lambs that had higher birth weights, weaning weights, and average daily gain than did lambs on other treatments.

Adult alpacas raised on range and monitored for one year had body weights and greasy fleece weights similar to those adults given partial or total access to cultivated pastures. Greasy fleece weights were 20 to 40% greater under good range than the Andean averages and 50 to 100% greater than production systems with low levels of technological inputs. Lambs born to female alpaca that grazed cultivated pastures were weaned three months earlier, and were bred one year earlier than females on native ranges.

Research Results

1. Complimentary grazing and comparative nutrition of llama, alpaca, and sheep.

Objective

To determine forage partioning among free-grazing ruminants and their respective nutritional demands for proper management.

Problem Statement and Approach

Competitive relationships among small ruminants and the impact on their nutrition has not been adequately investigated in the Altiplano. Data on diets, nutrients consumed, and digestive kinetics of mixed-species grazing groups was collected.

Justification

Information on common-use grazing is scant. Proper mixes of the most important small ruminants must be determined.

Project Progress

Several trials of comparative in vivo digestibility between alpacas and sheep, and llamas and sheep, have been reported. Only one

author found noticeable differences between alpacas and sheep, with alpacas exhibiting higher digestion coefficients. Others reported higher digestion coefficients for llamas than sheep, while another reported no differences (San Martin and Bryant, 1989).

Discrepancies in digestibility between species might be attributed to animal selectivity not taken into account in some experiments. A Texas Tech graduate student reported greater selectivity in sheep than alpacas. Van Soest (1982) noted that feed portions refused by selector animals usually were more lignified. If selection is not quantified, it may lead to apparently higher digestion coefficients in selector animals.

Another reason for discrepancies may be the quality of feed used. Our research shows that 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%. Greater digestion coefficients were reported for llamas than sheep on low and medium quality diets, but digestion coefficients were similar between llamas and sheep on high quality diets (Table 2).

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

Index	Dietary crude protein					
	<7.5%			>10.5%		
	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 llamas and sheep in relation to dietary quality.

Digestion coefficients	Quality						Overall mean	
	Low		Medium		High		Llama	Sheep
	Llama	Sheep	Llama	Sheep	Llama	Sheep		
Organic matter	51	41	60	52	73	75	62	56
Neutral detergent fiber	43	33	43	32	40	40	42	35
Acid detergent fiber	47	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/kg dry matter. Medium: 11% CP and 2.8 Mcal DE/kg DM. High: 15% CP and 3.2 Mcal DE/kg DM.

Greater efficiency of digestion in South America camelids (SAC) may be due 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 NH^+_4 concentrations in C1-C2 compared to sheep, which provides llamas with more nitrogen for microbial synthesis, thus improving digestibility.

Our studies in Peru showed that alpacas consumed mainly tall grasses in the wet season and short grasses in the dry season. Preferred species were *Festuca dolichophylla, Distichia muscoides, Trifolium amabile,* and *Bromus unioloides.*

SR-CRSP research reported grass consumption was highest during the driest months and consumption of grass-like species was inversely related to grass in the diet. Forbs in the diet increased in the early wet season. Alpaca ate more leaf material as the rainy season progressed. Tuis consumed more grass-like plants, forbs, and seeds than adults.

Researchers noted that alpacas are highly adaptable grazers; where grass was available, it comprised the bulk of the alpaca diet, but on a site with low grass availability and abundant sedges, diets were dominated by sedges. Although forbs did not contribute a large portion to the animal diet, they were consistently eaten. As the dry season progressed, the diet of "bofedal" alpaca (those occupying perennially green areas) became largely sedges and reeds (78%), while Altiplano alpaca diets were dominated by grass (60%).

In the Peruvian Altiplano, 80% of the total livestock are produced by small holders and small communities; llamas and alpacas are mixed with sheep and managed together. Few studies have compared dietary composition between these herbivores to understand how they partition the forage resource. Researchers found that alpacas selected more tall grasses and less short grasses than sheep. Grass-like plants were important to alpacas in the early rainy season. Highest index (70%) of diet similarity was during intermediate months between the dry and rainy seasons.

A Peruvian Ph.D. student sponsored by the SR-CRSP, Felipe San Martin, 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 *Festuca rigida* range site (Feri). On the improved pasture, sheep ate at least 2.6 times more legumes than SAC. This lower selectivity for legumes by SAC might explain why bloat has not been reported in SAC. On the rangeland, llamas selected for tall, coarse bunchgrasses and ate more stems and less leaves than alpacas and sheep. This selection by llamas suggests that they can be classified as bulk and roughage eaters of dry regions, as Van Soest (1982) classified old world camelids.

Sheep showed less selection for tall grasses and more selection for leaves than alpacas and llamas. Alpacas exhibit intermediate selectivity between llamas and sheep. This suggests that alpacas are more grazer-selectors than llamas. San Martin 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 high between llamas and alpacas on the Feri range site, and between alpacas and sheep on the Fedo range site. In a complementary grazing system, llamas and sheep offer the most efficient way for harvesting available forage, while alpacas seem to be adequate for single-species use of rangelands.

Domesticated SAC seem to be adapted to areas where more coarse forage is available and nutrients are diluted by structural carbohydrates that are difficult to digest. These characteristics are present in the Altiplano region, where long dry periods (four months of every normal year) and cyclic years of drought are not uncommon. These climatic variations contrib-

ute to the scarce supply of quality forage. Our results demonstrate that South American camelids have adapted by reducing intake and decreasing the transit time of digesta through the tract to enhance microbial attack of forages high in structural carbohydrates. South American camelids are physiologically adapted to high altitudes and are a more appropriate species to utilize the sparse and fibrous vegetation in the ranges of the Altiplano.

Normal adult body weights for sheep, alpacas, and llamas in the Peruvian Altiplano are 40, 65, and 108 kg, respectively. For comparative purposes, these values correspond to 15.9, 22.9, and 33.5 kg of metabolic weight (kg $W^{0.75}$), respectively. Thus, respective alpaca and llama metabolic weights are 1.4 and 2.1 times that of sheep (1.0). Further, a llama's metabolic weight is 1.5 times that of alpacas. Considering a 30% lower intake in SAC than sheep, the stocking ratio would be 1.0:1.0 for alpaca:sheep (1.4x0.7) and 1.5:1.0 for llamas:sheep (2.1x0.7). These alpaca:sheep and llama:sheep ratios are quite different from published stocking ratios which, without differentiation between alpacas and llamas, indicate ratios from 1.5 to 1.8 per sheep unit. It is important to note that these ratios do not incorporate herbage and environmental characteristics.

Project Achievements

Publication of research results in *Applied Animal Behavior* in 1989 (Pfister *et al.* 23:237-246) and three abstracts and presentations. See Publications.

Changes in 1990 Workplans

The SR-CRSP program was closed due to security problems and will be moved to Bolivia.

2. Use of crop residues as supplemental feed for alpacas and llamas.

Objective

To evaluate the potential of crop residues as feed for camelids.

Problem Statement and Approach

Animals suffer from malnutrition. By-products may be used to meet nutrient deficiencies. Llamas, alpacas, and sheep were hand-fed various crop by-products and digestible organic matter and water consumption was determined, along with the effect of processing oat straw on dry matter consumption.

Justification

Redirection of crop by-products to camelids has not been explored.

Project Progress

Relevant data are presented in tables 3, 4, and 5.

Table 3. Organic matter digestion (%) of crop residues by llama, alpaca and sheep.

Crop residue	Llama	Alpaca	Sheep
Avena sativa	68[a]	70[a]	62[b]
Vicia faba	59[a]	58[a]	56[a]
Chenopodium quinoa	64[a]	62[a]	50[b]

Greater digestion capability was observed in South American camelids than sheep for *Avena* and *Chenopodium*. This suggests that llamas and alpacas could be supplied fodder from these plants to provide an adequate supplement.

Table 4. Relationship of water consumption (l/100kg BW) to dry matter intake in llama, alpaca, and sheep.

Diet	Llama	Alpaca	Sheep
Chenopodium quinoa	1.59[b]	2.24[a]	2.14[a]
Vicia faba	1.69[b]	2.27[a]	2.22[a]

Table 5. Dry matter consumption (kg/100 kg BW) of oat straw by llama, alpaca, and sheep.

	Llama	Alpaca	Sheep
Whole	1.0	1.2	2.2
Chopped	1.0	1.2	1.7
Treated with ammonia*	1.4	1.6	2.4

*Urea 3%

Consumption was positively affected by urea treatment in all three species. This suggests that treatment with urea can increase consumption of oat straw.

Project Achievements

Six B.S. theses were produced from this work: one at Huancayo University, two at Cuzco University, one at IVITA-San Marcos University, and two at UNA-La Molina. See Publications.

In addition, one presentation was made and an abstract published at the APPA meeting in Lima by Valenza *et al.* See Publications.

3. Field work has ceased and publications are pending for the following projects.

- Community validation and testing
- Rate of digestion of tree and shrub foliage by goats.
- Selectivity, diet quality and intake by goats on North Coast rangeland.

4. For studies of range animal nutrition and range management, the following results apply.

A. Nutrition of herded sheep.

Botanical and nutritional compositions of diet and voluntary intake by herded Corriedale sheep grazing native range in southern Peru were determined. Diet composition and nutrition varied with season and herding. Sheep diet composition was influenced by available forage and thus shifted from short-grass in the dry season to grass-like plants in the early rainy season and to tall grasses in the late rainy season. Forbs consisted of 10% of the diet and appeared to be of nutritional importance. Crude protein (CP), highly correlated to digestible energy, decreased from 13.6% to 5.6% with increasing maturity of vegetation (Table 6).

Table 6. Means and standard errors for percentages of crude protein (CP), and organic matter digestibility (IVOMD), contents of sheep diets, Chuquibambilla Research Station, Peru.

Month	CP (%)[1]	IVOMD (%)
Jun.	7.1 ± 0.30^{ef}	55.2 ± 0.02^{bc}
Jul.	9.5 ± 0.36^{cd}	59.7 ± 0.01^{ab}
Aug.	5.6 ± 0.21^{f}	56.1 ± 0.01^{bc}
Oct.	7.4 ± 0.39^{def}	52.9 ± 0.01^{bc}
Nov.	5.5 ± 0.53^{f}	48.5 ± 0.04^{c}
Dec.	9.1 ± 0.64^{cd}	60.9 ± 0.01^{ab}
Jan.	13.6 ± 0.42^{a}	60.1 ± 0.01^{ab}
Feb.	12.1 ± 0.53^{ab}	68.2 ± 0.01^{a}
Mar.	11.1 ± 0.66^{bc}	60.6 ± 0.02^{ab}

*Values within the same column with the same superscript are not statistically different (P>0.05).
[1]All nutrient contents were calculated on dry matter basis.

Intake was influenced by season, with lower intake values of 82.8 g/kg $BW^{0.75}$ observed during the dry season vs 99.7 g/kg $BW^{0.75}$ during the wet season (Table 7).

Table 7. Daily forage intake of grazing sheep expressed on an organic matter basis (g OMI/day), % body weight (% BW), metabolic body weight (g/kg $BW^{0.75}$), and as related to available forage (g OMI/kg DM).

Month	%BW	g/kg $BW^{0.75}$
Jun.	2.5	67
Jul.	4.5	119
Aug.	2.2	58
Oct.	3.3	87
Nov.	3.7	96
Dec.	3.2	86
Jan.	3.8	100
Feb.	5.1	127
Mar.	3.3	86
Average	3.5	92

Sheep may be deficient in energy and crude protein during gestation and early lactation.

Stocking rates for sheep in Peru are based on grazing trials and an accepted intake of 2% BW. As stated before, ewe equivalents are used as standard stocking units in Peru. In the Puna, Arturo Florez determined a stocking rate of two ewe equivalents (e.e.) per hectare per year was satisfactory for animal performance and range forage production on good condition rangeland. Other studies supported this stocking rate in terms of range forage productivity. Using the concept of 60% utilization of total herbage, they recommended a stocking rate of 1 to 2.5 e.e./ha, depending on site productivity. From our average herbage production of 2010 kg DM/ha, 60% forage utilization, and estimated average intake of 1.4 kg DM/day, stocking rates should be 2.0 to 2.4 e.e./ha per year. This is in agreement with the conventional stocking rate of 2.0 e.e./ha per year for this region.

2. Influence of Improved Forages

Sheep. We studied the influence of improved nutrition using cultivated pastures at breeding and during late gestation and early lactation for three years in the central Andes. In contrast to ewes grazing native pastures, ewes grazing cultivated pastures for seven weeks prior to breeding had a greater ($P < .05$) percentage of lambs born. Lambs born to ewes that grazed cultivated pasture during the last trimester of gestation and early lactation had higher birth weights ($P < .05$), weaning weights ($P < .05$), and average daily gain ($P < .05$) than did lambs in the other treatments. The nutritional influence of grazing cultivated pasture was not important during late gestation and early lactation, which coincides with the late dry season. Strategic grazing of cultivated pastures is most beneficial during critical periods such as early lactation that overlap with the latter portion of the nutritionally stressful dry season (Table 8).

Table 8. Reproductive performance of ewes and lamb weights under three grazing treatments in the Peruvian Andes[a]

Item	Breed	Trilac	Range	SE
Lambs born, %[c]	101[d]	99[d]	88[e]	3.2
Net lamb crop, %[f]	89[d]	88[d]	75[e]	3.1
Lamb birth wt, kg	4.1[d]	4.4[e]	3.9[d]	.15
Lamb weaning wt, kg	24.6[d]	26.8[e]	23.4[d]	1.0
Lamb ADG, g	152.2[d]	167.1[e]	145.9[d]	7.4

[a]Treatments were as follows: Breed is 7-wk access to cultivated pasture prior to, and for 4 wk after, breeding; Trilac is 20-wk access to cultivated pasture including 7 wk at breeding, plus 6 wk during late gestation and 7 wk after parturition; Range is grazing only native range yearlong.
[b]As a percentage of ewes exposed to rams.
[c,e]Means in the same row with different letters differ ($P<.05$).
[d]Lambs were weaned on March 2 or 3 each year of the study.

Alpaca. Data is scare about alpacas raised on native range. Adult females (n = 85) placed on ryegrass-white clover pastures for 20 months prior to parturition at La Raya had an 18% death loss, a gross lamb crop of 55%, and crias with a birth weight of 8.1 kg (F.C. Bryant, unpublished data). Our production data were similar to survey data from production systems with high levels of technological input. However, death loss was much greater than for Andean averages. Young (four to five months) alpaca females (n = 40) raised on the same cultivated pastures had 12% greater gross lamb crop than adults, but their crias had lower birth weights (7.5 kg). Death loss of young dams was only 2% greater for adult dams. Weight gain of males on cultivated pastures was 11.2 kg over six months (F.C. Bryant, unpublished data).

Adult alpacas raised on range and monitored for one year had body weights and greasy fleece weights similar to those of adults given partial and total access to cultivated pastures (Table 9).

Control animals (SAIS Pachacutec) had lower greasy fleece weights (Table 9). Compared with Andean averages of better production systems, greasy fleece weights were 20% to 40% greater under the good range conditions of SAIS Pachacutec. Greasy fleece weights were 50% to 100% greater than production systems with low levels of technological input.

Compared with animals on native range (n = 30), alpaca females (n = 30) raised on cultivated pastures were weaned at 30.4 kg, three months earlier. (A. Florez, unpublished data). Moreover, they reached a breeding weight (50 kg) one year earlier than females on native range. Thus, females on cultivated pasture were bred at one year of age and had crias at two years of age, compared with females on native range that were bred at two years and gave birth at three years. Usually, peasant communities breed alpaca females at three to four years of age.

Training Progress and Institutional Development

Long-term

Full support: Sergio Soltero (Mexican), Ph.D., Range Management, February 1991 expected completion date, Texas Tech University.

Partial support (tuition only): Isaac M. Ortega (Chilean), Ph.D., Range Management, May 1991 expected completion date, Texas Tech University.

Short-term

Range Management collaborators in Peru participated in workshops at Cuzco and Lima on topics of range management and animal nutrition.

Table 9. Adult and greasy fleece weights of alpaca after 1 year of diets from range, range and cultivated pasture[a], cultivated pasture[a] and the SAIS rangeland at SAIS Pachacutec, Peru.

Feed Source	No.	Initial wt, kg (6-19-84)	Final wt, kg (7-5-85)	Wt change, kg	Greasy fleece wt, kg
Native range	25	58.0	59.7	+1.7	2.3
Native range + cultivated pasture[b]	25	55.0	59.8	+4.8	2.2
Cultivated pasture only	25	54.0	60.0	+6.0	2.4
SAIS	25	57.0	58.0	+1.0	1.9

[a]Cultivated pasture was orchardgrass and red clover.
[b]Diet source was native range plus cultivated pasture during the last third of gestation.

Other Contributions

Contributions to U.S. Agriculture

Research by Sergio Soltero and Isaac M. Ortega was directed at understanding the impact of short duration grazing and stocking rate on rangeland vegetation and native fauna.

Contributions to Host Country

B.S. graduates at four institutions were assisted in their thesis work by Co-PI Felipe San Martin. Contributions to workshops in country were documented previously. Financial support of $8,475 was provided to a workshop in Cajamarca, Peru, as well as to Drs. Flores and San Martin to travel to sites in Peru as part of the INIAA strengthening program.

Linkages and Networking

Texas Tech University financially supported Dr. Arturo Flores as Secretariat of the Andean Small Ruminant Network by providing $12,500 in salary and support services after the Program office officially closed. Texas Tech University was the only institution of the SR-CRSP in Peru to do so.

A sabbatical/development leave was provided to Dr. Felipe San Martin to travel to the United States to work with PI Fred C. Bryant in analyzing research data. Total financial support was provided to Drs. Flores and San Martin to travel to the ALPA meetings in Brazil and give research papers and present the Andean Small Ruminant Network idea to participants.

Publications

Theses

Valenza, D. 1989. Digestibility of crop residues in llama, alpaca and sheep. B.S. Thesis. UNSAAC, Cuzco.

Calderon, W. 1989. Digestibility of different forage quality in llama, alpaca and sheep. B.S. Thesis. UNSAAC, Cuzco.

Vallenas, G. 1990. Rate of digestion in alpaca of crop residues. B.S. Thesis. San Marcos University, Lima.

Tovar, A. 1990. Comparative intake of oat straw in llama, alpaca and sheep. B. S. Thesis. Huancayo University, Junin.

Mendoza, C. 1989. Efecto de la deprivacion deagua sobre el consuma y deigestibilidad de ovinos y alpacas. B.S. Thesis. UNA-La Molina, Lima.

Soto, H. 1989. Respuesta comparativa en el engorde estabulado del ovino, la alpaca y la llama. B. S. Thesis. UNA-La Molina, Lima.

Publications in Journals and Books

Astorga, L., E. Cari, M. Luque, L. Venegas, A. Schlundt and G. Atamari. 1989. Forage quality and availability on three range sites of the Peruvian antiplano. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 30-55.

Astorga, J., V. Choquehuanca, M. Rubio and F. C. Bryant. 1989. Succesional trends related to grazing exclusion on altiplano rangelands. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 1-20.

Blackburn, H. D., F. C. Bryant, T. C. Cartwright, L. C. Fierro, and J. Astorga. 1989. Corriedale sheep production when supplemented with ryegrass pasture in Southern Peru. Agric. Systems. 30:101-115.

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Internatl. Stockman's School Handbooks. Pages 89-112.

Bryant, F. C., A. Florez, and J. Pfister, 1989. Sheep and alpaca productivity in high Andean rangelands in Peru. J. Anim. Sci. 67:3087-3095.

Coronado, L. 1989. Fattening sheep on cultivated pastures. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 112-118.

Espinoza, J., F. San Martin, D. Holgado and F. Suarez. 1989. Incidence of poisonous plant toxicity affecting the peruvian livestock industry. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 83-96.

Fierro, L. C., and F. C. Bryant. 1989. Nutrition of herded sheep in the Andes of southern Peru. J. Small Ruminant Res. 3:117-134.

Fierro, L. C., and F. C. Bryant. 1989. Grazing activities and bioenergetics of sheep grazing native range in southern Peru. J. Small Ruminant Res. 3:135-146.

Flores, A. and F. C. Bryant. 1989. Manual de pastos y forrajes. Sector Agrario, INIPA. Lima, Peru. 206p.

Oscaona, L., E. Flores and F. C. Bryant. 1989. Dietary composition and forage intake of sheep grazing under continuous and rotation pastures on central sierra rangelands. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 56-66.

Pfister, J. A., F. San Martin, L. Rosales, D. V. Sisson, E. Flores, and F. C. Bryant. 1989. Grazing behavior of llamas, alpacas, and sheep in the Andes of Peru. Appl. Anim. Behavior Sci. 23:237-246.

Rueda, J., E. Flores and J. Pfister. 1989. Effects of stocking rate on botanical composition of the diet of sheep grazing high mountain range. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 21-29.

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San Martin, F. and F. C. Bryant. 1989. Investigaciones Sobre Pastos y Forrajes de Texas Tech University en el Peru. Tech. Art. T-9-584. College of Agric. Sciences, Texas Tech Univ., Lubbock, TX 79409.

San Martin, F., and F. C. Bryant. 1989. Nutrition of domesticated South American llamas and alpacas. J. Small Ruminant Res. 2:191-216.

San Martin, F. and F. C. Bryant. 1989. Comparative digestibility between llamas and sheep as affected by diet quality. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 67-82.

San Martin, F., J, A. Pfister, L. Rosales, R. Farfan and T. Huisa. 1989. Grazing behaviour of llamas, alpacas and sheep in the Andes of Peru. *In* F. San Martin and F. C. Bryant (Eds.), Volume V. Research results in range management and improved forages. Tech. Art. T-9-584. College of Agric. Sci. Texas Tech University, Lubbock, TX. 128p. Pages 97-111.

Abstracts and presentations

Huisa, T., R. Farfan, D. Holgado, and F. San Martin. 1990. Producion y calidad nutritive de

asociaciones regetales altoandinas. XII Reunion Cientifica anual del APPA. Lima, Peru.

San Martin, F. 1990. Selectiondad forriajera y nutricion de llamas y alpacas. A. 18.3. XI Congreso Panamericano de Ciencias Veterinarias. Lima, Peru.

San Martin, F., F. C. Bryant, and J. Pfister. 1990. Selectividad, consumo, y importamiento alimenticional pastoreo de llama, alpaca y ovinos en los Andes del Peru. XII Reunion Cientifica anual del APPA. Lima, Peru.

Valenza, D., F. San Martin, D. Holgado, and R. Farfan. 1989. Digestibilidad comparativa de los pastrojos de Quinua (Chenopodium quinoa) y haba (Vicia faba L.) entre ovinos, alpacas y llamas. XII Reunion Cientifica anual del APPA. Lima, Peru.

Socioeconomics of Crop and Livestock Production

◆ University of Missouri

Sociological analysis of small ruminant production systems

- **In the United States**
- **In Indonesia**
- **In Peru**

◆ Winrock International

Economic analysis of small ruminant production and marketing systems

- **In Indonesia**
- **In Peru**

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Sociological Analysis of Small Ruminant Production Systems in the United States

University of Missouri-Columbia
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J. L. Gilles, Sociologist, UMC
D. Adkins, Information Officer, UMC
E. Mathias-Mundy, Veterinary Scientist, Iowa State University
C. M. McCorkle, Anthropologist, UMC
T. Schillhorn van Veen, Veterinary Scientist, Michigan State University

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Research Results

Objectives

The Sociology Project laid out five plans of synthesizing, cross-site research, analysis, and/or write-up for 1989-90. These U.S. efforts were designed to build upon the project's more than ten years of research to arrive at more general principles applicable across regions.

Project Progress and Achievements

Model of Biosocial Roles in Crop and Livestock Production

Building upon SR-CRSP experiences in Peru and Kenya plus additional documentation from around the world, this thrust was intended to model the relative, culture-specific responsibilities of men, women, boys, girls, community groups, etc. in decision-making, technological knowledge, management, and taskwork in plant and animal agriculture. The larger aim was to provide guidelines for development planners in mounting and directing livestock interventions and information to the groups who could best utilize them. Unfortunately, work on this proposed subproject was tabled for lack of sufficient personnel.

Women in Livestock Development

This constituted a supporting subproject to the above, geared toward initial document

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and data collection, with the aim of producing an annotated bibiliography. Again, however, human resources to implement this study were not forthcoming.

Ethnoveterinary R&D: A Global Perspective

In conjunction with Peruvian, Dutch, and German veterinarians, an annotated bibliography of ethnoveterinary knowledge and practice worldwide was prepared and published (see publications lists), including a 48-page analytic overview. The purpose was to begin to assess the possibility of utilizing or modifying indigenous animal health technologies as low-cost alternatives to conventional ones that are too expensive, inaccessible, or incomprehensible to smallholder stockraisers. Also planned under this subproject was publication in Peru of an annotated, Spanish-language bibliography on ethnoveterinary R&D in Latin America. Due to the SR-CRSP/Peru phase-down, however, these materials did not reach print. However, additional, unplanned publications were completed, including preparation and submission for journal publication of a review article on ethnoveterinary medicine in Africa and preparation and presentation of a parallel review for Asia at the Second International Congress of Ethnobiology, Kunming, China, October 1990.

Sociology of Range Management

This subproject, which constituted the M.S. thesis of Mr. Ibrahima Garba of Niger (see training and publications), consisted of an overview and analysis of shortcomings in the planning of USAID range and livestock development initiatives in Africa. The aim was to learn from past mistakes in mounting future efforts. The study concluded that the failure of livestock projects in Africa during the 1970s and 1980s was not due to institutional or cultural factors but rather to the planning process itself. Planners frequently developed programs based on untenable assumptions about local institutions and producers. This is not surprising given that local officials and experts had only minimal involvement in project planning, and that herders and livestock producers typically had virtually no input into the design of livestock initiatives.

Synthesis of a Decade of Research Results from the SR-CRSP

Research alone is of little value unless results are thoroughly analyzed, synthesized, and reported in a fashion intelligible and accessible to both social- and technical-science investigators in agricultural development, plus government administrators and general publics in the countries concerned. A continuation of activities begun in 1986, the objective of this subproject is to prepare manuscripts and other materials with the following content and structure (excluding those products already noted above).

1. *The Social Sciences in International Agricultural Research: Lessons from the CRSPs.* An edited anthology that reached print in 1989 (Lynne Rienner Publishers), this book focuses on the roles of sociology and anthropology in international agricultural R&D, within the CRSP paradigm of melding social and biological research. The volume features contributions from social scientists on five CRSPs (Bean/Cowpea, Nutrition, Peanut, Small Ruminant, and Sorghum/Millet) and a special section of commentary by CRSP technical scientists in agricultural economics, animal science, food science, and plant breeding. One hundred copies were distributed to AID missions worldwide.

2. *Plants, Animals, and People: Agropastoral Systems Research* is a five-site synthesis of interdisciplinary research to date by Sociology Project investigators (both U.S. and host country). The book is now under contract to Westview Press and will appear in 1991. The anthology incorporates 12 chapters spanning research by rural sociologists, anthropologists, economists, range managers, human ecologists, and others linked with the project.

3. *Ethnoveterinary Research and Development* (in progress, under contract with Kegan Paul International) is an anthology of approximately 20 chapters by veterinarians, anthropologists,

geographers, historians, and area-studies experts of diverse nationalities (e.g., Ethiopia, France, Germany, Holland, India, Mauritania, Mexico, Nigeria, Peru, Senegal, U.S.). Topics span: ethnoetiological and therapeutic theory and practice; ethnopharmacology and toxicology; epidemiology; traditional methods of disease prevention and control and other management methods (e.g. artificial incubation, feed supplementation); native healers; and delivery of veterinary and public health care to rural peoples.

4. *People, Pastures and Productivity* (in progress). This anthology, scheduled for publication in 1991, overviews basic issues and problems in the sociology of range management and presents a series of case studies based on SR-CRSP research in Peru and Morocco. Also included is an annotated bibliography of works in this field. Seven of the eight chapters are authored by present or past SR-CRSP participants.

5. *Peasant Agropastoralism: Application of a Cross-Cultural Model* (working title). This scholarly monograph, under contract to University of Utah Press, draws upon SR-CRSP research in highland Peru to validate a cross-culturally workable model of peasant agropastoralism to better inform development projects operating in such mixed farming, subsistence-oriented economies.

6. *SR-CRSP Sociology Project Technical Reports.* On-going production and dissemination, with reports housed in the following collections: CABI, ILEIA (in Amsterdam), ODI's Pastoral Development Network, NTIS, UMC's Ellis Library, the University of Kentucky's Applied Anthropology Collection.

7. "Communicating Project Results: A Model from the Small Ruminant CRSP" presents a global model of SR-CRSP communications strategies as a useful guide to other international development projects. The article is currently under review by the newly created FSR&E journal.

8. Brochure on the Sociology and Economics Projects. A synopsis of Sociology and Economics efforts and achievements to date, with B&W and/or color plates. Production of this item was contigent upon continuation of the SR-CRSP and is now scheduled for 1991.

9. On-going organized outreach and dissemination of information about Sociology Project achievements to local, donor, and other media (print, radio, television). A highlight of this effort in 1989-90 was inclusion of portions of the SR-CRSP/Indonesia videotape, with commentary by C. M. McCorkle, in the 13-part PBS series "The Gentle Doctor: Veterinary Medicine" (segment on international veterinary medicine).

Training Progress and Institutional Development

D. Adkins, BSc, Agricultural Journalism, University of Missouri-Columbia, expected 1991.

I. Garba, MSc, Rural Sociology, University of Missouri-Columbia, 1990.

J. Grimes, BSc, Agricultural Journalism, University of Missouri-Columbia, 1989.

D. Kruse, BSc, Agricultural Journalism, University of Missouri-Columbia, expected 1992.

Other Contributions

In 1989-90, M. F. Nolan and C. M. McCorkle respectively initiated and served on a UMC planning committee to establish the first, university-wide Undergraduate Minor in International Agriculture. Gilles, McCorkle, and Nolan also presented a series of invited lectures on global animal agriculture to classes in the UMC Department of Animal Science. McCorkle gave a seminar on work-in-progress on the SR-CRSP's model of biosocial roles in agricultural and rural development to the 25th Annual International Community Development Institute at UMC. She also sat on the 1990 Rural Sociological Society Panel on Women's Career Paths in Rural Sociology. Gilles and M.D. Fernández addressed the 1990 American Association of Animal Sciences on the subject of "Preparing for International Animal Agriculture: The SR-CRSP Experience."

Publications

The following publication is a result of the Brazil project which was phased-out in 1987.

Manuscripts Submitted or in Press

Primov, G. The Role of Goats in Agropastoral Production Systems of the Brazilian Sertao. In: C.M. McCorkle, ed. *Plants, Animals, and People: Agropastoral Systems Research.* Westview Press, Boulder, CO. (In press.)

The following publications are a result of the Morocco project. The University of Missouri portion of the project was phased-out in 1988.

Books and Chapters in Books

Gilles, J.L. In progress. *The Sociology of Range Management.*

Gilles, J.L. 1988. Slippery Grazing Rights: Using Indigenous Knowledge for Pastoral Development. In: E.E. Whitehead, C.F. Hutchinson, and B.N. Timmerman, eds. *Arid Lands Today and Tomorrow: Proceedings of an International Research and Development Conference.* Westview, Belhaven. pp. 1159-1166.

Journal Articles, Referred (SR-CRSP)

McCorkle, C.M., M.F. Nolan, K. Jamtgaard, and J.L. Gilles. 1989. Social Research in International Agricultural R&D: Lessons from the Small Ruminant CRSP. *Agriculture and Human Values* 6(3):42-51.

Manuscripts Submitted or in Press

Mendes, L., and H. Narjisse. In press. Range-Animal Ecology and Agropastoralism in Morocco's Western High Atlas Mountains. In: C.M. McCorkle, ed. *Plants, Animals, and People: Agropastoral Systems Research.* Westview Press, Boulder, CO.

Abstracts

McCorkle, C.M., and J.L. Gilles. 1986. Role, Status, and Stereotype: Social Scientists in International Development. *Sociological Abstracts,* Supplement 142:228, Aug (supporting).

Technical Communications

Gilles, J.L., and M.D. Fernandez. 1990. Preparing for International Animal Agriculture: The SR-CRSP Experience. American Association of Animal Sciences, Ames, IA.

Sociological Analysis of Small Ruminant Production Systems in Indonesia

University of Missouri-Columbia
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S. Wahyuni, Social Scientist, RIAP
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P. Ludgate, Resident Scientist, Winrock
C. McCorkle, Anthropologist, UMC
J. Gilles, Sociologist, UMC
T. Connelly, Anthropologist, Indiana University
M. Chaiken, Anthropologist, Indiana University

U.S. Institution

University of Missouri-Columbia

Collaborating Institution

Research Institute for Animal Production (RIAP), Balei Penelitian Ternak, P. O. Box 123, Bogor, Indonesia

Summary

Objectives were to study the process of dissemination of information, to assess the role of small ruminants in plantation systems, and to improve farming systems research. Study results made it clear that women played an important role in small ruminant production and therefore must be involved directly in the flow of information. A case study in North Sumatra indicated no relationship between farm size and family income, underscoring the complicated nature of the social economy in that region. A workshop in 1990 acquainted scientists in the Research Institute for Animal Production with the principles of the farming systems approach.

Research Results

Objectives

Project objectives were to study the process of dissemination and the adoption of small ruminant production packages, to assess the role of small ruminants in plantation systems and to upgrade the capacity to conduct farming systems research.

Project Progress and Achievements

Village Women's Groups Engaged in Small Ruminant Production

The focus of this project was to devise technology packages and dissemination strategies in order to improve small ruminant production among women producers. Women play an important role in Indonesian small ruminant production. Devising methods to disseminate small ruminant technology to them will be an important element of an overall development strategy. The approach undertaken was to organize women's groups, or to utilize existing groups, to serve as vehicles for transmitting information. An evaluation of changes in small ruminant production management strategies would follow. Data was collected and analysis was begun. Further analysis was thought necessary and it is expected that a report will be published 1990-91.

Extension Seminar

This project was not undertaken due to new responsibilities of the RIAP collaborating scientist.

Evaluation of SR-CRSP Input in Cerebon

One of the earliest sites for SR-CRSP on-farm research was in Cerebon, West Java. Early in the history of the program a significant program of data collection, coupled with farmers' meetings and technology dissemination was undertaken. Most activities ceased about 1985 and as yet no evaluation of the long-term effects of those early efforts has been done. Data for evaluation was collected, but before analysis could be undertaken the collaborating scientists were assigned other duties which forced a suspension of activities.

Gender Gap Study

This study continues a series of studies which have sought to clarify sex role differentiation with regard to small ruminant production. Such knowledge is critical if appropriate technologies and strategies for disseminating these technologies are to be developed. In the case of this study a modified survey approach which combined in-depth interviews, questionnaires, and scalogram analysis was undertaken. An analysis was begun after the data was collected; however, further analysis is necessary and it is expected that a report will be published in 1990-91.

Dissemination of SR Technology to Non-OPP Farmers

This study was not undertaken due to time constraints of investigators.

Peasant Household Production in Plantation Areas: A Case Study of North Sumatra

At the time that the preliminary 1989-90 workplans were developed (Fall, 1988) this study was not discussed. It was undertaken by Sri Wening for her M.S. thesis research and actually approved in the 1990-91 plan of work. The study sought to begin to build a data base to support the SR-CRSP effort in North Sumatra. Specifically, it sought to study the dynamics of farm size, off-farm income, household resources, and livestock production. Knowledge of how these are interconnected will be critical in order to anticipate the consequences of the sheep-under-rubber technology package being developed.

Data for the study were collected in the summer of 1990. Preliminary analysis showed 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). A majority of all farm size groups

raised cattle as compared with only 55% for the largest land owning group. Overall, mean numbers of animals raised were in direct relation to farm size.

Analysis and writing will continue in the fall of 1990 and winter of 1991 with the goal of completing the study by March/April, 1991.

Workshop: Role of Social Sciences in Farming Systems Research

The 1989 EEP report suggested a concerted effort to acquaint RIAP scientists (social and biological) with the principles of the farming systems approach. The availability of a modest amount of project carry-forward funds, and the high priority placed on this activity by the host country, allowed the workshop to be undertaken in the summer of 1990. The workshop was conducted by Dr. Thomas Conelly and Dr. Miriam Chaiken over a three-week period. Dr. Conelly and Dr. Chaiken were both well acquainted with FSR principles and with SR-CRSP. Dr. Conelly had previously served as the SR-CRSP sociology resident scientist in Kenya.

The workshop emphasized four themes:

1. Significance of inequality and gender in determining farmer's responses to new ideas;
2. Importance of incorporating farmer's concerns into research at all phases;
3. Strength and limitation of the sample survey; and
4. Potential and limitation of social science in FSR.

Specific topics covered included:

* Role of key informants
* Importance of in-depth knowledge
* Using informant ranking systems
* Construction of a wealth index
* Random time allocation studies to observe behavior rather than reports of behavior
* Sampling methods
* Conducting "sondeos"
* Techniques for improving questionnaires
* Data coding and analysis
* Collecting data on household food consumption to increase imports

The workshop was attended by 15 participants (all RIAP staff) and six to eight observers. The group included six women and 17 men. A variety of disciplines was represented. The approach emphasized interactive participation, small group discussion, and practical exercises, and a significant period was spent in the field to try out techniques first hand. No further effort in 1990-91 is planned.

Training Progress and Institutional Development

S. Wahyuni, M.S., Rural Sociology, Institut Pertanian, Bogor, 1990.

Sri Wening Handiyani, M.S., Rural Sociology, University of Missouri-Columbia, expected 1991.

Other Contributions

McCorkle and Nolan participated in discussions held to outline a priority research agenda on agrosylvopastoralism in the ASEAN countries as part of the AARD/SR-CRSP/IDRC Workshop on Integrated Tree Cropping and Small Ruminant Production Systems (IPS) held in Medan, North Sumatra, in September 1990.

Publications

Thesis and Dissertations

Wahyuni, S. 1990. *Peranan Wanita Dalam Usahatam Ternak Keluarga, Cabang Ruminsia Kecil: Studi Kasus di Desa Srogol, Kecamatan Cijeruk, Kabupaten Bogor, Popinsi Java Barat* (Women's Roles in Household Farming Systems, with a Focus on Small Ruminants: A Case Study in Srogol Village, Subdistrict of Cijeruk, Bogor, West Java). M.S., Rural Sociology, Fakultas Pascasarjana, Institut Pertanian Bogor.

Books and Chapters in Books

Lipner, M.E., and M.F. Nolan. 1989. Dilemmas of Opportunity: Social Sciences in CRSPs. In: C.M. McCorkle, ed. *The Social Sciences in International Agricultural Research: Lessons from the CRSPs.* Lynne Rienner Publishers, Boulder, CO (supporting). pp. 20-36.

Manuscripts Submitted or in Press

Bilinsky, P., and M.Gaylord. In press. Outreach Pilot Project: Small Ruminant Research and Extension in West Java. In: C.M. McCorkle, ed. *Plants, Animals, and People: Agropastoral Systems Research.* Westview Press, Boulder, CO.

McCorkle, C.M., and D. Esslinger. Communicating Project Results: A Model from an International Agricultural R&D Project. Under review at *Journal of Farming Systems Research-Extension* (supporting).

Technical Communications

Mathias-Mundy, E. 1990. Ethnoveterinary Medicine in Asia: A resource for development. International Congress of Ethnobiology, Kunming, China (supporting).

McCorkle, C.M., D. Esslinger, and J. DeWeese. 1989. Communicating Project Results: A Model from the Small Ruminant CRSP. *Proceedings of the 1988 Farming Systems Research and Extension Symposium* (referred). pp. 331-347.

Wahyuni, S. 1990. Sociological Variables Influencing Women's Roles in Smallholder Farming Systems. 1990 Asian Farming Systems Research and Extension Symposium: Sustainable Farming Systems - 21st Century Asia, Bangkok.

Wahyuni, S. 1990. Sumbangan Wanita Terhadap Pendapatan Dari Usahatani Ternak Ruminansia Kecil (Women's Contribution to Small Ruminant Income). In *Seminar Pengembangan Ternak Potong di Pedesaan Dalam Rangka HUT XXIV Facultas Peternakan Unsoed (10 Februari 1966-10 Februari 1990) 3 Maret 1990. Tema: Memperluas Kesempatan Kerja Melalui Pengembangan Ternak Potong IUntuk Meningkatkan Pendapatan Petani Peternak.* Fakultas Peternakan, Universitas Jenderal Soedirman, Purwokerto.

Wahyuni, S., P.J. Ludgate, and M.F. Nolan. 1990. Dissemination of Small Ruminant Production Information in Outreach Pilot Project (OPP) Villages in the Bogor District of West Java. In *Resource Utilization for Livestock Production in Malaysia: Proceedings of the 13th Annual Conference of the Malaysain Society of Animal Production.* Malacca, Malaysia. pp. 250-255.

Wahyuni, S., P.J. Ludgate, and K. Suradisastra. 1990. The Crop Dynamic among OPP Farmers in the Bogor District of West Java, Indonesia. 1990 Asian Farming Systems Research and Extension Symposium: Sustainable Farming Systems - 21st Century Asia, Bangkok.

Verbal Presentations

N.A. 1989. Ruminant Research Has International Perspective. *Spectrum* 16(2):3 (supporting).

(Kenya). In: C.M. McCorkle, ed. *Plants, Animals, and People: Agropastoral Systems Research.* Westview Press, Boulder, CO.

Sociological Analysis of Small Ruminant Production Systems in Peru

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University of Missouri-Columbia

Host Country Institution

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Summary

With the phase-down in Peru, the objective has been to complete all data analysis and publish the findings of the sociology project. This has included the publication and dissemination of the Peru techpack *Improving Andean Sheep and Alpaca Production: Recommendations from a Decade of Research in Peru.*

Research Results

Objectives

The main objective during this final year of phase-down in Peru has been to complete all data analysis and to synthesize and publish the findings from Sociology Project research during its decade of involvement in the country.

Project Progress and Achievements

A major highlight of this wind-up effort has been the 1990 publication and broad-based dissemination (in both English and Spanish) of the Peru techpack, *Improving Andean Sheep and Alpaca Production: Recommendations from a Decade of Research in Peru.* This effort was headed up by the Sociology Project. Many other publications also reached print during 1989-90, including seven Spanish-language monographs, for which Sociology had coordinating responsibility. These were widely disseminated in Peru among interested parties such as AID, PVOs and NGOs, INIAA, and other groups. Finally, Sociology played a coordinating role in exploring future outlets for popular and extension-oriented publication of SR-CRSP findings in the Peruvian development magazine *Minka.*

Training Progress and Institutional Development

M. Estofanero, M.S., Community Development, University of Missouri-Columbia, 1990.

M. D. Fernandez, M.S., Rural Sociology, University of Missouri-Columbia, expected Spring 1991.

M. E. Fernandez, Ph.D., Rural Development, University of Reading, UK, expected Spring 1991.

K. Jamtgaard, Ph.D., Rural Sociology, University of Missouri-Columbia, 1989.

M. Abuhudba, M.S., Rural Sociology, University of Missouri-Columbia, expected Spring 1991

In addition, Resident Scientist Fernandez participated in directed several SR-CRSP training and outreach workshops in Peru and other Andean countries in 1989-90.

Other Contributions

During 1989-90, Gilles and McCorkle served as reviewers for the National Science Foundation on doctoral research proposals to investigate peasant agropastoralism in the Andes. McCorkle served on a team to conduct the midterm evaluation of AID/Peru's Agricultural Technology Transformation Project.

Publications

Thesis and Dissertations

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Economic Analysis of Small Ruminant Production and Marketing Systems in Indonesia

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Summary

The economics subprogram in Indonesia focused on constraints to increased productivity on smallholder sheep and goat farms, particularly in West Java and North Sumatra. Strong emphasis was placed on farmer participation by discussing with them their needs, problems, and reactions to suggested animal husbandry technologies. Establishment of an exchange environ-

ment required a changed attitude on the part of the research personnel and their understanding of farmers welfare objectives as well as their available resources. Information was obtained monthly on animal selling age, body weight when sold, the price, and marketing channels.

Generally, farmers did not sell their animals at the optimum age but later, usually to take advantage of the higher selling price during the Islamic holiday season. Marketing was done either directly or through a village middleman with only a third sold directly by the farmers. Reasons for this was time lost to other production activities.

The objectives of a village small ruminant production scheme were to introduce selected farmers to productions with different levels of returns, to obtain monthly income, and to use breeding, management, health, feeding, and marketing procedures for a complete commercial operation. The objective was also to test intensive production schemes in terms of profitability, feasibility, and social acceptability. The ultimate goal is to provide technology packages based on proven production practices.

Research Results

Objectives

The economics subprogram of the SR-CRSP has focused on the constraints to increased productivity and production on the smallholder sheep and goat farmers in Indonesia, particularly in West Java and North Sumatra. The need to work together with these resource-poor farmers has been recognized due to the potential contribution that they can have toward increasing the animal protein supply in Indonesia. These smallholder farmers can also concurrently make a contribution to agricultural development and improvements in farm family welfare by raising sheep and goats. An on-farm research (OFAR) model was selected very early in the implementation phase of the SR-CRSP to place strong emphasis on a farmer-oriented approach. The basis of the OFAR approach has been through farmer participation and collaboration in the research process by talking with the farmers about their needs, problems, and reactions to suggested animal husbandry technologies.

This collaborative approach has remained the focal point for the ongoing SR-CRSP economics subprogram's on-farm, technology-testing trials. These activities have focused on the technical and socioeconomic feasibility of the suggested production technologies and marketing strategies discussed with the smallholder farmers through the Outreach Pilot Project (OPP). The OPP has evolved over the past two and a half years to include a continuous exchange of information between the small ruminant farmers and the researchers, who are viewed as partners in the research process. There has been an emphasis on using the farmers' participation and adoption of the suggested technologies as a means to monitor and evaluate the production technologies and marketing strategies discussed and to determine areas where more research efforts were still required. Through the OPP's monthly on-farm visits by the researchers and the bimonthly discussion sessions, problem identification and assessment become a continual process.

Project Progress and Achievements

The acceptance of the animal production technologies and marketing strategies, presented to the OPP farmers for testing, were monitored monthly by the various discipline scientists involved in the on-farm technology testing program (nutrition, breeding, economics, health, and management). This approach differs markedly from the earlier years of the OPP where the researchers took a more formal consultative approach wherein they made most of the decisions based on their own research priorities. More recently, the OPP research approach has emphasized more farmer participation, shifting toward a more collaborative mode of on-farm research. This change in approach came about from the perception that an inadequate amount of information, concerning the farmers' production constraints and the

viability of the suggested production technologies, was being exchanged between the farmers and scientists.

One of the overall results of this year's on-farm research program, the final year of the OPP, was that the researchers reinforced the basic premise of OFAR research of the need to create a collaborative environment that promotes the exchange of ideas between researchers and the small ruminant farmers. Moreover, to establish this exchange environment requires researcher training and a learning attitude by the researchers toward the farmers regarding their interest in changes and an understanding and appreciation of both the farmers' family welfare objectives and the socioeconomic constraints on allocating family resources toward small ruminant production.

The economic subgroup of the OPP focused attention on four parameters in their consideration of the farmers' decision-making regarding the sale of their animals. Information relating to the selling age, body weight at the time of sale, selling price, and marketing channels was gathered from the monthly farm monitoring visits by using a checklist. A complete summary of results is provided in "Outreach Pilot Project On-farm Resaerch Activities Annual Report for 1988-1989" (Ludgate and Prijanti, 1990) with the following highlights mentioned briefly.

Generally, the farmers did not sell their animals at the optimum market age (12-18 months). Only 30% of the OPP farmers sold their sheep and/or goats during this optimum age. Almost 60% of the farmers sold their animals after this period. The major reason for this practice was to take advantage of the Islamic holiday seasons where the selling price increases significantly.

An analysis of the data relating animal body weight and selling price indicates that there is a relationship between animal body weight and price level. This analysis suggests that the older the animals, the greater the body weight and the higher the selling price of the animals. However, the efficiency of the input and output of this marketing situation has to be given further consideration.

The two marketing channels usually used by the farmers to sell their animals are either indirectly to the middlemen in their villages or directly in the market. Only 33% of the OPP farmers sold their small ruminants directly in the market, with the remainder using the village collectors. It was recognized that for many farmers it was difficult to take time away from their other agricultural production activities to sell their animals in the market. This was especially true with the additional risk of having to return with unsold animals and pay an additional transportation fee.

Village Small Ruminant Intensive Production Scheme

Research findings produced by the SR-CRSP-Balitnak joint activities from the different disciplines are now available for dissemination or on-farm testing. Application of these technologies to rural farmers or other interested producers is the most important task of technology developers. One interesting area to be explored in an interdisciplinary mode, given the available research finding, is improving rural family welfare through increasing the productivity of farm output, such as small ruminants. The success of this effort is highly dependent upon the collaboration, participation, and contribution of each discipline since the farmer himself is a farm manager facing multidisciplinary problems. Therefore, a good, strong research framework is necessary for the project to accomplish its objectives.

The principal objective of this project is to demonstrate and at the same time to determine whether it is possible to increase the income of small ruminant farmers through production testing schemes. In addition, we want to determine how acceptable and extendable these production practices are to other farmers. The specific objectives of this research include:

1. Introduce selected farmers to production schemes suggesting different levels of returns from a village-intensive small ruminant production operation;

2. Explain to the farmers the most ideal production scheme, under different resource endowments, to obtain a regular monthly income from a small ruminant enterprise;

3. Introduce production technology packages consisting of breeding, feeds and feeding, management, health, and marketing strategies for a complete commercial operation;

4. Test the intensive production schemes introduced in terms of their economic profitability, technical feasibility, and social acceptability; and

5. Provide technology packages for further dissemination based on the production schemes introduced, tested, and developed.

Proposed activities, objectives and targets of each discipline are presented in the following sections.

Breeding and Reproduction

Evaluating the animals' reproductive performance is the main activity for the first year of the VIPS project. The performance measures are those treatments imposed by the nutrition and management disciplines. Also, evaluation will be made on the basis of the breeding lines used (high and low prolificacy) and from the performance of their progeny. Live weight, post-partum oestrus, conception, gestation length, litter size, pre-weaning growth rate, mortality, and age and weight at puberty are parameters to be recorded.

Feeds and Feeding

The nutrition subprogram activities include observations on the effect of flushing on the ewes during a six-week period before and after parturition in order to improve the ewes' productivity. Feed supplements, in the form of mineral block mixed with 200 grams soybean oil cake, will be given daily to each of four ewes while the other four are to be used as control animals. Mortality rate, birth type, and weaning weight are to be recorded. Feed intake will be measured once a month. Laboratory analyses are required for about 544 samples of each of dry matter, nitrogen, and organic matter respectively.

Management

Research activities under the management discipline will follow the production schedule of the animals and implementation of suggested management practices. Animal housing, barn partitioning, health care, feeding, and mating time, as well as the general procedures for better animal management, are the major tasks of the management discipline.

Production and Marketing

Efficiency in animal production, regular farm income generated by small ruminant enterprise, and a better marketing strategy are among the objectives of the economic discipline although there seem to be more exogenous factors that play significant roles in determining the success of this production scheme than those endogenously manageable by the farmer. The efficiency criteria to be evaluated are, among others, time required to reach market age, amount of inputs (labor and effort) used to produce the marketed animals in terms of marginal productivity of inputs used, and the level of price received at the farmgate. The term "market age" refers to the time at which the animals are supposedly disposed with some nominal returns to the farmer. The optimal time is the period where the marginal benefits of keeping the animals are a least equal to their additional cost of holding the animals for some additional time. Previous information on the growth curve of village sheep production are used to determine the time interval during which the animals have to attain certain productivity standards. It is expected that the scheme will produce a generation of one-year-old offspring each month after month seventeen of the project. This provides the farmer with a regular monthly income from selling the off-

spring. Farm budgets and related financial analysis will be assessed at each production stage. The regularity of income flow is expected to stimulate the farmer to achieve a higher productivity level as a response to the level of price received. Therefore, the objective of increasing farmer income, in the long run, can be achieved by improving small ruminant production through the intensive production scheme.

At the aggregate level, improved production efficiency can be shown by collective action in the villages. This action is actually a result of a multiplier effect of the project in which interested farmers in the same village will follow the demonstration scheme. Returns to the project can be measured annually through assessment of accumulation of increased production (quantitatively) and improved family welfare (qualitatively).

Long-term objectives include: 1) developing marketing strategies as productivity increases and different qualities of animals are demanded; 2) improving marketing efficiencies (operational and pricing) as the supply of arm animals shifts; (3) evaluating market structure-conduct-performance at both rural and urban markets; and (4) assessing the integrated production scheme on a larger scale.

Research Methods

Each farmer participant will receive one ram and eight ewes. Rams to be used in the VIPS are considered to be prolific animals (high-line and low-line) contributed by the SR-CRSP's breeding project from the breeding station in Cicadas, West Java. Ewes will be provided from returned OPP animals and will be distributed at three delivery times in order to avoid simultaneous mating since each ewe will be mated in one-month intervals according to the scheme. Lambs will be weaned at three months of age. These lambs are then kept for nine more months before reaching market age (village data show optimum holding age for the lambs is 12 months). Therefore, month seventeen is the first time the project scheme will sell the first generation of offspring. Since the production scheme is composed of eight different ewes with one-month mating intervals, after seventeen months the production scheme will sell one generation of offspring each month. For progeny testing purposes, selection of female lambs reserved for replacement will be conducted at each generation. Once selected female lambs are identified, the ewe will then be replaced.

Training Progress and Institutional Development

Long-Term

Atien Priyanti. M.S. University of Arkansas, Agricultural Economics.

M.E. Yusnandar, B.S. degree, Pakuan University, Bogor. Economics.

Agus Muljadi Natasukarya. Ph.D. University of the Philippines, Los Banos, Philippines. Agricultural Economics.

Achmad Hanafiah, Ir/B.S. equivalent degree, Sekolah Tinggi Ilmu Pertanian, Tanjungsari. Agricultural Economics.

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Summary

Activities of the Peru program ended in September, 1990, after ten years. The Andean Small Ruminant Research Network is being initiated to continue and encourage the exchange of information on research developments. A Ph.D. thesis was completed in August, 1990, that indicated that the overvalued exchange rates encouraged sheep meat imports and required export subsidies or tax credits for textiles. Policies that increased meat prices generally lowered wool prices. A devaluation of the exchange rate appeared as the most effective way to increase producer revenue.

The activities of the economics component in Peru were modest. The most important achievements was the training of two Ph.D. students, Corinne Valdivia and Domingo Martinez.

Overview

After a period of nearly ten years (1981-1990) the activities of the SR-CRSP in Peru ended in September, 1990. The Andean Small Ruminant Research Network began in October, in an effort to continue and encourage the flow and exchange of information on research activities and results. The Network will also provide small grants and offer workshops in relevant topics.

Research Results

The results of Corinne Valdivia's dissertation have important policy implications for the future of small ruminant production in Peru,

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Bolivia, and other Andean countries. Additional work will be pursued in the coming year.

Because of the jointness of output--wool and sheep meat--government policies directed to benefit textiles have had an impact on overall sheep production. Results from a simulation model of the small ruminant sector in Peru indicate that overvalued exchange rates have encouraged sheep meat imports and required export subsidies or tax credits for textiles. Sheep producer revenues respond better to higher retail meat prices than to higher wool prices. Policies that increase meat prices generally result in lower wool prices. A devaluation of the exchange rate appears as the most effective way to increase revenues for producers.

Peru Tech Pack

The English and Spanish versions of the Peru Techpack have been published and distributed. Domingo Martinez contributed one chapter on the economics of livestock research and development.

Other Activities

Enrique Ospina and Domingo Martinez participated in the PAC meeting in Lima in January,1990. Decisions were made at this meeting on the techpack, the Andean Network, and planning for the phase-out.

Domingo Martinez participated in the research council for sheep and cameloids to provide support to INIAA's livestock research department, including the elaboration of research plans.

Martinez also provided support to the Research Center of the Department of Economics and Planning (CIDEP) of the Universidad Nacional Agraria (UNA). The vehicle and one of the microcomputers used by the project were transferred to UNA to help the department in its research programs.

Flor Robles, a student at UNA, received initial support to work on her thesis on economics of livestock improvement.

Martinez attended the Farming Systems Symposium at Michigan State University with partial support from SR-CRSP.

Several activities took place in preparation for the site visit to Bolivia for the agropastoral component September, 1990. These activities include developing a list of personal, institutional, and donor contacts and conducting an extensive survey of the most recent reports on economic performance of agriculture in the region.

Training Progress

Corinne Valdivia completed a Ph.D. in Agricultural Economics at the University of Missouri in August, 1990. Dissertation title: Impact of Government Policies on the Small Ruminant Sector of Peru.

Domingo Martinez returned to the University of Missouri in September, 1990, to finish his dissertation, after having spent most part of the year on leave in Peru. He is expected to finish all degree requirements around January 1991.

Publications

Martinez, Domingo and Mercedes Barrera. 1989. "Uso del Trabajo Familiar en Comuninades Agropastoriles Andinas." In M. Fernandez (ed.) *El Trabajo Familiar y el Rol de la Mujer en la Ganaderia de las Comunidades Alto-Andinas de Produccion Mixta.* PVTC, Lima, pp.24-48.

Martinez, Domingo. 1990. "Economic Methods for Livestock Research and Development in the Andes." Chapter 3 in C. McCorkle (ed.) *Improving Andean Sheep and Alpaca Production. Recommendations from a Decade of Research in Peru.* University of Missouri and SR-CRSP.

Martinez, Domingo. 1990. "Metodos Economicos para la Investigacion y el Desarrollo Ganadero en los Andes." Capitulo 3 en C. McCorkle (ed.) *Mejoramiento de la Produccion Andina de Ovinos y Alpaca. Recomendaciones de una Decada de Investigacion en Peru.* INIAA y Programa Colaborativo de Apoyo a la Investigacion de Rumiantes Menores.

Project Expenditures

- Expenditures by Program
- 1989-1990 Approved Program Budgets
- Matching Contributions from U.S. Institutions
- Summary of Host Country Contributions

SMALL RUMINANT CRSP
USAID GRANT NO. DAN-1328-G-SS-4093-00
EXPENDITURES BY PROGRAM

Institution	Year Six 1984/85	Year Seven 1985/86	Year Eight 1986/87	Year Nine 1987/88	Year Ten 1988/89	Year Eleven 1989/90 @	Total
California	$192,562.10	$258,979.52	$216,229.92	$193,411.97	$235,093.47	$276,324.46	$1,372,601.44
California	$119,308.75	$142,139.33	$132,401.92	$0.00	$0.00	$0.00	$393,850.00
Colorado	$159,902.05	$157,787.88	$131,447.80	$168,782.58	$164,143.00	$144,763.52	$926,826.83
Missouri	$270,247.05	$307,072.42	$204,442.54	$240,555.18	$249,231.09	$288,682.30	$1,560,230.58
Montana	$145,000.00	$144,000.00	$126,400.00	$104,717.98	$149,281.30	$162,589.57	$831,988.85
North Carolina	$235,178.00	$244,088.00	$165,900.00	$205,718.10	$185,710.05	$182,073.97	$1,218,668.12
Texas A & M	$158,827.67	$144,451.44	$65,380.21	$0.00	$0.00	$0.00	$368,659.32
Texas A & M	$143,489.80	$155,836.79	$175,909.65	$207,788.84	$184,271.32	$169,326.13	$1,036,622.53
Texas Tech	$282,151.09	$246,138.86	$113,615.10	$187,549.88	$151,354.00	$150,000.00	$1,130,808.93
Utah State	$180,566.51	$178,183.00	$126,400.00	$104,699.92	$90,288.48	$172,005.59	$852,143.50
Utah State	$195,000.00	$156,755.09	$21,900.00	$0.00	$0.00	$0.00	$373,655.09
Washington	$158,632.69	$176,310.01	$123,022.15	$168,985.00	$160,000.00	$160,000.00	$946,949.85
Winrock Econ	$235,000.00	$258,584.43	$198,365.81	$234,960.01	$251,500.00	$236,105.32	$1,414,515.57
Winrock DPG	$200,019.76	$228,936.79	$207,610.00	$245,509.31	$244,606.72	$264,839.00	$1,391,521.58
Subtotals	$2,675,885.47	$2,799,263.56	$2,009,025.10	$2,062,678.77	$2,065,479.43	$2,206,709.86	$13,819,042.19
Host Countries							
Brazil	$125,202.15	$108,969.41	$59,874.67	$0.00	$0.00	$0.00	$294,046.23
Indonesia	$95,001.04	$70,454.82	$25,735.50	$72,204.58	$45,678.07	$120,074.50	$429,148.51
Kenya	$73,777.56	$55,922.68	$40,597.29	$72.36	$721.12	$36,876.63	$207,967.64
Morocco	$39,681.21	$47,894.74	$69,230.01	$12,448.94	$19,425.65	$22,294.21	$210,974.76
Peru	$129,422.10	$121,942.83	$59,778.00	$99,470.95	$34,169.86	$53,761.34	$498,545.08
Subtotals	$463,084.06	$405,184.48	$255,215.47	$184,196.83	$99,994.70	$233,006.68	$1,640,682.22
Mgt Entity *	$376,306.95	$415,263.66	$438,094.62	$453,412.46	$442,225.41	$584,734.57	$2,710,037.67
Misc Expenses	$0.00	$11,541.71	$0.00	$0.00	$0.00	$0.00	$11,541.71
Subtotals	$376,306.95	$426,805.37	$438,094.62	$453,412.46	$442,225.41	$584,734.57	$2,721,579.38
TOTALS	$3,515,276.48	$3,631,253.41	$2,702,335.19	$2,700,288.06	$2,607,699.54	$3,024,451.11	$18,181,303.79

* Expenditures include those for the External Evaluation Panel, Board and Technical Committees, Workshops, and Strategic Meetings and Conferences.

@ These are preliminary final expenditures for year 11. The funds will be fully expended on this grant.

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SMALL RUMINANT CRSP

USAID GRANT NO. DAN-1328-G-SS-4093-00

APPROVED PROGRAM BUDGETS

Institution	Discipline	Year 6 84/85	Year 7 85/86	Year 8 86/87	Year 9 87/88	Year 10 88/89	Year 11 89/90	Total
California	Breeding	$242,034.00	$226,100.00	$165,900.00	$160,000.00	$210,000.00	$210,000.00	$1,214,034.00
California	Health	$170,000.00	$150,750.00	$73,100.00	$0.00	$0.00	$0.00	$393,850.00
Colorado State	Health	$170,000.00	$153,450.00	$126,400.00	$160,000.00	$160,000.00	$160,000.00	$929,850.00
Missouri	Sociology	$307,800.00	$295,700.00	$173,400.00	$210,000.00	$210,000.00	$210,000.00	$1,406,900.00
Montana State	Breeding	$145,000.00	$144,000.00	$126,400.00	$100,000.00	$125,000.00	$125,000.00	$765,400.00
North Carolina	Nutrition	$235,178.00	$240,488.00	$165,900.00	$160,000.00	$179,500.00	$190,000.00	$1,171,066.00
Texas A&M	Management	$185,000.00	$121,500.00	$67,200.00	$114,000.00	$0.00	$0.00	$487,700.00
Texas A&M	Systems	$185,000.00	$187,026.00	$142,200.00	$11,000.00	$140,000.00	$140,000.00	$805,226.00
Texas Tech	Range	$297,000.00	$239,850.00	$126,400.00	$160,000.00	$150,000.00	$150,000.00	$1,123,250.00
Utah State	Physiology	$195,000.00	$161,030.00	$21,900.00	$0.00	$0.00	$0.00	$377,930.00
Utah State	Range	$190,000.00	$168,750.00	$126,400.00	$120,000.00	$118,505.00	$150,000.00	$873,655.00
Washington	Health	$170,000.00	$165,150.00	$126,400.00	$160,000.00	$160,000.00	$160,000.00	$941,550.00
Winrock Int'l	Economics	$235,000.00	$258,829.00	$165,900.00	$210,000.00	$210,000.00	$210,000.00	$1,289,729.00
Winrock Int'l	Management	$232,000.00	$234,900.00	$169,900.00	$180,000.00	$180,000.00	$180,000.00	$1,176,800.00
Subtotal:		$2,959,012.00	$2,747,523.00	$1,777,400.00	$1,745,000.00	$1,843,005.00	$1,885,000.00	$12,956,940.00
Management Entity *		$450,000.00	$432,000.00	$300,200.00	$450,000.00	$440,000.00	$500,000.00	$2,572,200.00
Contingency Funds		$89,200.00	$27,412.00	$55,600.00	$220,000.00	$183,295.00	$122,800.00	$698,307.00
Overseas Sites		$501,788.00	$393,065.00	$316,000.00	$300,000.00	$333,700.00	$292,200.00	$2,136,753.00
Linkages		$0.00	$0.00	$0.00	$93,000.00	$0.00	$0.00	$93,000.00
Subtotal:		$1,040,988.00	$852,477.00	$671,800.00	$1,063,000.00	$956,995.00	$915,000.00	$5,500,260.00
Total:		$4,000,000.00	$3,600,000.00	$2,449,200.00	$2,808,000.00	$2,800,000.00	$2,800,000.00	$18,457,200.00

* Allocations include funding for External Evaluation Panel, Board Meetings, Technical Committee, and other Meetings.

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SMALL RUMINANT CRSP
USAID GRANT NO. DAN-1328-G-SS-4093-00
MATCHING CONTRIBUTIONS FROM U.S. INSTITUTIONS

#	Subgrantee	Year 6 84/85	Year 7 85/86	Year 8 86/87	Year 9 87/88	Year 10 88/89	Year 11 @ 89/90	Total
101	UCD - Genetics	$106,748.75	$117,007.00	$104,646.00	$96,529.00	$93,826.00	$96,486.00	$615,242.75
102	UCD - Health	$60,184.00	$40,921.00	$45,289.00	$0.00	$0.00	$0.00	$146,394.00
104	Colorado State	$56,667.00	$53,833.00	$53,334.00	$53,333.00	$53,333.00	$55,050.00	$325,550.00
105	Missouri	$95,388.54	$94,190.49	$53,386.56	$74,120.23	$83,436.34	$77,107.90	$477,630.06
106	Montana State	$331,265.00	$262,557.00	$184,001.30	$221,920.86	$242,705.80	$85,682.45	$1,328,132.41
107	North Carolina	$87,462.00	$80,549.04	$64,731.00	$71,184.27	$67,342.08	$73,287.88	$444,556.27
109	Texas A&M	$66,474.41	$67,573.65	$77,098.72	$56,144.27	$59,805.21	$49,486.79	$376,583.05
110	Texas A&M Mgt	$59,755.04	$64,026.43	$46,311.50	$0.00	$0.00	$0.00	$170,092.97
111	Texas Tech	$114,381.91	$110,950.00	$59,125.79	$83,694.40	$101,011.71	$71,304.27	$540,468.08
113	Utah State Repro	$90,408.40	$128,057.46	$6,998.17	$0.00	$0.00	$0.00	$225,464.03
114	Utah State Range	$103,929.97	$116,204.92	$122,213.49	$82,321.87	$84,474.79	$71,965.92	$581,110.96
115	Washington St.	$89,817.59	$85,610.80	$129,872.17	$67,314.96	$61,959.01	$53,372.42	$487,946.95
116	Winrock Intl - Econ	$78,111.67	$73,975.07	$68,262.09	$75,969.90	$83,316.13	$85,750.70	$465,385.56
117	Winrock Intl - D.P.G.	$58,364.49	$73,428.47	$79,461.02	$85,773.51	$82,981.46	$79,511.28	$459,520.23
	Subtotal:	$1,398,958.77	$1,368,884.33	$1,094,730.81	$968,306.27	$1,014,191.53	$799,005.61	$6,644,077.32
	Percentage:	34.97%	38.02%	44.70%	34.48%	36.22%	28.54%	36.00%

@ These are preliminary final matching funds reported for year 11.

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Summary of Host Country Contributions

Country	1985	1986	1987	1988	1989	1990
Brazil	$1,925,625.95	$2,100,442.16	$2,276,953.84	$0.00	$0.00	$0.00
Indonesia	$367,022.00	$352,472.00	$353,372.00	$354,972.00	$354,972.00	$1,420,400.00
Kenya	$252,831.00	$258,364.00	$289,912.00	$293,782.00	$308,113.00	$317,081.00
Morocco	$1,000,000.00	$1,064,000.00	$1,152,000.00	$1,192,000.00	$1,239,000.00	None Reported
Peru	$276,400.00	$276,960.00	$249,270.00	$225,663.00	$189,819.00	$118,695.00
TOTAL	$3,821,878.95	$4,052,238.16	$4,321,507.84	$2,066,417.00	$2,091,904.00	$1,856,176.00

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Country	Discipline	Principal Investigator	Collaborating Scientist
Indonesia	Animal Nutrition	K. Pond	B. Haryanto
	Breeding	E. Bradford	I. Inounu
	Economics	H. Knipscheer	T. Soadjana
	Sociology	J. Gilles	K. Suradisastra
Kenya	Animal Health	T. McGuire	S. Waghela
		J. DeMartini	
	Breeding	J. Taylor	C. Ahyua
	Economics	E. Ospina	F. Nyaribo
	Production Systems	W. Getz	J. M. Onim
			P. Semenye
Morocco	Genetics	E. Bradford	A. Lahlou-Kassi
	Nutrition	K. Pond	F. Guessous
	Range	B. Norton	H. Narjisse
Peru	Animal Health	J. DeMartini	E. Ameghino
	Breeding	P. Burfening	J. Chavez
	Economics	H. Knipscheer	D. Martinez
	Rangement Management	F. Bryant	A. Florez
	Sociology	M. Nolan	M. Fernandez

Technical Committee
1991

Eric Bradford	University of California, Davis
Fred Bryant	Texas Tech University
Pete Burfening	Montana State University
Jim DeMartini	Colorado State University
Will Getz	Winrock International
Fouad Guessous	IAV, Hassan II, Morocco
Travis McGuire	Washington State University
Cyrus Ndiritu	KARI, Kenya
Mike Nolan	University of Missouri-Columbia
Ben Norton	Utah State University
Enrique Ospina	Winrock International
Kevin Pond, Chairman	North Carolina State University
Marwan Rangkuti	CRIAS, Indonesia
Jerry Taylor	Texas A&M University

Administrative Council

1991

Robert C. Albin, Chairman	Texas Tech University
Leonard Bull	North Carolina State University
Larbi Firdawcy	IAV, Hassan II, Morocco
James Henson	Washington State University
Carl Menzies	Texas A&M University
Cyrus Ndiritu	KARI, Kenya
Gordon Niswender	Colorado State University
Paul Rasmussen	Utah State University
Ned Raun	Winrock International
Kenneth Schneeberger	University of Missouri-Columbia
P. Sitorus	CRIAS, Indonesia
Barbara Webster	University of California, Davis
Open	Montana State University

External Evaluation Panel

1991

S. Gordon Campbell, Chairman	Cornell University
Cornelia Butler Flora	Virginia Polytechnic Institute
Hudson Glimp	University of Nevada, Reno
Martin Gonzalez	Mexico
Glen Vollmar	University of Nebraska, Lincoln

Management Entity Staff

Mary Keane	Administrative Assistant
Lucia Lojewski	Accountant
Maurice Peterson	Acting Resident Director
James Scott	Assistant Program Director

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